A. Vibert Douglas Student Note Books (i)

CONSTITUTION of MATTER.

E.R., Bohr, etc.

MATHEMATICAL THEORY

OF RELATIVITY

Eddington

A. V. Douglas.

A. V. Douglas.
Newnham College, Cambridge.

Michaelmas Term
1921.

Lent Term
1922.

Easter Term
1922.

Prof. Sir Ernest Rutherford
Cavendish Lab.

11.10.21.

Constitution of Matter.

B.C. 600 Thales - atoms - static elect.

Democritus - (Tyndall's Summary) Atoms, conservation of energy, etc. Purely intellectual.

Aristotle - experimental method but many erroneous deductions - undermined D's influence.

Dark ages.

Renaissance. Galileo confirmed much of Democritus' theory.

Modern.

1800 Dalton in Manchester

1808 Gay Lussac - Expt^al fact of gases combine in definite amts.

1811 Avogadro's Hypothesis based on Expts. of Gay Lussac.

This Hyp. later established as a fact.

Distinction betw mols. & atoms.

(confusion of use by early mod. physicists like Maxwell. clear distinction by Chemists)

Dimensions of Mols.

1. Crude idea of minuteness by complete distribut. of colour when small amt of dye is diss. in litre H$_2$O.

2. Optical method - λ for Red $8 \cdot 10^{-5}$ cm.
λ " violet $4 \cdot 10^{-5}$.

Soap film vertical gives gradual decrease of thickness

until thin enough for coloured depolarised band & then black opaque band where thickness is $< \frac{1}{4}\lambda < 10^{-5}$ cm.

Found to be black at 10^{-6} when certainly several mols thick.

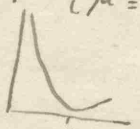
3. Radioactive method. active deposit of RaC due to 1 mg. Ra has wt. 2×10^{-11} gms. Dissolve it in acid & fill test tube with water & then evap. a drop on a Pt plate & see disch. discharge. thus detect 10^{-16} gms. RaC. & evidently many mols present in that amt.

4. Sodium thiosulphate + Soda in dilute HCl - finely divided S appears giving Tyndalls Blue (Sky blue by short wavelengths being scattered in polarised beams at rt. angles to diren. of vel.) Lord Rayleigh showed scattering $\propto \frac{1}{\lambda^4}$

Proc. R.S. A. Raman 100 p. 102 1921.
" " " Keen + Porter 87. p. 370 1914
Rayleigh Vol-5 p. 547.

1.5×10^9 per cc of S ptcls at max. opacity thickness 1.0μ to 3μ ($\mu = \frac{1}{1000}$ mm) in diam.

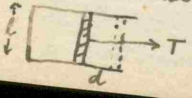
Intensity



L.V. King's work on blue sky radiation thickness & Avogadros No.

14.10.21.

1881 Kelvin's Estimate from Surface Tension.



T = surface tens. in dynes/cm
= work in forming 1 cm² new surface

Work = $2\pi ld$.

See P.+T. p. 164.

H = loss of heat / cm^2 = $\theta \frac{dT}{d\theta}$ θ = abs. temp.

experimentally $\frac{dT}{d\theta} = \frac{T}{600}$

Ex. Take temp 27°C = 300° abs. $T = 72$

$\therefore H = \theta \frac{dT}{d\theta} = 300 \times \frac{72}{600} = 36$ ergs.

$\therefore$ Total work/cm^2 = 72 + 36 = 108 ergs

Argument: Stretch 1 cc H_2O to area A cm^2

Work done 108 A ergs.

But this cannot exceed work req^d to convert 1 cc H_2O to steam i.e. complete separation of mols.

i.e. 580 gm. cal. = 580 × 4.18 × 10^7 ergs.

$\therefore$ A is obtainable

$+\frac{1}{A}$ = thickness of film at breaking pt

$+n < \frac{88}{10^8} < \frac{1}{10^8}$ cm. approx.

Kelvins Simile mol : orange :: orange : earth.

Kelvins 2nd argument - very ingenious.

Volta effect of contact of diff metals Cu Zn

voltage diff. .7 volt Pile very thin layers alternately.

Consider condenser idea. $C = \frac{V}{d}$ energy $\frac{1}{2}CV^2$

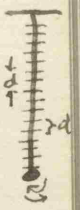
this energy shows itself in heat

then take heat evolved when alloy is made. latter is = or > total condenser heat.

Attempt that failed - Cauchy method.

Dispersion of light why shd. waves of long + short λ not travel with same vel. in water if perfectly

homogeneous? A wave must have at least 2 mols per λ. Proof no propagation of disturbance very quick i.e. λ < d. Sticks on cord from ceiling.



No. of ptcls per λ	2	4	8	12	20	∞
Vel of wave	63.6	90	97.4	99.	99.6	100

They took CS_2 Soln. μ (violet) $= \frac{1}{1.17}\mu_1$ (red)

this led to estimate { i.e. 12% diff of diam mol not $< 10^{-5}$ cm. wh is not correct.

The deduction is based on wrong theory of dispersion - Kelvin not familiar with works of Clerk Maxwell in Tripos Papers -

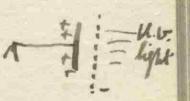
---

Ostwalds Phys. Chem. School temporarily influential ignores fundamental idea of atoms (Present teaching of Chem. in Toronto!)

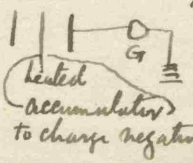
Electron Theory

Crooks + J.J.T. 1897 Cavendish Lab.

Ultra violet light has power to discharge neg. elect. Hertz + J.J.T. + Lenard + c showed this to be a stream of electrons.



Similarly in valve



Turn electrons back by mag. field unless vel. too great.

27/10/21

$\frac{e}{m}$ for H_+ = 95·73 EMU.

1 emu (quantity) liberates 01118 gm Ag. from Ag volt.

Let e = charge on one.
m mass
N = no of atoms per gm.

$Ne = 1$
$Nm = 01118$ ∴ $\frac{e}{m}$ for Ag. = 89·44.

For same e but mass hypothetical 1
then $\frac{e}{m}$ wd be = 89·44 × 107·86
= 9650 = at wt Ag when O = 16

∴ $\frac{e}{m}$ for H (1008)
is 95·73

N = avogadros no. = no. of ions in 1 gm mol (for O_2 16 gms)

$\frac{e}{m}$ for mass 1 = 9650

∴ $\frac{Ne}{Nm}$ = 9650
for mass 1 $Nm = 1$
∴ $Ne = 9650$ emu $= 9650 \times 3 \cdot 10^{10}$ ESU.

---

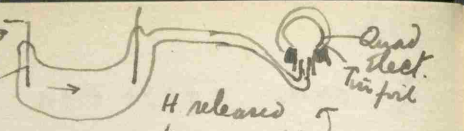
n = no. of mols. at S.T.P.

1 gm. mol. contains 22412 cc.

∴ $ne = \frac{9650 \times 10^0 \times 3}{22412} = 1.292 \times 10^{10}$ E.S.U.
$= 1.225$ at 15°C

Hence mass, charge, no. all obtained.

Townsend



is measured.

Issuing H passed into flask of water.
Cloud is formed & passes thro another flask with H_2SO_4

Cloud vanishes
Put thro water again & cloud reappears.

Cloud sinks gradually
e = charge on each drop
n = no. of drops.
ne = charge meas. by electrons / sec. = C
weigh cloud by increase in wt. in H_2SO_4 flask
W gms / sec
m = mass of a particle
$nm = W$
$\frac{e}{m} = \frac{E}{W}$

Stokes Law. terminal vel $\propto$ rad. a
$\propto$ coeff of viscosity η
Force $F = mg = 6\pi\eta a V$
$m = \frac{4}{3}\pi a^3 \rho$ density
$\therefore$ a is determinable if V being measured
a was approx. 10^{-4} cm.

$$V = \frac{2}{9}\frac{g a^2 (\rho - \sigma)}{\eta}$$ liq. gas

Take $a = \frac{1}{100}$ mm $g = 981$ $\rho = 1$ $\sigma = .00-$
$\eta = 1.8 \times 10^{-7}$ then $V = 1.2$ cm/sec

If a is $\frac{1}{1000}$ mm. V is .012 cm/sec.

Thus m is determined & hence e
Townsend $3. \times 10^{-10}$ e.s.u.

CTRW & J.J.T. Expansion & X-ray ionization
ions become centres of condensation.
ionization measured electrically - then condensed by expansion - measure wt. of water deposited - & rate of fall gives radius
Hence e (about 1902 or 3.
3.4×10^{-10}

Wilson + + +
H.A. — — —
Keep ions suspended.
or opp. ptl.
$e = 3.1 \times 10^{-10}$

Millikan. oil. ——— Variable voltage
Forces. mg down Xe up.
Hence e determinable.

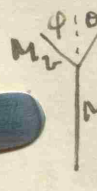
Discontinue attendance at course -
Hereafter notes on miscellaneous lectures of more advanced nature, bearing, though under other titles, on the Constitution of Matter -

α-Rays — Prof. Sir E. Rutherford.

Definite range (or ranges) for each substance emitting α rays. E.g. Ra C. 7 cm.
The range varies with half value period in a noticeable degree.

Effect on Range when absorber is placed in various positions. see Marsden + Richardson Phil Mag June 1913.

Mathematics of collision.



3 Eqns. of momentum + energy - giving v, u, tans φ etc.

Range after collision $\propto \frac{V^3}{(\text{charge})^2}$

Photographs of Shimizu

From math analysis the relations of the angles + lengths of spurs determine the nature of the bodies colliding - this looks like α hitting α or He but no He present or not 1 in many thousand

+ he obtain 14 such tracks in 3000

In two typical cases ~~length of spur was~~ if there had been no collision 1.2 mm + .8 mm i.e. these distances from end of track. Let vels be $v_1 + v_2$

$v_1 = \frac{1}{2.9}$ max. vel. of α ptcls Ra C - 7 cm range.

$v_2 = \frac{1}{4.5}$ " " " " "

since vel $\propto$ (distance still to go)$^{\frac{1}{2}}$.

Consider mass 4. Range before collision 3.4 mm.

Vel for this $\frac{1}{3.33} v_3$ for L.O.C. ?

Passage of α - thro O - charge 18.

No of ptcls deflected thro angle $\geq \phi =$

$5.2\ 10^{-4} \cot^2 \frac{\phi}{2} \left(\frac{v_3}{v}\right)^4$

∴ chance for 2 mm - track

$= .2 . 5.2\ 10^{-6} (3.3)^4 \cot^2 \frac{\phi}{2}$

$= 1.3\ 10^{-4} \cot^2 \frac{\phi}{2}$

$\rho = \frac{6.5}{100}$ i.e. 1 in 16 for ρ) 5^0

$\phi > 45^0$ gives $\frac{1}{400}$ which is the order of Shimizu's photos.

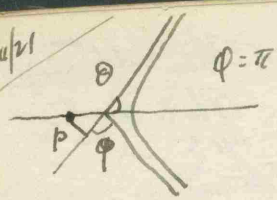
Thus correct order of probability of occurrence but evidently not O or N H

Consider chance of getting within
p of atom $= \pi p^2 nt$ t: dist travelled
for $\frac{1}{400}$ $p = 10^{-11}$

Suppose O nucleus composed of
4 He & α hits are when isolated
momentarily from others
Transference of vibrational energy
from α nearly to 1 or the 4 He
of O - 300000 volts only req^d to
separate it from other 3 α
it flies off - α ptcle can
supply this much energy.

Probability of deflection thro a
given angle $\propto \frac{1}{v^4}$.

17/4/21



$\phi = \pi - 2\theta$.

Theory of Single Collision Scattering.

Work done $= \frac{Ne}{b} \times E = \frac{1}{2} m v^2$

$b = \frac{2NeE}{mv^2} = \frac{NeE}{\text{energy of } \alpha \text{ ptcle}}$.

from prop^n of hyperbola. $b = p \cot \theta$.
Chance of hitting within area p is $\pi p^2 n t$
where t is thickness in cm.
To hit within ring p, $p + \delta p$ is
$2\pi p n t \, dp$.

But $\frac{\pi}{4} n t b^2 \cot \frac{\phi}{2} \operatorname{cosec}^2 \frac{\phi}{2}$

$\therefore$ No scattered thro angle ϕ $\quad \frac{\pi}{4} n t b^2 \cot^2 \frac{\phi}{2}$

$\frac{n t b^2 \operatorname{cosec}^4 \phi/2}{16}$ is no hitting $\frac{1}{2}$ sq cm screen

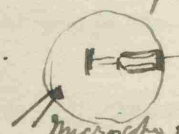
$\frac{1}{2} A\Omega$ screen.

No scattered thro given angle $\propto \frac{(neE)^2}{\operatorname{cosec}^4 \phi/2}$

The nuclear charge Ne is thus obtained

Read Geiger & Marsden Phil Mag. April. 1913.

Method.



Scintillations round are big angles when source was strong & small angles when source had decayed enough to make counting possible

Results in divide considerable exactitude to the Law & show that law holds to values of closest distance b (Ag. $3 \cdot 10^{-12}$
(Au) $5 \cdot 10^{-12}$

This gives max. dimension of nucleus.

To find min. " " " Consider Uranium

α particle gets up speed in field outside $7 \cdot 10^{-12}$ but α has a set on leaving.

It follows that inside a certain distance there must be an attractive force. near nucleus outside it α particle the electrostatic field dominates.

Energy of α ptcle in repulsive field is $\frac{Ne}{a}$

Suppose attractive field varies as Br^{-n}

Energy of α ptcle $= \frac{B}{n-1} r^{-n} / 2e$.

Resultant energy. $E = E_H + E_a + E_0$ or liberation

Repulsion } Attrn.
$-(2+Ne) E_2$ } E_a

Pth. for α Ur. 2.5×10^{-5}.

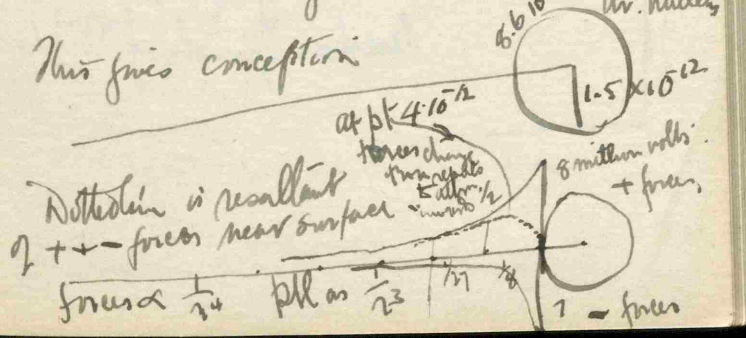
Pth. for surface. $8.6\ 10^6$ volts

" α from Ur $2\ 10^6$ " repl.

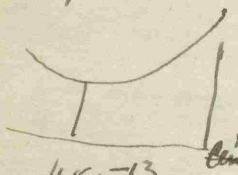
$\therefore$ attractive is $6.6\ 10^6$ "

This gives order $6.6\ 10^6$ volts

This gives conception



Compare Scattering Results (C & B)



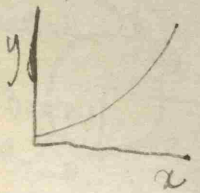
Div. $\frac{1}{r^2}$ Curve breaks down inside $4.5\ 10^{-13}$.

Consider Ur. ab no. 92 a wt 238.

Cube 4×4×4 He atoms.
Plenty of rooms left for electrons of mag. 10^{-13}

γ rays originate in nucleus (Ellis) as electron falls from one nucleus by to another ring.

Deviations from Dalton's Law. Mr Roberts 23/1/22 Bridgman.



deviations $y = \varphi(x)$ given by $\int \frac{\varphi(x)}{x}\,dx$

Isotopes of Hg. Dr Aston. 25/1/22

Fractional separation by evaporation - the lighter atoms rising & condensing on a flask cooled by liq air in it.

$$\frac{dn_1}{dn_2} = \frac{N_1 - n_1}{N_2 - n_2}\sqrt{\frac{M_2}{M_1}}$$

N_1, N_2 = original no of atoms of 2 isotopes
n_1, n_2 = no left after evaporation.

$M_1 = M_i(1-\Delta)$
$M_2 = M_i(1+\Delta)$

$$1 - d_2 = \frac{\Delta^2}{2+\Delta}\log_e \frac{v_2}{v_1}$$

200.6 is average.
Spectrum lines give band 197 – 200
line 202 faint line 204.
Density originally 1
of final residue 1.00023 –
of lightest fraction .99974

$$r_2 = \frac{m_2 + m_1}{m_2 - m_1}\sqrt{\frac{\text{Initial Vol}}{\text{Final Vol}}}.$$

$= 143\sqrt{1031.0}$ in this case

=

Similar method for isotopes of Cl

Dr Niels Bohr

6/3/22.

Quantum Thy.

J.J.T. E.R.

Planck - Oscillators - Einstein. Photoel.
$\nu = w_0$ $\Delta E = h\nu$

apply to At. constr. Stationary states from one to another, homogeneous train of monochromatic light. Use $h\nu = E' - E''$ to find frequency.

apply to H spectrum.

$\xi = \sum E \cos 2\pi(\omega t - \gamma)$ $\omega = \sqrt{\quad}$

$2a = \frac{Ne^2}{w}$ $\nu = K\left(\frac{1}{n^2} - \frac{1}{n'^2}\right)$

Balmer series

from lines obtain w the freq. of oscillation + $2a$ the major axis.

$w = 10^{15}$

$2a = 10^{-8}$

~~+ ie~~

Evaluating K.

$K = \frac{2\pi^2 e^2 m}{h^3}$ almost $\cdot \left[\times \frac{M}{1 - \frac{m}{M}} \right]$

$= 3.026 \cdot 10^{15}$

K for Hydrogen from spectrum

$= 3.029\ 10^{15}$

Fundamental is given by passage from one stationary state to next. + harmonics by passage to next consecutive states after first. This in coincidence due to Quantum Thy.

But the octave has not quite twice the freq. of the fundamental. + in case of H not nearly twice. This diff. gives clue to stability of atoms of elements.

H spectrum gives evidence of intermediate lines $\nu = K\left(\frac{1}{2^2} - \frac{1}{(n'' + \frac{1}{2})^2}\right)$

$= K\left(\frac{1}{\frac{n'}{2}^2} - \frac{1}{\frac{n''}{2}^2}\right) = 4K\left(\frac{1}{n^2} - \frac{1}{n'^2}\right)$

due to doubly charged particles He present with H

but $\frac{K}{K'} = 1.000407 = \frac{1 + \frac{m}{M}}{1 + \frac{m}{M}} = 1.000407$

H + He. ?

all Elements. Strongest lines given by

$\nu_L = N^2 K\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ N = atomic No. Moseley.

For complex elements:

Lines given by $\nu = f_1(n') - f_2(n'') =$

Na. Spectrum

S = Sharp series
P = Prime "
D = diffuse "

other jumps give lines in ultra violet etc —

Arc spectra $f_n(n) = \frac{K}{n^2}\varphi \cdot n$

$\varphi = 1 \quad n \to \infty$.

Spark " $f_n(n) = \frac{4K}{n^2}\varphi(n)$

In vapour state only certain positions are poss
Resonance phenom
Wood threw yellow line rays on Na vap
first resonance
Lord Rayleigh threw on rays of 2nd finer
series got yellow line i.e. it
jumped to successive
not direct to 2nd ps.
position

Voltage to produce ionisation 11.8 resonance
i.e. 1st possible jump 4.9

7/3/20.

Class. Th may be proved a limiting case of
the Generalized Q. Th.

$\nu_{n' \to n''} \sim (n' - n'')\omega$

$\mathfrak{J} = \Sigma C_\tau \cos 2\pi(\tau w t - \gamma)$

$\mathfrak{I} = \int_{\text{once round orbit}} 2T\,dt$ where $T = K.E.$

then $\mathfrak{I}$ has relation
$\delta E = \omega \delta \mathfrak{I}$

but $E = nh\omega$ + if ω is const $\mathfrak{I} = nh$

$\mathfrak{I}$ not changed if electron approaches new
stationary state very slowly — "adiabatic
change"

If stationary states are fixed by condn $\mathfrak{I} = nh$
then the condns of stability can be studied
by ordinary mechanics.

then $\nu_{n' \to n''} = \frac{1}{h}(E_{n'} - E_{n''}) = \frac{1}{h}\int \omega\, \delta\mathfrak{I}$

$\sim (n' - n'')\omega$.

Complicated motions
built up from number of periodic systems

$\mathfrak{J} = \sum C_{\tau_1 \ldots \tau_n} \cos 2\pi\{(\tau_1\omega_1 + \ldots \tau_n\omega_n)t + \gamma_{\tau_1 \ldots \tau_n}\}$

Use symbols of generalized mechanics
+ resolve in simple harmonic
constituents.

Smorfeo

$\mathfrak{I}_1 = \int_0 p_1\,dq_1$ ... $\mathfrak{I}_2 =$ $\mathfrak{I}_3 =$

$\mathfrak{I}_n = \int_0 p_n\,dq_n$

$\delta E = \omega_1 \delta \mathfrak{I}_1 + \ldots + \omega_n \delta \mathfrak{I}_n$ ← Bohr relation on which quantum theory is based

$\mathfrak{I}_1 = n_1 h$ $\mathfrak{I}_n = n_n h$.

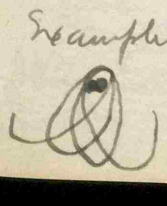
$\nu_{n_1' n_2' \to n_1'' n_2''}$

$= \frac{1}{h}(E_{n_1' n_2'} - E_{n_1'' n_2''})$

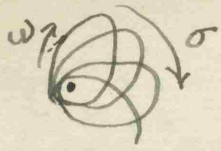
$= \frac{1}{h}\int \sim$

as in simple case above.

Example of this compounded motion



all loops similar but not
closed. Polar coords r θ.



Resolve into elliptical harmonic & repeate by 2 simple ones

$$\xi = \Sigma C \cos 2\pi \{\tau\omega + \sigma t - \gamma_\tau\} + \Sigma C_\tau \cos 2\pi \{\tau\omega - \sigma t - \delta_\tau\}$$

$J = nh \cdot P = Kh$ notation for simplicity

$\delta E = \omega \delta J - \sigma \delta P$

$\therefore E = \frac{}{J^2} \{1 + (\ )^2 (\frac{3}{4}) + \frac{1}{\delta P}\}$

Hence get ν

Spectrum lines from this formula are very nearly in agreement with observation for H.

Energy $W = \frac{hK}{n}$

Motion in atom is not pure periodic a pure periodic ell. orbit is unstable in changing external field - i.e. soft. but this ("spiral" ACD) ellipse is v. hard arrangement

From consid. of stability the major axis is not changeable but the eccentricity is not constant

2 Quantum nos. - applied to Na lines

K differs by 1 only for passage to diffe stationary state.

Moving mass of orbit not constant. i.e. σ varies. giving new lines

Zeeman effect

rotation about axes superimposed on old. $\omega + \frac{eH}{4\pi m}$.

mag field new term Σ_H of prob. depends only on mag. field.

linear polarization
circular "

Stark effect. even terms linear pol.
odd " circ. "

4/3/22 - Arrangement of electrons about nucleus & laws of properties of elements.

Periodic table

Early work of J.J.T. on electro neg & pos elements adjacent to inert gases.

Why an better Table?

Langmuir attempt - cellular structure not taking account of "point charge" forces between constituents of the atom "as many assumptions as elements".

Bohr's method to consider structure of atom when successive capture of an electron takes place.

Recall different shapes of orbit possible due to swinging of elliptical orbits due to Relativity influences.

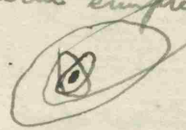
Sommerfeldt: E_{nk} = ——————

when 2 quantum nos. n & k determine the possible choice of orbits.

He – Spectrum 2 electrons in ~~[illegible]~~ 1_1 quantum orbits with planes inclined up to 16°.

2 electrons in He necessitate smaller orbit than in H. See later He spectrum

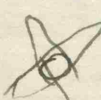
Consider 3rd electron Li =
Spectrum simpler.

Li.  orbits of 2 inner & of 3rd much larger. the parameter depending on the quantum no.

The normal state of an atom is determined by outer posn of the absorption line

No argument for existence of simple one plane orbit  2 electron.

Carbon ~~K2~~

Probably 4 electrons can  move in a 1 quantum orbit & visit inner orbit only 1 at a time

Other 8 probably in 2 quantum orbits orbits 1_1 & 2_1.

normals to planes of orbits probably taken from of chords from centre to corner of reg. tetrahedron.

Ne possibly 4 orbits of each kind with simple arrangement rel. to each other.

Mg Arc spectrum ∝ K
Spark " ∝ 4K

I	1_1
1 H	1
2 He	2

II	1_1	2_1	2_2
3 Li	2	1	
·		2	
·		3	
·		4	1
·			2
·			3
10 Ne	2	4	4

III	1_1	2_1	2_2	3_1	3_2	3_3
11 Na						
12						
·						1
						2
						3
18 A	2	4	4	4	4	4

K posn of Group IV
every orbit is one higher than for Na.

Ca. shows new characteristics due to different placing of the 3_3 q. orbits it being very firmly bound compared to the 4_1 q. orbit

IV	1_1	2_1	2_2	3_1	3_2	3_3	4_1	4_2
19 K	2	4	4	4	4	·	1	
20 Ca						·	2	
21 Sc						1	(2)	
						2	2	
29				6	6	6	1	1
							2	·
							2	1
							4	2
								3
36 Kr								4

magnetic properties of elements - no element up to Zr appears to be paramag.
Consider discrepancy in intensity due to loss of electron or electrons in formation of ~~ion~~ -ous or -ic ions.

Groups V

37 Rb — no electrons in 4th orbit it is too big & can find no place.
⋮
54 X — 5_1 5_2 begin to be occupied

Group VI — 5_4 & 5_6 are not occupied — $6_1 6_2$ is partly filled.

Groups XII.

87 not known
88 Ra — 5_5 6_4 6_5 6_6 not filled
118 — 7_1 ~~beg~~ is filled & 7_2 only 1 at 118th element.

from unit beyond Ur up to 117th would be too unstable to exist & 118 would be stable inactive gas probably

"We have at pres. ~~no~~ no def. picture of atomic forces - hence no complete theory is poss. yet.

Bring chem. & spectral data together.

Analogies If one inner electron be removed any other one can take its place.

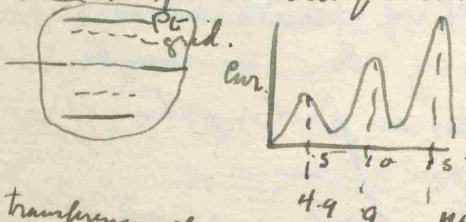
He - 2 — 2
Neon 10 — 2 4 4
Ar. 18 — 2 4 4 4 4
Kr 36 — 2 4 4 6 6 6 4 4
6 6 — 4 4

Xe - 54

Niton

13/3/22

He spectrum (arc) of 2 distinct types.
∴ 2 ways in wh. the electrons in a He atom can be emitted
Call it. Parhelium & Orthohelium.
For ord. in ultra violet
Franck's exptl. on coll. of electrons & atoms



transference of electron in normal atom to one of its inner stationary states.

In the orthohelium state it is a very active element & will combine with many

other elements very violently + returns quickly to its normal inactive state.

Interpretation of He spectrum

Spark spectrum same formula as for H except $4R$ for double charge on nucleus $\nu = 4R\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$

orbit of inner el. is very easily perturbed.

Latest calculations of Bohr permit of 2 el. in He not having a multi-periodic orbit but a mixed motion between the 2 classes with certain motions which do not allow of any stationary state at all.

If electron on outer as on line of maj. axis of inner, the inner turns

ang. vel. of outer el. increases as nearest eq. law & maintains its pos. as on prolongation of maj. axis of inner

∴ motion continues ad ∞.

$R^2 \frac{d\theta}{dt}$ for electron

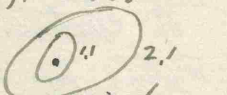
+ outer orbit also wrong

$\frac{e^2}{R^2} \neq \frac{A}{2^2}$

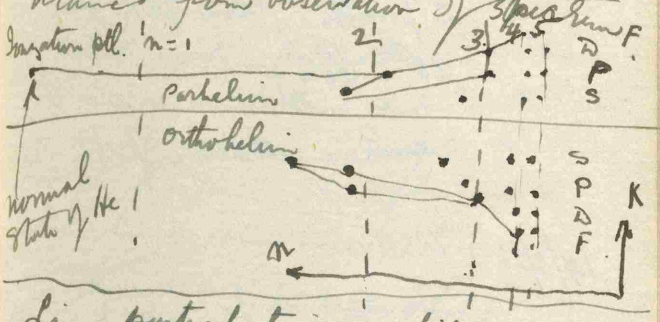
This will give a no. of stationary states.

Possible for the orbits to intersect until theoretically they coincide as a ⊙ with an el. at extremities of diam. This does not occur (in accordance with Q. Thy.)

Suppose inner is in a 1,1 orbit & outer in a 2,1 orbit.

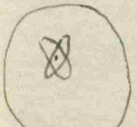


Theory gives stationary states to within 5% to 10% for orthohelium of values obtained from observation of spectrum

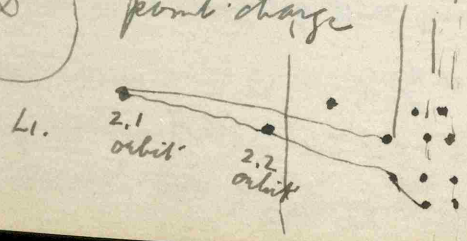


Li. perturbation of orbit gives a very rapid rotation.

Why no 1,1 orbit like normal state He



Inner system acts like a point charge

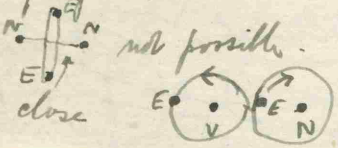


Considerations of field $\frac{e^2}{R^2} + \frac{A}{R^3}$ and polarization depending on $\frac{1}{R^2} + \frac{1}{R^3}$ for different orbits make the 1,1 orbit impossible

Doppler effect - superimposed on orbit are wavy motions -

If electrons are at aphelion or perihelion together this coincidence is always repeated

Hydrogen molecule - simple idea of close not possible. More likely very



maximum attractive force

14/3/22

· General formula $\nu = f_{K''}(n'') - f_{K'}(n')$

for H only one f ∴ only one set of stationary state transitions

Receiving mouth of lecture = $\mathcal{I}$

$\mathcal{I}_1 = \int m \frac{dx}{dt} dx$

$\mathcal{I}_2 = \int m x^2 \frac{d\varphi}{dt} dt = 210 A.$

$\mathcal{I}_1 = n_1 h \quad \mathcal{I}_2 = n_2 h$

$\mathcal{I}_1 + \mathcal{I}_2 = \mathcal{I} = nh$

$\mathcal{I}_2 = P = kh$

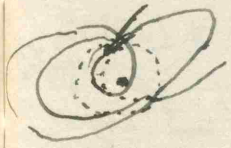
these frequencies refer to an orbit + to the rotation of this orbit

$f_K(n) = \frac{R}{(n+\alpha_K)^2}$ where R = Rydbergs. $+\alpha$ is nearly a const. in each series of stationary states but differing considerably for different series —

Simple formula $F = \frac{e^2}{r^2}$ does not give complete results of spectrum

Try $F = \frac{e^2}{r^2}\left(1 + \alpha \frac{a_0}{r}\right)$

Outside a certain region assumed nucleus the force on an electron in an outer orbit is almost as from a simple nucleus or pt. charge - i.e. Keplers motion but when it comes inside this region

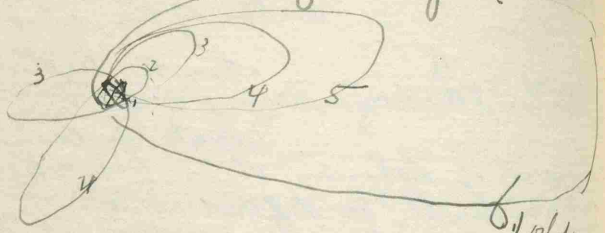


$\mathcal{I}'$ (for Keplers orbit)
$= \mathcal{I}_1' + \mathcal{I}_2' = \mathcal{I}_1 - \Delta_i \mathcal{I}_1 + \Delta_i \mathcal{I}_1 + \mathcal{I}_2$
$= \mathcal{I} - \Delta_i \mathcal{I}_1 + \Delta_i \mathcal{I}'$

For another case $\mathcal{I}' = \mathcal{I} - f(h) = nh - f(h)$
Sharp series

Consider Caesium - at. no. 55
the quantum orbits 1, 2, 3, 4, 5, 6
successively ~~later~~ are more elongated

ellipses with longer maj. axes - & vel at perihelion gtr & gtr.



1 orbit falls in very steeply towards nucleus in inner region.

Expression I_1 for the X_1 orbit depends partly on the outer portion & partly on the complicated inner region from value of I it is possible approx to work out what orbit the outermost electron must be moving in.

From previous $I' = I - \Delta.I_1 + \Delta I_1$ negligible

$= I + 6h - 4h$

$= I + 2h$

i.e. contributions of radial & angular quantum

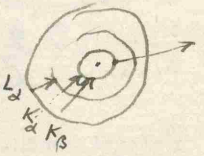
An outer orbit always cuts inner system at its perihelion. & if it is the outer orbit gives the light spectrum.

17/3/22.

Similarity between X-ray spectrum & optical Sp. Fundamental diff is in the absorption.

Assume roentgen spectrum due to 1 el taken right out from a ring

Sp place can be taken by infall of an el. from outer rings



$h\nu = E' - E''$

$K_\alpha + L_\alpha = K_\beta$ is energy relation

Sommerfeld's formula for energy W takes account of relativity terms & depending on 2 quantum constants $W_K = Rhc(\nu - a_x)^2$ is Moseley's formula. the a varies for the K_1, L_β rings & is the screening constant.

Atoms of the same element assumed to vary the shells or rings being sometimes ⊙ & sometimes ◎ el. This is not plausible from chem & phys props. & substitute idea that ecca each may be slightly diff. i.e. orbits 2_1 or 2_2 possible & the relativity modification is diff. in the 2 cases.

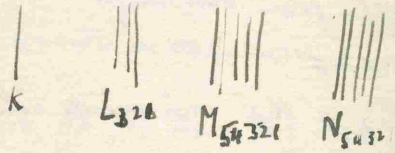
Doublet lines due to alternate orbits of certain classes i.e. ~~3_1 3_2~~, ~~3_2 3_2~~ : 3_1 a 3_1 b

3_2 a 3_2 b

for these alternate 'levels' or rings the screening constant is slightly diff.

1, orbit is	K	rings
2, 2 + 3	L	
3	M	
4, 2 3 4	N	
5, ...	O	
6, 2 3 . .	P	

Xenon



Krypton K L_{321} M_{54321}

L_2 = 2, a orbit
L_β = 2, b "

no line appears in the spectrum below two a or two b levels always below a absorbing

hence the identity of $K_\alpha + L_\alpha = K_\beta$ does not ever appear in the Roentgen spectrum

External forces do not sensibly disturb rings giving roentgen spectra as they giving optical spectra.

Spectra of rare earths gives 4/4 orbits' spectra

Chem. props vary periodically
Spectra " " linearly.

3rd quantum no. applicable to orientation of orbits.

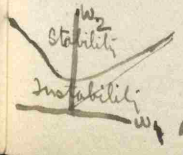
Stability of Viscous Fluids - Mr G. I. Taylor, F.R.S.

Cavendish - 10/5/22

Expts. of Osborne Reynolds never gave consistent results for pt. of instability relative to velocity. Mathematics very intricate. Select case of 2 concentric cylinders with water between + pin holes on inner on a middle section thro which coloured liquid is forced when rotation is at regd rate.

for any rotation ω_1 inner ω_2 outer $\frac{\omega_1}{\omega_2}$ + and > 1 the centrifugal force sends out the coloured fluid along the lines of stream which when the ratio exceeds a certain amt. gives alternate planes of outgoing + incoming with circular motion in opp. dir. above & below each

For $\frac{\omega_1}{\omega_2}$ - and > a definite integral value there is a place (in section B) where the turning takes place before reaching the outer cylinder wall. & a forced motion is taking place out side not shown by the coloured liquid. This is all predicted mathematically + disk. between planes calc. + expt coincided to 5%



Theoretical + expt curves lie very nearly coincident. Calculation of former involved approximate evaluation of huge determinants involving 43,000 terms &c.

Tablet in Lecture Room F. Arts School.

Fifth International Congress of Mathematicians
Cambridge August 1912.

In memory of Arthur Cayley
Sadlerian professor of pure
Mathematics 1863 - 1895
a tribute
from Mathematicians of
all lands — also of

George Howard Darwin K.C.B.
Plumian professor of
Astronomy 1883 - 1912 and
President of the Congress 1912
a tribute
from his Colleagues.

Mathematical Theory of Relativity

Professor A.S. Eddington. April 22/22.

References:- Relativity & Electron Thy. Cunningham.
1918 Report - Analytical - Eddington.
Space Time & Matter - Eng. trans - Wesl. (difficult)

Physical quantities - definitions. e.g. energy. either what its props. are or how to recognize it. i.e. Laws of Conservation. make idea of energy correspond to it - not suitable to experimental physics - but good for mathematics.
Fundamental definitions must rest on what we know experimentally, and on ideal props wh we think should exist. Pure Math. manufactures its quantities from certain starting pts. by calculation.
Consider length & parallax - former is fundamental
Relation betw. the phys. quantities we manufacture & the existant world condns. is that former are measure numbers of latter.
Codes i.e. parallax & distance are measures of same condn in diff. codes -
not necessarily a resemblance between our manufactured condition & the actual world condn.
This indirect knowledge is all we can ever attain.

Various codes to be kept distinct.
This is what the Calculus of Tensors does -
& this method appears final in dealing with the absolute world of wh. we get a partial impression by experience.
a physical quantity is defined as the expression of the

math. operations work. it is the result i.e. force = mass

Difference in time between two events leads to idea of relativity of measurement.

Only things not affected by this relativity: mass of a number, action, entropy.

Length 10^{-15} cm. difficulties are possible in such small quantities i.e. ordinary conception may break down - possibly difficulties in quantum th. are due to this

Fundamental Relativity - idea.

2 observers with diff. motions use diff. frames of ref. in space & time none more fundamental than the other

Method of Partitions - purely hypothetical

Frame of ref. 4 dimensional $x_1 x_2 x_3 t$.

Take a regular pentagon & give the (x_4) coords of its pts: thus gives its shape - also its orientation.

Give the dist. from one pt to others & so get only the shape

Similarly in 4 dimensions get the fundamentals only.

Hence

"Everything we can know in the connection connected with the location which enters its observational knowledge is contained in a relation of extension between pairs of events."

Thus only the indeterminateness of orientation remains.

"The relation of extension is called the interval its measure is ds.

Two systems are identical if & only if all intervals are equal. Thus if S, S' are same the mechanism remain identical tho as best the orientation motion &c may be different as discovered with observation in some larger system.

Keep side by side the definition of coords & of intervals & we require a formula to pass from one to other.

The interval ds between $x_1, x_2 x_3 x_4$ and $x_1 + dx_1$

is given by.

$$ds^2 = g_{11} dx_1^2 + 2 g_{12} dx_1 dx_2 + \ldots$$

General quadratic form of 10 terms.

This is indicated as fitting in with the observational world of phenomena.

other codes would take $\log ds$ or ds^2 or $f(ds)$ as the interval - but the simple ds has advantages. General geom. is embraced euclidean as a particular case.

Consider length AB = CD provided by measuring relative to a scale PQRS (any) We assume the scale has not changed. i.e. intervals are same. say. interval PQ = interval AB = interval CD. actually it is the distance PQ = dist AB = that we have measured neglecting time.

i.e. Space considered apart from time means interval is reduced to distance.

Newer truths of Pythagoras' Theo. + Euc. I. 47. when dealing with small Δ's.

Both scale + clock measure equality of interval the one eliminating time + the other space.
In general if we can measure an interval with the scale we cannot with clock + vice versa.

hence we have scale-intervals
+ clock-intervals.

then $ds^2 = g_1 dx^2$ may give either real or imaginary intervals.

"imaginary" means only terminology not anything with a mystical significance.

25/9/22.

$$ds^2 = g_{11} dx_1^2 + g_{22} dx_2^2 + 2 g_{12} dx_1 dx_2 \cdots$$

In general g's vary from pt to pt in world.
Consider a homogeneous region where g's are const.
It reduces to.

$$ds^2 = dy_1^2 + dy_2^2 + dy_3^2 + dy_4^2 \quad (A)$$

for consider

$$y_1 = a_1 x_1 + a_2 x_2 + \cdots a_4 x_4$$
$$y_2 = b_1 x_1 + b_2 x_2 \cdots$$
etc.

This gives 10 equations to determine 16 constants.
If g depends on position it introduces part. diffs which are not generally reducible to this simple form.
Consider all the events in which y_4 has a special value $y_4 = $ const.

then $ds^2 = dy_1^2 + dy_2^2 + dy_3^2$.
Cf. in rect. coords. $ds^2 = dx^2 + dy^2 + dz^2$.
The intervals are alike ∴ the systems are observationally the same.

Imaginary constants might have to be introduced to get x or y_1, y_2, y_3 or y_4 might be imag.

a clock at rest (if moving it goes slow)
gives equal intervals of time between cycles.
$dx\,dy\,dz = 0$ + $ds = dy_4$
in $ds^2 = dx^2 + dy^2 + dz^2 + dy_4^2$
and $dy_4 \propto dt$. $= \underline{ic\,dt}$. (say)

now. $ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2$ (a)

If we had chosen more general form.

$$ds^2 = \alpha dx^2 + \quad + \quad - c^2 dt^2 - 2\alpha\,dx\,dt - 2\beta dy\,dt - 2\gamma dz\,dt \quad (B)$$

Case (1) $dt = 0$
(2) $dx\,dy\,dz = 0$ to test for meaning of dy_4
equally applicable to B.

Now consider diff of time betw 2 events at diff places.

(1) Transport chronometer. from $(x_1, 0, 0)\ t_1$ to $(x_2, 0, 0)\ t_2$
diff of clock reading
$= \int_1^2 ds$ $dy\,dz$ terms go out of B

$$= \int dt \left(1 + \frac{2u}{c} - \frac{u^2}{c^2}\right)^{\frac{1}{2}} \qquad ds = ic\,dt\left(1 + \frac{2}{c}\frac{dx}{dt} - \frac{1}{c^2}\left(\frac{dx}{dt}\right)^2\right)^{\frac{1}{2}}$$

where $u = \frac{dx}{dt}$ = vel. of clock.

This cannot reduce to $t_2 - t_1$.

Try moving clock very slowly. i.e. u very small + approx. result req. $\frac{u^2}{c^2} = 0$

$$= \int dt \left(1 + \frac{1}{2}\frac{u}{c}\right) = \int dt \left(1 + \frac{1}{2}\frac{dx}{dt}\right) = t_2 - t_1 + \frac{1}{2c}(x_2 - x_1)$$

i.e. only if $\alpha = 0$ does interval of time $= t_2 - t_1$ for u very small.

∴ formula in general are of ⓐ

2. By light signals - similar result is obtained.

$ds^2 = dy_1^2 + dy_2^2 + dy_3^2 + dy_4^2$

$= dy_1'^2 + \ldots + dy_4'^2$ etc since many ways of reducing to this form.

i.e. space time frame is indeterminate but determinate relation between them is pure math. Ordinary 4 dimensional transformation eqns of rect. coords will apply.

i.e. translation + rotation.

rotation involving y_4 is the one relevant

$y_1 = y_1' \cos\theta - y_4' \sin\theta$.

$y_4 = y_1' \sin\theta + y_4' \cos\theta$.

i.e. $x = x' \cos\theta - ict' \sin\theta$

$ict = x' \sin\theta + ict' \cos\theta$.

If real θ is an imag. angle.

∴ put $u = ic \tan\theta$.

$\tan^2\theta = -u^2$

$\sec^2\theta = \frac{c^2}{c^2 - u^2}$

$\cos\theta = \left(1 - u^2/c^2\right) = \beta$

then $x = \beta(x' - ict' \frac{u}{ic})$

$ict = \beta x' \tan\theta \frac{u}{ic} + ict'$

$x = \beta(x' - ut')$ ⇔ $y = y'$ I

$t = \beta(t' - \frac{ux'}{c^2})$ $z = z'$

These are the most general transformation eqns (used by Lorentz)

Try to get a phys. interpretn of u.

Say. S S' at rest in their respective frames.

S loves is $x = \text{const.}$

$x' - ut' = \text{const}$ in S' frame.

i.e. u = vel. of S rel. to S'

Solve I for x'

$x' = \beta(x + ut')$

$t' = \beta(t + \frac{ux}{c^2})$

i.e. sign of u is reversed.

Point in S with vel. v' in S' frame
" v in S "

$v' = \frac{dx'}{dt'}$

$v = \frac{dx}{dt}$

$\frac{dx}{dt'} = \frac{\beta(dx' - u\,dt')}{\beta(dt' - u\,dx'/c^2)}$

$\frac{dx}{dt} = \frac{dx'}{dt'} - u \Big/ 1 - \frac{u}{c^2}\frac{dx'}{dt'}$

$= \frac{v' - u}{1 - \frac{uv'}{c^2}}$ verified if $v' - u$ as assumed in ord. kinematics

Apply this to light in stream of water.

S at rest V = vel of light in vacuo

S' moving water. μ = refr. index of water

$v' = V/\mu$

$$v = \frac{\frac{V}{\mu} - u}{1 - \frac{uV}{\mu c^2}}$$ If u small so that $\frac{u^2}{c^2}$ negligible

$$= \frac{V}{\mu} - u + \frac{uV^2}{\mu^2 c^2} = \frac{V}{\mu} - u\left(1 - \frac{V^2}{c^2}\frac{1}{\mu^2}\right)$$

This is Fresnel's convection coefficient
i.e. vel. of light is changed not by vel. of stream but by this fraction of it.
Experimentally confirmed by Fresnel + Zeeman — fraction obtained $\left(1 - \frac{1}{\mu^2}\right)$

c as here used is of fundamental importance deeper than fact of its being the vel. of light.

Michelson + Morley.

$+v'$ $\qquad$ $-v'$

$\frac{v' - u}{1 - uv'/c^2}$ $\qquad$ $\frac{-v' + u}{1 + uv'/c^2}$

They are equal + equal to c if work if $u = v' = c$

If $\left(\frac{dx}{dt}\right)^2 + \text{—} \quad \text{—} = c^2$

$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2 = 0$
or accented letters.

This is the deductive treatment as opposed to the inductive method wh. begins with the M+M. Expt. as starting pt. + from it reaches the general law of intervals.

April 27th.

$-ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$. Expt. identifies c with vel. of light.

write if

$+ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$

$$\left(\frac{ds}{dt}\right)^2 = c^2 - \left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2\right]$$

$= c^2 - v^2$ $\qquad$ v = vel. of a pt'd. body along the track of the interval.

call real intervals $v < c$ vel. of light.
timelike + unimpossible intervals spacelike.
if $v < c$ as is physical limitation
$\therefore$ interval is timelike.
Man is conscious of time intervals but deduces his space intervals.

From any event radiate intervals

$0 = c^2 dt^2 - dx^2 - dy^2 - dz^2$

gives a cone separating the timelike from the spacelike intervals

(Pass. thro' zero from real to imag.)

There is continuity across the boundary of cone.
also a discontinuity

$v = \frac{v' - u}{1 - uv'/c^2}$ $\qquad$ If $v_1 = c + \xi$
$v_2 = c - \xi$.

rel. vel. $= \frac{v_1 - v_2}{1 - v_1 v_2/c^2}$

$= \frac{2\xi}{1 - \frac{c^2 - \xi^2}{c^2}} = \frac{2c^2}{\xi}$

i.e. Consider 2 vels. 300000.1, 299 999.
rel. vel. $= \frac{2 \times 10^{10}}{1}$

180 000 000 000

i.e. In physical sense vel. just greater than c is not continuous with vel. " less " c.

"World-line" has a linear structure in 4 dimens.
Phys time a series of partitions
Time-sense is within our brains - a series of pt's in our world line.

Primitive idea of external partition lasted till 1667 when when R — ? on eclipses discovered time for transit of light & invented a revised system of partitions

Lorentz Eqns.

① $x = \beta(x' - ut')$ $\quad t = \beta(t' - \frac{ux'}{c^2})$

② $x' = \beta(x + ut)$ $\quad \beta$ always $(\;)'$.

from ② $x + ut = \frac{x'}{\beta}$.

S divides S''s measures by β in x dirn.
but accepts his y & z. $y = y'$ $z = z'$.

S' ⌐ → x
1 metre both ways.

S considers it contracts in going from one dirn to other.

Similarly a clock will go slow.

from ① first. $dt = \beta\, dt'$

i.e. S reduces all S''s time intervals.

Consider 2 events at same time in diff places.

A' $dt' = 0$ B' $dx' \neq 0$

i.e. not simultaneous to both observers. $dt = \frac{\beta u dx'}{c^2}$

Infinitesimally slow rel. del. to S is not the same " " " " " S' hence the diff in time dt exists.

S' pt of view.

dx' for $\frac{x'}{dx'}$ times.

clock loses at rate $1-(1-\frac{du'}{c^2})^{\frac{1}{2}}$

for time $\frac{x'}{du'}$.

∴ product is total loss = diff of v^2 order

from S's pt of view. of S''s clock

clock time $= (1-\frac{u^2}{c^2})^{\frac{1}{2}}$

clock loss in $(1-\frac{u^2}{c^2})^{\frac{1}{2}} \frac{u\,du}{c^2}$ clock seconds per true sec.

dist to go is $\frac{x'}{\beta}$

& ∴ time is $\frac{x'}{\beta\, du}$ in true sec.

Total loss in prod. $= \frac{u\,x'}{c^2}$ clock sec.

This is the correction S has to apply $\beta\frac{ux'}{c^2}$

Comparing time by electromag. signals involves a convention giving same result.

S' $\underset{A}{t_A} \rightarrow \overset{t_{A'}}{\leftarrow} \underset{B}{t_B}$ Convention $t_B = \frac{1}{2}(T_A + t_{A'})$

always assuming vel. of light same in both dirns

vels. $c-u$ $\quad c+u$.

true going $\frac{x}{c-u}$ returning $\frac{x}{c+u} = \frac{x(c-u)}{c^2-u^2}$

$= \frac{x(c+u)}{c^2-u^2} = \frac{\beta^2 x}{c^2}c + \frac{\beta^2 x}{c^2}u = \frac{\beta^2 x}{c^2}c - \frac{\beta^2 x}{c^2}u$

not same

∴ $t_B = \frac{1}{2}(t_A + t'_A) \pm \frac{\beta x u}{c^2}$, $\frac{\beta^2 x' u}{c^2}$

not as assumed above.

Large intervals corresponding gives similarity of extension

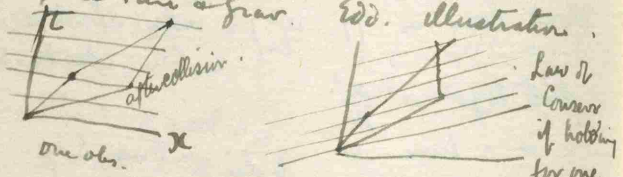
Minkowski intervals " exactly " " " of inertia.

Here consider inertia & Law of C. of E.

Momentum $M\frac{dx}{dt}$ $M\frac{dy}{dt}$ $M\frac{dz}{dt}$

hence M depends on observer not on body itself intrinsically.

Space Time & Grav. Edd. illustration.



∴ instead of defining momentum $M\frac{dx}{dt}$

call it $M\frac{dx}{ds}$ Taking full interval ds.

& 2 obs - will get diff values for momentum but Law of C of E will hold for both

Define as $m\frac{dx}{ds}$ $m\frac{dy}{ds}$ $m\frac{dz}{ds}$

where m same for all observers

where $M = m\frac{dt}{ds}$

$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2$

$\frac{dt}{ds} = (c^2 - v^2)^{-\frac{1}{2}}$

Apr. 29th/22.

Momentum components.

$M\frac{dx}{dt}$ - .

where M is rel. to observer.

$m\frac{dx}{ds}$ . . .

m is a no. attached to particle & const for all observers.

$M = m\frac{dt}{ds}$ $\qquad M = m\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$

i.e. mass M depends on motion in this way.

Experimentally verified with electrons - & shown to be a general prop. of mass not an electrical prop.

m is the invariant or proper mass - (and = M when body is at rest.

add a fourth component $m\frac{dt}{ds}$ $(= Mc)$

i.e. $m\frac{dx}{ds}$, $m\frac{dy}{ds}$, $m\frac{dz}{ds}$, Mc.

i.e. momentum gives the 3 space components & mass . . time component.

giving a 4 dimensional vector.

$M = m\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = m + \frac{1}{2}mv^2 - \ldots$

if ~~velocity~~ $c = 1$

In identifying energy with mass.

In mechanics we define change of energy not energy

not quite so simple if $c \neq 1$.

$$M = \frac{E}{c^2} \qquad (\text{i.e. } 1\text{gm} = 9\times10^{20}\text{ ergs})$$

If $\frac{1}{2}mv^2$ is defined as energy.
then actually $M = E$ is only approx.
for the law of conservation demands rigorous
K.E treatment taking all other terms.
Thus Cons. of mass becomes C. of energy.
Distinguish betw. invariant (m) + conservation (M)
the former is same for all observers
" latter " " " " changes in the system
The permanence of m is accidental like "rigidity".
Heat a billiard ball + M increased
due to higher speed of mols due to el. mg.
waves absorbed.
But el. mag waves have no invariant ~~mass~~ m.
m for an electron we believe permanent
but each el. has its rel.
+ not same rel. to axes of bil. ball.
$\therefore m$ (for ball) $\neq \Sigma m$ (electrons
but M (" ") $= \Sigma M$ (el)

General Transformations

Lorentz. $x_1\ x_2\ x_3\ x_4$ to $x_1'\ x_2'\ x_3'\ x_4'$
where latter are any function of former.

$$x_1 = f_1(x_1'\ x_2'\ x_3'\ x_4')$$

$$dx_1 = \frac{df_1}{dx_1'}dx_1' + \frac{\partial f_1}{\partial x_2'}dx_2' + \text{——}$$

Subst in general eqn.

$$ds^2 = g_{11}dx_1^2 + \text{——}$$
$$= g_{11}'dx_1'^2 \qquad \text{also quadratic}$$

Example. ($c=1$) $ds^2 = -dx^2 - dy^2 - dz^2 + dt^2$ (1)
rotating coords $x_1'\ x_2'\ x_3'\ x_4'$
ord. Kinematics transf$^{\text{n}}$ in ~~x=~~

$$x = x_1'\cos\omega x_4' - x_2'\sin\omega x_4'$$
$$y = x_1'\sin\omega x_4' + x_2'\cos\omega x_4'$$
$$z = x_3'$$
$$t = x_4'$$

$$dx = dx_1'\cos\omega x_4' - dx_2'\sin\omega x_4' - \omega(x_1'\sin\omega x_4' + x_2'\cos\omega x_4')dx_4'$$

$$dy = dx_1'\sin\omega x_4' + dx_2'\cos\omega x_4' + \omega(x_1'\cos\omega x_4' - x_2'\sin\omega x_4')dx_4'$$

$$dz = dx_3' \qquad dt = dx_4'.$$

Result is

$$ds^2 = -dx_1'^2 - dx_2'^2 - dx_3'^2 + \{1 - \omega^2(x_1'^2 + x_2'^2)\}dx_4'^2 + 2\omega x_2'dx_1'dx_4' - 2\omega x_1'dx_2'dx_4'$$

where coeffs are $g_{11}' = -1$ etc.
$g_{44} = \{\text{——}\}$

Centrifugal force is necessarily contained in this general rotational system.

Ord. kinematic formulae used leaving out Fitzg. contr. & clock alteration

To take account of these troubles is impracticable as it wd. bring us back to the non rotating system ①.

In rotational system - the scale & clock are not the natural equipment for exploration try something simpler -

2 test objects - a moving ptcl & a light-wave

moving ptcl. $x = a + bt$ $y = a + dt$ $z = e + ft$.

Diff. Eqns. $\frac{d^2x}{ds^2} + \frac{d^2y}{ds^2} + \frac{d^2z}{ds^2} - \frac{d^2t}{ds^2} = 0$

i.e. $\delta \int ds = 0$ i.e. straight is shortest dist betw. 2 pts.

This is equally applicable in any coord system.

Light wave Same eqns are satisfied additional condn of a vel.

$ds = 0$ (in this system $c = 1$)

Observer choses system $x_1\ x_2\ x_3\ x_4$

& geom is $ds^2 = g_{11}\,dx_1^2 + \text{———}$

& let him be under mistaken impression that there are simply $x\ y\ z\ t$.

$ds_0^2 = -dx_1^2 - dx_2^2 - dx_3^2 + dx_4^2$

(his mistaken value of interval)

He then gets a discrepancy with his observational ds - & thinks his test bodies are interfered with by some supernatural power.

He finds the moving body shows the discrep.

$\delta \int ds_0 = 0$ he takes to be uniform motion in str. line.

whereas $\delta \int ds$ is the actual.

Newtonian name for this supernatural agency is "field of force".

call $ds_0^2 = -dx_1^2 - \cdots\cdots$

the Abstract Geometry.

call $ds^2 = g_{11}\,dx_1^2 + \text{———}$

the natural geom.

A field of force represents a discrep. between the natural geom. & the abstract geom attributed by the mind

Abstract geom is Galilean coords.

(i.e. for 3 dim. Euclidean)

In general g's are not constant hence no reduction to form of latter or Galilean.

What is done is to treat the reqm absolutely not applic. to the gal. coords by the gal coords & then the discrep. is allowed for by a "field of force" = gravitation

Example observer on earth takes x y z t space & time
& builds up his nomenclature accel. vel.
etc.
Theoretical motion of apple should be a str. line
but is exptly found to be a parabola.
∴ introduce a "field of force" to account
for deviation.
By suitable transform of coords
elim. centrifugal force +
the residue is terrestrial grav.

2 sides of tri > 3rd in space
analogous in time AB + BC > AC.
3 events at
diff. times & place
clock measurement
2 partic sides are < less than 3rd
(no measuring backwards with a
clock.

Involving Geom + mechanics (electromechanics)
① $\delta\int ds = 0$ and for light ② $ds = 0$ are not
theoretical but experimental results.
If experimental is ① absolutely accurate
& universal in application
Does ② still hold in large space-time region
where rectangular axes & their coord are not
applicable.

The principle of equivalence states that $\delta\int ds = 0$
is likely to hold for curved space in all circumstances
where the curvature terms have vanished
If applying eqn to more complex motions
as $\delta\int(1 + \partial B^{\rho}_{\mu\sigma} B^{\mu\nu}_{\rho}) ds = 0$ where the BB
terms ~~go~~ out.
i.e. Similar phenomena are classified
under P. of Eq. But there are
phen. not to be so classified & here P. of E.
breaks down.

The track of a moving ptcl is unique
no matter what observer
only specification of unique track not involving
new universal constants is $\delta\int ds = 0$
hence they are probably true. $+ ds = 0$

Tensor Calculus now req^d for further
development
Transf^n from $x_1\ x_2\ x_3\ x_4$ to $x_1'\ x_2'\ \ldots$
displacement $dx_1\ dx_2\ dx_3\ dx_4$ undergoes trans
$$dx_1' = \frac{\partial x_1'}{\partial x_1} dx_1 + \frac{\partial x_1'}{\partial x_2} dx_2 + \ldots + \frac{\partial x_1'}{\partial x_4} dx_4 \quad ①$$
Define a contra variant vector
$(A^1\ A^2\ A^3\ A^4)$ on transf^n it becomes $(A'^1\ A'^2\ A'^3\ A'^4)$

when ① holds.

$$A'_1 = \frac{\partial x'_1}{\partial x_1} A^1 + \frac{\partial x'_1}{\partial x_2} A^2 + \text{— —}$$

$$A'^2 = \frac{\partial x'_2}{\partial x_1} A^1 + \quad A^2 \quad \text{— —}$$

Now consider an invariant quantity function as φ The potential indepdt. of coords.

gradiant $\frac{\partial \varphi}{\partial x_1}$, $\frac{\partial \varphi}{\partial x_2}$ . . .

Variation of these

$$\frac{\partial \varphi}{\partial x'_1} = \frac{\partial \varphi}{\partial x_1}\frac{\partial x_1}{\partial x'_1} + \frac{\partial \varphi}{\partial x_2}\frac{\partial x_2}{\partial x'_1} + \\ + \frac{\partial \varphi}{\partial x_4}\frac{\partial x_4}{\partial x'_1}$$

This is a Covariant ~~vector~~.

a typical transfn is given by.

$$A'_1 = \frac{\partial x_1}{\partial x'_1} A_1 + \frac{\partial x_2}{\partial x'_1} A_2 + + \frac{\partial x_4}{\partial x'_1} A_4$$

a covariant not necessarily the variation of a gradiant.

Vector Math. idea. 4 nos.

eg. 4, 6, 2, 12 assoc. with a pt in space + a coord system $x_1 x_2 x_3 x_4$ transform to coord. syst. $x'_1 x'_2 x'_3 x'_4$ what do nos become.

If another set of nos. (9, 2, 14, 1) means same pt in second system

Take 3 dimens. example. Quantity A

XYZ in xyz system prevails.

RΘΦ . rθφ .. ..

ΛMN . λμν +som ad ∞

easier to take a rule of passage from 1 syst to any other.

Rule must connect XYZ RΘΦ $\frac{\partial x}{\partial r}$ $\frac{\partial^2 \theta}{\partial x \partial y}$ . . . . . + derivatives upto any order of the xyz rθφ

Consider law $R = \frac{\partial r}{\partial x} X + \frac{\partial r}{\partial y} Y + \frac{\partial r}{\partial z} Z$

$$\Theta = \frac{\partial \theta}{\partial x} X + \frac{\partial \theta}{\partial y} Y + \frac{\partial \theta}{\partial z} Z.$$

Try now to get to λμν system.

$$\Lambda = \frac{\partial \lambda}{\partial r} R + \frac{\partial \lambda}{\partial \theta} \Theta + \frac{\partial \lambda}{\partial \varphi} \phi \qquad \text{subst + collect terms.}$$

$$= \left(\frac{\partial \lambda}{\partial r}\frac{\partial r}{\partial x} + \quad + \quad \right) X$$

$$+ \left(\frac{\partial \lambda}{\partial r}\frac{\partial r}{\partial y} + \frac{\partial \lambda}{\partial \theta}\frac{\partial \theta}{\partial y} + \right) Y$$

$$+ \left(\right) Z.$$

$$= \frac{\partial \lambda}{\partial x} X + \frac{\partial \lambda}{\partial y} Y + \frac{\partial \lambda}{\partial z} Z$$

a happy accident —

Try rule $R = \frac{\partial^2 r}{\partial x^2} X + \frac{\partial^2 r}{\partial y^2} Y + \frac{\partial^2 r}{\partial z^2} Z$

does not reduce to same rule for Λ.

[Discussed in Thy. of Groups]

This 1st rule is ∴ Self consistent + is same as that for Contravariant vector.

The covariant vector is not self consistent

[There is one other self consistent rule possible.

$$R = \frac{\partial_n}{\partial x} X + \frac{\partial_2}{\partial y} Y + \frac{\partial_2}{\partial_2} Z) \left\{ \frac{\partial(r,\theta,\varphi)}{\partial(x,y,z} \right\}^n$$

The Jacobi terms by its law of multiplication works to same form on each transformation.
This is taken account of in later work.]

A is a common name associated with diff. sets of coords according to the above rule.

[All systems of coords on equal footing if not take X,Y,Z. + always transform from XYZ direct to other system

Physical Idea of Vector.

X,Y,Z X',Y',Z' The physical thing behind these is the vector idea.
i.e. measure no. of world cond^n in any no. of codes.

Simplest idea a world cond^n expressed by one measure no. $\lambda = 3.10^{10} T$ holds in one code only c.g.s.
but $\lambda = cT$ holds in any code where c in c.g.s. units is 3×10^{10}.
i.e. assign to c dimensions + hence its value in any measure code is implied.

There are states in world not to be expressed in one measure no. i.e. force.
Need an eq^n applicable to all measure codes —
Take a world cond^n having 4 measure nos.

$$A_1 A_2 A_3 A_4 = B_1 B_2 B_3 B_4$$

Change code

$$A_1' A_2' A_3' A_4' = B_1' B_2' - -$$

Same operation on both sides of eq^n.
Introduces math vector
by associating it with a change of coords from $x_1\ x_2$ — to $x_1'\ x_2'$ — —
by transform either as a cov. or contrav. vector.
Both sides have to be treated alike
only 2 possibilities the cov. or contrav.
This is generalized dimensions
applicable to 4, 16, 64 — measure nos.
up to 1660 when new methods become possible.
Coord. systems are identification nos. for world states + therefore akin to measure nos.

$dx_1, dx_2 dx_3 dx_4$ we call or consider by the nature of our minds a change in location. Intrinsically it is no diff from a change in ptl. but we interpret it graphically & hence get our idea of space & time.

for geom. consistency $dx_i = \frac{dx_i}{dx_i'} dx_i'$ we must chose the contrav.

In rectangular coords. the distinction between cov & cov ceases to exist as $\frac{dx_i'}{dx_i} + \frac{dx_i}{dx_i'}$ are same but in oblique coords this is not ocase & in elem. mech. the usual vector is the contrav. vector. The cov. does not lend itself to geom. rep^{n} being as it were the reciprocal of the displacement.

Consider force if defined by $m \times a$ then $\frac{d^2x}{dt^2}$ comes in & contrav is ask if defined by

work = force × displacement

invariant = something × displacement. then here force is a cov. vector.

Law for contrav. vector

$$A_i' = \frac{\partial x_i'}{\partial x_1} A_1 + \frac{\partial x_i'}{\partial x_2} A_2 + \text{——}$$

$$= \sum_{\alpha=1}^{4} \frac{\partial x_i'}{\partial x_\alpha} A_\alpha$$

or $A'^{\mu} = \sum_{\alpha=1}^{4} \frac{\partial x_\mu'}{\partial x_\alpha} A^\alpha$

notation convention if same α comes in twice it implies summing 1 to 4 thus omit the Σ

$A'^{\mu} = \frac{\partial x_\mu'}{\partial x_\alpha} A_\alpha$

$A'_\mu = \frac{\partial x_\alpha}{\partial x'_\mu} A_\alpha$ n.b. if α in numer. then A_α if α in denom. A^α

This notation automatically does the Summations.

1. $ds^2 = g_{\mu\nu} dx_\mu dx_\nu$ $\mu + \nu$ each appear twice

$\therefore$ implies $\sum_{\mu=1}^{4} \sum_{\nu=1}^{4} g_{\mu\nu} dx_\mu dx_\nu$

$(g_{\mu\nu} = g_{\nu\mu})$

2. $\frac{\partial x_\mu}{\partial x_\alpha'} \cdot \frac{\partial x_\alpha'}{\partial x_\nu}$ stands for

$\frac{\partial x_\mu}{\partial x_1'} \frac{\partial x_1'}{\partial x_\nu} + \frac{\partial x_\mu}{\partial x_2'} \frac{\partial x_2'}{\partial x_\nu} + \quad +$

$= \frac{\partial x_\mu}{\partial x_\nu} = 0$ $(\mu \neq \nu)$ always except

if $(\mu = \nu)$ when it $= 1$

3. $\left(\frac{\partial x_\mu}{\partial x'_\alpha}\frac{\partial x_\alpha}{\partial x_\nu}\right)A_\nu$ Evaluate. values of ν are $\mu.\sigma.\tau.\rho$

These give $1.A_\mu + 0.A_\sigma + 0.A_\tau + 0.A_\rho$

i.e. ( ) is a substitution ~~operator~~ factor substituting μ for ν or ν for μ on everything, vectors or not.

Call these suffixes appearing twice dummy suffixes. They can be changed to any other symbol without affecting the other suffixes.

i.e. $\frac{\partial x_\mu}{\partial x'_\nu}\cdot\frac{\partial x'_\nu}{\partial x_\alpha}A_\alpha$ is exactly the same as (3).

Vector is a set of 4 quantities.
a Tensor is a " " 16, 64 .... quantities.

Call $A^{\mu\nu}$ a tensor
& classify them by their transformation formulae
Invariant is tensor of 0^{th} Rank.
Vector is Tensor of 1^{st} Rank.
(a) " " " " 2^{nd} "
(b) " " " " 3^{rd} "

a.
$$A'^{\mu\nu} = \frac{\partial x_\mu}{\partial x_\alpha}\frac{\partial x'_\nu}{\partial x_\beta}A^{\alpha\beta} \quad \text{Contravariant}$$

$$A'_{\mu\nu} = \frac{\partial x_\alpha}{\partial x'_\mu}\frac{\partial x_\beta}{\partial x_\nu}A_{\alpha\beta} \quad \text{Covariant}$$

$$A'^{\nu}_{\mu} = \frac{\partial x_\alpha}{\partial x'_\mu}\frac{\partial x'_\nu}{\partial x_\beta}A^{\beta}_{\alpha} \quad \text{Mixed.}$$

Extension

b.
$$A'^{\sigma}_{\lambda\mu\nu} = \frac{\partial x_\alpha}{\partial x'_\lambda}\frac{\partial x_\beta}{\partial x'_\mu}\frac{\partial x_\gamma}{\partial x'_\nu}\frac{\partial x'_\sigma}{\partial x_\delta}A^{\delta}_{\alpha\beta\gamma}$$

this implies 256 eqns each with 256 terms on R.H. Side.

Sum of 2 tensors of same kind is a tensor since Transf^n laws are linear

Consider $A^{\beta}_{\alpha} + B^{\beta}_{\alpha} = C^{\beta}_{\alpha} - D^{\beta}_{\alpha}$
If it holds in one syst. of coords it will hold in any.
Bring to L.H. Side & $T^{\beta}_{\alpha} = 0$
then all the components of the tensor in all systems of coords vanish.

Prod. of 2 tensors is a tensor.

$$A'^{\sigma}_{\lambda}A'_{\mu\nu} = \frac{\partial x_\alpha}{\partial x'_\lambda}\frac{\partial x_\beta}{\partial x_\delta}A^{\delta}_{\alpha}\frac{\partial x_\beta}{\partial x'_\mu}\frac{\partial x_\gamma}{\partial x'_\nu}A_{\beta\gamma}$$

of form $A^{\sigma}_{\lambda\mu\nu}$ (Tensor rank altered)

Contraction operator.

$$A'^{\nu}_{\lambda\mu\nu} = \frac{\partial x_\alpha}{\partial x'_\lambda}\frac{\partial x_\beta}{\partial x'_\mu}\frac{\partial x'_\gamma}{\partial x_\gamma}\frac{\partial x'_\nu}{\partial x_\sigma} A^{\delta}_{\alpha\beta\gamma\sigma}$$

(substitution operator)

$$= \frac{\partial x_\alpha}{\partial x'_\lambda}\frac{\partial x_\beta}{\partial x'_\mu} A^{\gamma}_{\alpha\beta\gamma}$$

= ord cov. trans. of 2nd rank.

∴ tensor character in $A_{\lambda\mu}$

i.e. upper + lower suffixes alike are dummys + cancel out giving the character of the tensor by what is left. Called Contraction from German verjüngung

4) $A_\mu B^\nu$ 16 quantities.

disjoint quantities A_1B^1 $A_2B^2 \ldots A_4B^4$

$A_\mu B^\mu$ by the convention stands for $\sum$

$A_\mu B^\nu$ is called outer product

$A_\mu B^\mu$ " " inner " as is an invariant with dummy suffixes cancel out.

Quotient of 2 tensors is a tensor in a sense.

Division does not really come in.

Consider $C(\mu\nu\sigma) A^{\mu}_{\nu\rho} = B_{\rho\sigma}$

$C(\mu\nu\sigma) = \dfrac{B_{\rho\sigma}}{A^{\mu}_{\nu\rho}} \rightarrow$ symbolic representation $C^{\nu\rho}_{\rho\sigma\mu}$

$C^{\nu}_{\sigma\mu} A^{\mu}_{\nu\rho} = B_{\rho\sigma}$ gives the form of a tensor by prime of dimensions (analogous)

Example.

$ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu$

Invariant = $g_{\mu\nu}\,(dx)^\mu\,(dx)^\nu$ since contrav.

∴ $g_{\mu\nu}$ must be a tensor with its suffixes below to cancel out giving an invariant as req^d by L.H.S. of eq.

∴ $g_{\mu\nu}$ a cov. tensor.

Denote determinant of $g_{\mu\nu}$ (4 rows + cols

$|g_{\mu\nu}| = g$

$g^{\mu\nu}$ = minor of $g_{\mu\nu} \div g$

$\begin{vmatrix} g_{11} & \cdots & \cdots & \cdots \\ \vdots & \cdots & \cdots & \cdots \\ \vdots & \cdots & \cdots & \cdots \\ \vdots & \cdots & \cdots & \cdots \end{vmatrix}_{\nu,\sigma}$

Consider $g_{\mu\nu} g^{\mu\sigma} = g^{\sigma}_{\nu}$ μ a dummy 4 terms

It vanishes since juggling lines of det. gives 2 rows same

if $\nu \neq \sigma$ $g_{\mu\nu} g^{\mu\sigma} = 0$

if $\nu = \sigma$ $= 1$.

Hence a substitution operator

$g^{\sigma}_{\nu} A^{\nu} = A^{\sigma}$ a mixed tensor

i.e. $\begin{vmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$ is a mixed tensor of 2nd rank + a substitution operator.

Now. $g_{\mu\nu}$ g^{ν}_{μ} $g^{\mu\nu}$ are 3 fundamental tensors describing the state of the world.

$g_{\mu\nu} A^{\mu} = B_{\nu}$ a cov. vector. ①

$g_{11} A^1 + g_{21} A^2 + g_{31} A^3 + g_{41} A^4 = B_1$, $\mu = 1$

$g_{12} A^1 + g_{22} A^2 + g_{32} A^3 + g_{42} A^4 = B_2$ $\nu = 2$

$g_{13} A^1$

$g_{14} A^1$

$$A^1 = \begin{vmatrix} B_1 & g_{21} & g_{31} & g_{41} \\ B_2 & g_{22} & . & . \\ B_3 & . & . & . \\ B_4 & . & . & . \end{vmatrix} \div g$$

Hence $A^1 = g^{11} B_1 + g^{12} B_2 + g^{13} B_3 + g^{14} B_4$

$A^2 =$

$A^3 =$

$A^4 =$

or ① + the eqns are expressed by

$A^{\mu} = g^{\mu\nu} B_{\nu}$ by generalized method of inversion

Define A_{μ} as $A_{\mu} = g_{\mu\nu} A^{\nu}$

Recip. relation $A^{\mu} = g^{\mu\nu} A_{\nu}$

Consider. $A_{\lambda\mu\nu}$

$A_{\lambda\mu}{}^{\nu} = g^{\nu\sigma} A_{\lambda\mu\sigma}$.

operators $g^{\mu\nu}$ raises suffix + substitutes μ for ν

g^{ν}_{μ} simple substitution.

$g_{\mu\nu}$ lowers suffix + substitutes.

In Euclidean geom. $ds^2 = dx^2 + dy^2 + dz^2$

g_{11} g_{22} $g_{33} = 1$

others $= 0$.

i.e. $g_{\mu\nu} = g^{\nu}_{\mu} = g^{\mu\nu}$ hence multiplying by these operators does not alter tensor

∴ no distinction as long as we keep to rect. coords.

In ord. rect. coords. (A_1, A_2, A_3) (B_1, B_2, B_3)

Scalar prod. $A_1 B_1 + A_2 B_2 + A_3 B_3$

written thus $A_{\mu} B_{\mu}$ not a tensor + not interesting

∴ as rect. coords. no alteration of vector if we write it $A_{\mu} B^{\mu}$ an invariant corresponding to scalar prod.

① A_{μ} $\perp^{r}$ B_{μ} if $A_{\mu} B^{\mu} = 0$.

cf. 2 vectors are $\perp^{r}$ if their scalar prod = 0

② Length of vector A_{μ} (or A^{μ}) is $l^2 = A_{\mu} A^{\mu}$

i.e. $A_1^2 + A_2^2 + A_3^2$ as in ord. geom.

$dx_\mu = (dx)^\mu$ by notation

$ds^2 = g_{\mu\nu}(dx)^\mu \cdot (dx)^\nu$

$= (dx)_\nu \cdot (dx)^\nu$ = Sq. of length of vector dx_μ.

i.e. the interval is the length of the displacement

If length vanishes i.e. $ds = 0$
the vector is $\perp^r$ (no meaning in 3 dimensions)

∴ displacement along a light track is self-perpendicular.

Equations of Geodesic

i.e. track of moving ptcl when $\int ds$ is stationary. & track is varied at beginning & end of path.

Set $ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu$

vary ds

$2\,ds\,\delta(ds) = \delta g_{\mu\nu} \cdot dx_\mu dx_\nu$
$+ g_{\mu\nu}\, dx_\nu\, \delta(dx_\mu)$
$+ g_{\mu\nu}\, dx_\mu\, \delta(dx_\nu)$ } These terms are same as $\mu\nu$ are dummies

$= \frac{\partial g_{\mu\nu}}{\partial x_\sigma} \delta x_\sigma\, dx_\mu dx_\nu + g_{\mu\nu}\, dx_\mu\, d(\delta x_\mu) +$
$g_{\mu\nu}\, dx_\mu\, d(\delta x_\nu)$ Since in Calc. of Variations d & δ are interchangeable

$= \frac{1}{2}\int \Big(\frac{\delta g_{\mu\nu}}{\delta x_\sigma} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds} \delta x_\sigma$
$+ g_{\mu\nu} \frac{dx_\nu}{ds} \frac{d}{ds} \delta x_{\kappa\sigma}$
$+ g_{\mu\nu} \frac{dx_\mu}{ds} \frac{d}{ds} \delta x_{\kappa\sigma} \Big)\, ds = 0$

change dummies to σ

keep on integrating by parts till only parameters remain

$= \frac{1}{2}\int \Big(\frac{\delta g_{\mu\nu}}{\delta x_\sigma} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds} - \frac{d}{ds} g_{\sigma\nu} \frac{dx_\nu}{ds} - \frac{d}{ds} g_{\mu\sigma} \frac{dx_\mu}{ds} \Big) \delta x_\sigma\, ds = 0$

only true if integrand vanishes
i.e. (———)

$= \frac{1}{2} \frac{\delta g_{\mu\nu}}{\delta x_\sigma} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds} - \frac{1}{2} \frac{\delta g_{\sigma\nu}}{\delta x_\mu} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds}$

Dummy dummy suffixes

$- \frac{1}{2} g_{\sigma\nu} \frac{d^2 x_\nu}{ds^2} - \frac{1}{2} \frac{\delta g_{\nu\sigma}}{\delta x_\mu} \frac{dx_\nu}{ds} \frac{dx_\mu}{ds}$
$- \frac{1}{2} g_{\mu\sigma} \frac{d^2 x_\mu}{ds^2} = 0$

$= \frac{1}{2} \frac{dx_\mu}{ds} \frac{dx_\nu}{ds} \Big(\frac{\delta g_{\nu\sigma}}{\delta x_\mu} + \frac{\delta g_{\mu\sigma}}{\delta x_\nu} - \frac{\delta g_{\mu\nu}}{\delta x_\sigma} \Big) - g_{\sigma\alpha} \frac{d^2 x_\alpha}{ds^2} = 0$

Putting in α for σ is here the only real suffix. & the 4 eqns are the Geodesic -

Simplify by mult. by $g^{\sigma\varepsilon}$

$$g^{\sigma\varepsilon} g_{\sigma\alpha} = g^{\varepsilon}_{\alpha}.$$

$$\frac{d^2 x_\varepsilon}{ds^2} + \frac{1}{2} g^{\sigma\varepsilon}\left(\frac{\delta g_{\mu\sigma}}{\delta x_\nu} + \frac{\delta g_{\nu\sigma}}{\delta x_\mu} - \frac{\delta g_{\mu\nu}}{\delta x_\sigma}\right)\frac{dx_\mu}{ds}\frac{dx_\nu}{ds} = 0 \qquad (A)$$

$\sigma\ \mu\ \nu$ are all dummy suffixes.

$\varepsilon(1,2,3,4)$

4 eqns giving curvatures of track in terms of gradients or accel. in terms of velocity.

Special notation.

Define $[\mu\nu\sigma] = \frac{1}{2}\left(\frac{\delta g_{\mu\sigma}}{\delta x_\nu} + \frac{\delta g_{\nu\sigma}}{\delta x_\mu} - \frac{\delta g_{\mu\nu}}{\delta x_\sigma}\right)$

$$\left\{\begin{matrix}\mu\nu\\ \lambda\end{matrix}\right\} = g^{\sigma\lambda}[\mu\nu,\sigma]$$

or $$[\mu\nu,\lambda] = g_{\sigma\lambda}\left\{\begin{matrix}\mu\nu\\ \sigma\end{matrix}\right\}$$

(A) is the $\left\{\ \right\}$ symbol. write it.

$$(B)\quad \frac{d^2 x_\varepsilon}{ds^2} = \left\{\begin{matrix}\mu\nu\\ \varepsilon\end{matrix}\right\}\frac{dx_\mu}{ds}\frac{dx_\nu}{ds} = 0.$$

These are Geodesic eqns in simplest form

Note: $[\mu\nu,\sigma] + [\sigma\nu,\mu] = \frac{\delta g_{\mu\sigma}}{\delta x_\nu}$

[ ] represents 40 diff. symbols bec. $\mu\nu$ are interchangeable

giving 10 possible combns. + σ has 4 $\therefore$ 40 different ones.

$\frac{\delta\varphi}{\delta x_\nu}$ is a cov. tensor where φ_ν is grad.

but $\frac{\delta^2\varphi}{\delta x_\mu \delta x_\nu}$ is not a tensor unless $\frac{\delta\varphi}{\delta x_\nu}$ is invariant

In physics derivatives are necessary

$\therefore$ find tensors to express them.

Consider $\frac{dx_\mu}{ds}$ a contrav. vector

$\therefore$ if A_μ be cov.

$\left(A_\mu \frac{dx_\mu}{ds}\right)$ is an invariant.

on a specification of each pt. of a curve.

$\therefore$ the rate of change is invariant

$\therefore \frac{d}{ds}\left(A_\mu \frac{dx_\mu}{ds}\right)$ is invariant

but curve must be defined indep^t of the coords

$\therefore$ choose a geodesic.

$\frac{\delta A_\mu}{\delta x_\nu}\frac{\delta x_\nu}{\delta s}\cdot\frac{\delta x_\mu}{\delta s} + A_\mu \frac{d^2 x_\mu}{ds^2}$ is invar^t along geodesic $\therefore$ replace d^2

$$A_\mu \frac{d^2x_\mu}{ds^2} = A_\varepsilon \frac{d^2x_\varepsilon}{ds^2} = -A_\varepsilon \left\{\mu\nu,\varepsilon\right\} \frac{dx_\mu}{ds}\frac{dx_\nu}{ds}$$

$$\therefore \left[\frac{\partial A_\mu}{\partial x_\nu} - \left\{\mu\nu\varepsilon\right\} A_\varepsilon\right] \frac{dx_\mu}{ds}\frac{dx_\nu}{ds} \text{ is inv.}$$

along geod

& it is evident along any curve since the x^{th} deriv. is now eliminated.

$\therefore$ $[\quad]$ is a tensor of 2^{nd} rank.

$A_{\mu\nu} C^\mu C^\nu$ is inv.

$$A_{\mu\nu} = \frac{\partial A_\mu}{\partial x_\nu} - \left\{\mu\nu,\varepsilon\right\} A_\varepsilon$$

= the covariant derivative of A_μ

4/3/22. (Copied)

Covariant deriv. of cov. vector A_μ.

$$A_{\mu\nu} = \frac{\partial A_\mu}{\partial x_\nu} - \left\{\mu\nu,\varepsilon\right\} A_\varepsilon.$$

Cov. der. of contravar. vector A^μ

$$A^\mu_\nu = \frac{\partial A^\mu}{\partial x_\nu} + \left\{\varepsilon\nu,\mu\right\} A^\varepsilon$$

By lowering suffix rule $A_\mu = g_{\mu\sigma} A^\sigma$

Substituting $A_{\mu\nu} = \frac{\partial}{\partial x_\nu}(g_{\mu\sigma} A^\sigma) - \left\{\mu\nu,\varepsilon\right\} g_{\varepsilon\sigma} A^\sigma$

Diff^g $= g_{\mu\sigma}\frac{\partial A^\sigma}{\partial x_\nu} + A^\sigma\left(\frac{\partial g_{\mu\sigma}}{\partial x_\nu} - [\mu\nu,\sigma]\right)$

since by lowering last suffix we convert $\{-\}$ to $[-]$.

$$[\mu\nu,\sigma] + (\sigma\nu,\mu) = \frac{\partial g_{\mu\nu}}{\partial x_\nu}$$

$$\therefore A_{\mu\nu} = g_{\mu\sigma}\frac{\partial A^\sigma}{\partial x_\nu} + [\sigma\nu,\mu] A^\sigma$$

We raise μ by mul. by $g^{\mu\varepsilon}$

$$A^\varepsilon_\nu = \frac{\partial A^\varepsilon}{\partial x_\nu} + \left\{\sigma\nu,\varepsilon\right\} A^\sigma$$

$$\therefore A^\mu_{\nu} = \frac{\partial A^\mu}{\partial x_\nu} + \left\{\varepsilon\nu,\mu\right\} A^\varepsilon$$ the cov. der. of a contr. vector.

Differentiation of tensors.

$\frac{d}{ds}\left(A_\mu \frac{dx_\mu}{ds}\right)$ is inv^t along a geodesic.

$\frac{d}{ds}\left(A_{\mu\nu\sigma\tau\ldots} \frac{dx_\mu}{ds}\frac{dx_\nu}{ds}\frac{dx_\sigma}{ds}\frac{dx_\tau}{ds}\ldots\right)$ is inv^t clearly

Results from above –

Diff. $A_{\mu\nu}$ with regard to σ

$$A_{\mu\nu\sigma} = \frac{\partial A_{\mu\nu}}{\partial x_\sigma} - \left\{\mu\sigma,\varepsilon\right\} A_{\varepsilon\nu} - \left\{\nu\sigma,\varepsilon\right\} A_{\mu\varepsilon}$$

$A^\rho_{\lambda\mu\nu}$ with regard to σ

$$A^\rho_{\lambda\mu\nu\sigma} = \frac{\partial A^\rho_{\lambda\mu\nu}}{\partial x_\sigma} - \left\{\lambda\sigma,\varepsilon\right\} A^\rho_{\varepsilon\mu\nu} - \left\{\mu\sigma,\varepsilon\right\} A^\rho_{\lambda\varepsilon\nu} - \left\{\nu\sigma,\varepsilon\right\} A^\rho_{\lambda\mu\varepsilon} + \left\{\varepsilon\sigma,\rho\right\} A^\varepsilon_{\lambda\mu\nu}$$

Diff^{n} of a product Ord. rule applies for covariant differ^{n}

$$(A_\mu B_\nu)_\sigma = \frac{\partial A_\mu B_\nu}{\partial x_\sigma} - \left\{\mu\sigma,\varepsilon\right\} A_\varepsilon B_\nu - \left\{\nu\sigma,\varepsilon\right\} A_\mu B_\varepsilon$$

$$= B_\nu \frac{\partial A_\mu}{\partial x_\sigma} + A_\mu \frac{\partial B_\nu}{\partial x_\sigma} - \left\{\mu\sigma,\varepsilon\right\} A_\varepsilon B_\nu - \left\{\nu\sigma,\varepsilon\right\} A_\mu B_\varepsilon$$

$$= B_\nu \left(\frac{\partial A_\mu}{\partial x_\sigma} - \left\{\mu\sigma,\varepsilon\right\} A_\varepsilon\right) + A_\mu \left(\frac{\partial B_\nu}{\partial x_\sigma} - \left\{\nu\sigma,\varepsilon\right\} B_\varepsilon\right)$$

$$= B_\nu A_{\mu\sigma} + A_\mu B_{\nu\sigma}$$

Apply to find cov. der of $(g_{\mu\nu})_\sigma$

$$g_{\mu\nu\sigma} = \frac{\partial g_{\mu\nu}}{\partial x_\sigma} - g_{\varepsilon\nu}\left\{\mu\sigma,\varepsilon\right\} - g_{\mu\varepsilon}\left\{\nu\sigma,\varepsilon\right\}$$

$$= \frac{\partial g_{\mu\nu}}{\partial x_\sigma} - [\mu\sigma,\nu] - [\nu\sigma,\mu]$$

$$= \frac{\partial g_{\mu\nu}}{\partial x_\sigma} - \frac{\partial g_{\mu\nu}}{\partial x_\sigma} = 0$$

Similarly for $g^{\mu\nu}$ and g^{ν}_{μ}

Thus the fundamental tensor behaves as a constant in covariant differ^{n}.

Use & meaning of covariant derivs. When $g_{\mu\nu}$ const. Christoffel symbols vanish. In this case cov. der is same as ordinary deriv.

$A_{\mu\nu} = \frac{\partial A_\mu}{\partial x_\nu}$ This holds for Galilean coords. where $g_{\mu\nu}$ are constant

Potential - with vel. c.

$\Box\phi \equiv \frac{\partial^2\phi}{\partial t^2} - \nabla^2\phi = 0$ the wave propagation eqn.

$\frac{\partial^2\phi}{\partial t^2} - \frac{\partial^2\phi}{\partial x^2} - \frac{\partial^2\phi}{\partial y^2} - \frac{\partial^2\phi}{\partial z^2} = 0$

$-\frac{\partial^2\phi}{\partial x_1^2} - \frac{\partial^2\phi}{\partial x_2^2} - \frac{\partial^2\phi}{\partial x_3^2} + \frac{\partial^2\phi}{\partial x_4^2} = 0$

this in Galilean

$g^{11} = -1 \quad g^{22} = -1 \quad g^{33} = -1 \quad g^{44} = 1$

other g's are $= 0$.

$g_{\mu\nu}\frac{\partial^2\phi}{\partial x_\mu \partial x_\nu} = 0$ may be written for above since (eg.) $g^{12} = 0$.

$\frac{\partial\phi}{\partial x_\nu}$ is a cov. vector - call it ϕ_ν

$\frac{\partial^2\phi}{\partial x_\mu \partial x_\nu} = \frac{\partial\phi_\nu}{\partial x_\mu}$ this in Galilean coords. is the same as the cov. der. $g_{\mu\nu}$

Then we may write

$g^{\mu\nu}\phi_{\mu\nu} = 0$ an inv. eqn

Thus if $g^{\mu\nu}\frac{\partial^2\phi}{\partial x_\mu \partial x_\nu}$ is satisfied in one orig. Galilean system of coords $g^{\mu\nu}\phi_{\mu\nu}$ is sat^{d} in all systems

Take $g^{\mu\nu}\left(\frac{\partial}{\partial x_\mu}\phi_\nu - \left\{\nu\mu,\varepsilon\right\}\phi_\varepsilon\right) = 0$

This becomes

$g^{\mu\nu}\left(\frac{\partial^2\phi}{\partial x_\mu \partial x_\nu} - \left\{\nu\mu,\varepsilon\right\}\frac{\partial\phi}{\partial x_\varepsilon}\right) = 0$

Note transf^{n} of coords does not involve change of kind of space Thus above will not hold in

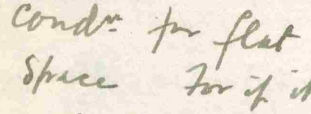
region of world where there are no gal. coords
But here the P. of Equiv. comes out. (only of
course a plausible suggestion to be tested by exp!)
This deals with use but with regard to
meaning :- Derivatives gives rate of change
of p. q
But take Eulers eqns for rotating axes
h_1 h_2 h_3 ang. mom.
$\frac{\partial h_1}{\partial t}$ $\frac{\partial h_2}{\partial t}$ $\frac{\partial h_3}{\partial t}$ replaced by
$\frac{\partial h_1}{\partial t} - w_2 h_3 + w_3 h_2$ to compensate for
spurious change introd. by rotation
or field of force uniform in coords
$R \Theta \phi$. altho field uniform R not
const. at diff. points.
$\therefore \frac{\partial R}{\partial x}$ or $\frac{\partial R}{\partial \Theta}$ do not indicate a change
of field necessarily.
Cov. der. gives the real rate of change
of the phys. quantity we take off from appar.
rate of change a term due to peculiarity
of the coords.
When the g_{ik}'s are const. the Christoffel
symbols vanish + $\therefore$ real change seems
to be same as spurious change (change
of rect. coords) So it cannot hold
in a gravitational field.

Note general inapplicability of notion of
abs. change.
$\frac{\partial^2 \phi}{\partial x \partial y} = \frac{\partial^2 \phi}{\partial y \partial x}$, is $A_{\mu\nu\sigma} = A_{\mu\sigma\nu}$?
We have $A_{\mu\nu\sigma} = \frac{\partial}{\partial x_\sigma}\left(\frac{\partial A_\mu}{\partial x_\nu} - \left\{\mu\nu,\varepsilon\right\} A_\varepsilon\right) -$
$- \left\{\mu\sigma,\varepsilon\right\}\left(\frac{\partial A_\varepsilon}{\partial x_\nu} - \left\{\varepsilon\nu,\rho\right\} A_\rho\right) - \left\{\mu\sigma,\varepsilon\right\}\left(\frac{\partial A_\mu}{\partial x_\varepsilon} - \left\{\mu\varepsilon,\rho\right\} A_\rho\right)$
$= \frac{\partial^2 A_\mu}{\partial x_\sigma \partial x_\nu} - \left\{\mu\nu,\varepsilon\right\}\frac{\partial A_\varepsilon}{\partial x_\sigma} - \left\{\mu\sigma,\varepsilon\right\}\frac{\partial A_\varepsilon}{\partial x_\mu}$
$- \left\{\mu\sigma,\varepsilon\right\}\frac{\partial A_\mu}{\partial x_\varepsilon} + \left\{\mu\sigma,\varepsilon\right\}\left\{\varepsilon\nu,\rho\right\} A_\rho$
$+ \left\{\mu\sigma,\varepsilon\right\}\left\{\mu\varepsilon,\rho\right\} A_\rho - \sum_\varepsilon A_\varepsilon \frac{\partial}{\partial x_\sigma}\left\{\mu\nu,\varepsilon\right\}$
$A_{\mu\nu\sigma} - A_{\mu\sigma\nu} = A_\rho\left\{\mu\sigma,\varepsilon\right\}\left\{\varepsilon\nu,\rho\right\} - A_\rho\left\{\mu\nu,\varepsilon\right\}\left\{\varepsilon\sigma,\rho\right\}$
$- A_\rho \frac{\partial}{\partial x_\sigma}\left\{\mu\nu,\rho\right\} + A_\rho \frac{\partial}{\partial x_\nu}\left\{\mu\sigma,\rho\right\}$
$= A_\rho\left(\left\{\mu\sigma,\varepsilon\right\}\left\{\varepsilon\nu,\rho\right\} - \left\{\mu\nu,\varepsilon\right\}\left\{\varepsilon\sigma,\rho\right\} - \frac{\partial}{\partial x_\sigma}\left\{\mu\nu,\rho\right\} + \frac{\partial}{\partial x_\nu}\left\{\mu\sigma,\rho\right\}\right)$
RHS is a tensor.
$A_{\mu\nu\sigma} - A_{\mu\sigma\nu} = A_\rho\left[B^\rho_{\mu\nu\sigma}\right]$ The Riemann Christoffel tensor
It is made up entirely of
Christoffel symbols containing 1st + 2nd ders
of $g_{\mu\nu}$, + $g_{\mu\nu}$ themselves; $\therefore$ it is of
the fundamental series & thus has a

property of space & not of anything in space
It is of 4th rank.
The vanishing of the Riemann Christoffel (R-C) tensor is the necessary & suffic condn for flat or homaloidal space. For if it vanishes $g_{\mu\nu}$ are const & if it does not vanish $g_{\mu\nu}$ are not so.
$B^{\rho}_{\mu\nu\sigma} = 0$ if this be so it holds in all coord. systems. Thus & hence clearly if $g_{\mu\nu}$ are const. the R.C.T. vanishes. The converse is not so easily proved.

11/5/22. Tensors at a pt. A_μ at x_μ
another $A_{\mu+d\mu}$ at $x_{\mu+dx}$.
apparent change is $\frac{\partial A_\mu}{\partial x_\nu} dx_\nu$
absolute change - $A_{\mu\nu} dx_\nu$
If no abs. change.
$A_{\mu\nu} = 0$
$\frac{\partial A_\mu}{\partial x_\nu} - \{\mu\nu,\alpha\} A_\alpha = 0$ is condn for displacement without Abs. change,
or $dA_\mu = [\mu\nu,\alpha] A_\alpha \, dx_\nu$

call this parallel displacement when cov. dev. vanishes, i.e. no abs. change.
Take a vector at any pt. & move by ∥ displt. over & over again to another pt.



$$dA_\mu = [\mu\nu,\alpha) A_\alpha \, dx_\nu$$
$$\delta A_\mu = \int_1^2 dA_\mu = \int_1^2 \{\mu\nu,\alpha\} A_\alpha \, dx_\nu$$

Try another path. Same if a complete differential integral, different if A_μ not a complete differential & depends on path.
Rule for perf. diffl.
$X_1 dx_1 + X_2 dx_2 + X_3 dx_3 + X_4 dx_4$ is p. diffl
if $\frac{\partial X_2}{\partial x_1} - \frac{\partial X_1}{\partial x_2} = 0$ & all similar combns.
for small values of ν & σ this is
$$\frac{\partial X_\nu}{\partial x_\sigma} - \frac{\partial X_\sigma}{\partial x_\nu} = 0$$
∴ Above condn is.
$$\frac{\partial}{\partial x_\sigma}\left[\{\mu\nu,\alpha\} A_\alpha\right] - \frac{\partial}{\partial x_\nu}\left[\{\mu\sigma,\alpha\} A_\alpha\right] = 0$$
Work it out:-
$$A_\alpha\left[\frac{\partial}{\partial x_\sigma}\{\mu\nu,\alpha\} - \frac{\partial}{\partial x_\mu}\{\mu\sigma,\alpha\} + \{\mu\nu,\sigma\}\frac{\partial A_\alpha}{\partial x_\sigma} - \{\alpha\sigma,\varepsilon\} A_\varepsilon\right.$$

$$-\left\{\mu\sigma\,\alpha\right\}\left\{\alpha\nu,\varepsilon\right\}A_\varepsilon .$$

α is dummy put in ε. in [ ]

& get.

$$A_\varepsilon\left[\frac{\partial}{\partial x_\sigma}\left\{\mu\nu,\varepsilon\right\}-\frac{\partial}{\partial x_\nu}\left\{\mu\sigma,\varepsilon\right\}+\left\{\mu\nu,\alpha\right\}\left\{\alpha\sigma,\varepsilon\right\}-\left\{\mu\sigma,\alpha\right\}\left\{\alpha\mu,\varepsilon\right\}\right]$$

$$=0.$$

i.e. R-C Tensor $B^{\varepsilon}_{\mu\nu\sigma}=0.$

& if this it so a vector can be displaced by any path by ||$^{\text{le}}$ displ$^{\text{t}}$ & no abs change is involved.

This gives a vector field which is uniform. This state cannot exist if RCT $\neq 0$.

Analogy in 2 dimens.

on a plane ya can have a uniform wind - but not on surface of earth. where directions wd. not be same.

Here consider any developable surface (eg cylinder) as a flat surface.

consider a box enclosed by 4 vectors & by || displ displace box all over field by considering each side. these boxes give oblique Cartesian coords - for which all g's are constant. This is converse of former problem 3 pages back.

Consider R. C. Tensor.

$$B^{\rho}_{\mu\nu\sigma}=\left\{\mu\sigma,\varepsilon\right\}\left\{\varepsilon\nu,\rho\right\}-\left\{\mu\nu,\varepsilon\right\}\left\{\varepsilon\sigma,\rho\right\}-\frac{\partial}{\partial x_\sigma}\left\{\mu\nu\rho\right\}+\frac{\partial}{\partial x_\mu}\left\{\mu\sigma,\rho\right\}$$

Mult by $g_{\rho\varepsilon}$ on $B^{\rho}_{\mu\nu\sigma}$

$$B_{\mu\nu\sigma\varepsilon}=\left\{\mu\sigma,\alpha\right\}\left[\alpha\nu,\varepsilon\right]-\left\{\mu\nu\alpha\right\}\left[\alpha\sigma,\varepsilon\right]-\frac{\partial}{\partial x_\sigma}\left[\mu\nu,\varepsilon\right]+\frac{\partial}{\partial x_\mu}\left[\mu\sigma,\varepsilon\right]-\left\{\mu\nu\rho\right\}\frac{\partial g_{\hat{\rho}\varepsilon}}{\partial x_\sigma}-\left\{\mu\sigma,\hat{\rho}\right\}\frac{\partial g^{\alpha}_{\rho\varepsilon}}{\partial x_\mu}$$

There 2 to compensate

ρ is dummy put α.

Combine 1 & 6 + 2 & 6.

$$=-\left\{\mu\sigma,\alpha\right\}\left[\varepsilon\nu,\alpha\right]+\left\{\mu\nu\alpha\right\}\left[\varepsilon\sigma,\alpha\right]-\frac{1}{2}\frac{\partial}{\partial x_\sigma}\left[\frac{\partial g_{\mu\varepsilon}}{\partial x_\nu}+\frac{\partial g_{\mu\varepsilon}}{\partial x_\mu}-\frac{\partial g_{\mu\nu}}{\partial x_\varepsilon}\right]+$$

$$+\frac{1}{2}\frac{\partial}{\partial x_\nu}\left[\frac{\partial g_{\sigma\xi}}{\partial x_\nu}\frac{\partial g_{\rho\sigma}}{\partial x_\mu}\frac{\partial g_{\mu\rho}}{\partial x_\xi}\right]$$

Interchanging $\mu \leftrightarrow \xi$.

& it remains symmetrical by sign change

also by μ, ξ + ν, σ no change

$\mu\nu\sigma\xi$ + s.v. reverses sign

$\nu\sigma$ " "

both simultaneously no change.

Hence $B_{\mu\nu\sigma\xi}$ has remarkable symetrical properties.

∴ only values of $\mu + \xi$ giving anything are the 6 others only change sign

12	23	
13	24	
14	34	

Similarly 6 for $\nu\sigma$.

Hence 36 —

$\mu\xi$	$\nu\sigma$	
12	12	nothing fresh
12	23	
23	12	} are same.

Hence 6 stand alone

+ remaining 30 are paired

∴ Total no are $6 + \frac{30}{2} = 21$.

the other property

$B_{\mu\nu\sigma\xi} + B_{\mu\sigma\xi\nu} + B_{\mu\xi\nu\sigma} = 0$

rotating cyclicly.

This reduces to 20 as 21st can be got from above relation.

∴ R.C.T. gives rise to 20 indept eqns.

If R.C.T. $\neq 0$.

Choose a region about some pt. where to 1st order the g's are const.

① $\frac{\partial g_{\mu\nu}}{\partial x_\sigma}$ Linear alteration of coords. in rotation + alters g's.

2nd quadratic transf^n:

② $x'_\xi = a^\xi_\mu x_\mu + a^\xi_{\mu\nu} x_\mu x_\nu$

this alters 1st derivs. of g's.

③ if $x'_\xi =$ " → " $+ a^\xi_{\mu\nu\rho} x_\mu x_\nu x_\sigma$

then curvature is altered + 2nd derivs of g's.

④ giving 40 possible conds. making the expression $\frac{\partial g_{\mu\nu}}{\partial x_\sigma}$ vanish

⊗ gives 80 condns for coeffs.
while $\frac{\partial^2 g_{\mu\nu}}{\partial x_\nu \partial x_\sigma}$ have $10 \times 10 = 100$
∴ not sufficient to cover a
i.e. 20 condns
which correspond to the 20
components of the R.C.T.
Thus see that the R.C.T. exhaus
the 20 degrees of freedom.
∴ no other tensor possible
unless going beyond 2nd de
except a function of $g_{\mu\nu}$
+ $B_{\mu\nu\sigma\rho}$

Applic^n to Law of Gravitat^n
Eqns are thus expected to be
2nd order. Find a tensor
not beyond 2nd order & co
of (i

Consider $g^{\sigma\rho} B_{\mu\nu\sigma\rho} = 0$
the simplest which suggests itself
fulfilling the condns.

It is a contracted R.C.T. written
thus $B^{\sigma}_{\mu\nu\sigma} = 0$

[Why $g^{\sigma\rho}$? try $g^{\mu\rho} B_{\mu\nu\sigma\rho} = 0$
no good because antisymetrical in
$\mu\sigma\rho$ + in pairs all wd go out.
If $g^{\mu\nu}$ same result would be got as
by $g^{\sigma\rho}$]

Call $G_{\mu\nu} = B^{\sigma}_{\mu\nu\sigma}$
$= -\frac{\partial}{\partial x_\alpha} \left\{ \mu\nu, \alpha \right\}$ (4 term) $+ \left\{ \mu\alpha, \beta \right\} \left\{ \nu\beta, \alpha \right\}$ (16 term)
$+ \frac{\partial}{\partial x_\mu} \left\{ \nu\alpha, \alpha \right\} - \left\{ \mu\nu\alpha \right\} \left\{ \alpha\Sigma, \Sigma \right\}$ (4 term)

Symetrical in μ + ν giving
10 diff. eqns to examine the
grav. ptl. to determine the 10 $g_{\mu\nu}$.
This is Law of Grav. in Empty Space.

It is remarkable that a partic. Solution
has been found. (There are some 25 i term involved)

Take case of a region surrounding
sun, symetrical props + coords
static.
∴ form of Solⁿ wanted is

$ds^2 = -dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\varphi^2) + dt^2$ in Euclidean coords.

alter it without destroying symetry. Put in function of r obviously

$ds^2 = -f_1(r)\,dx^2$
$\quad - f_2(r)$
$\quad + f_3(r)\,dt^2$

$g_{11} = f_1(r)$
$g_{22} = f_2(r)$
$g_{33} = f_3(r)$

for evaluation of these see Eddingtons Report.

Partic soln is

$ds^2 = f^{-1}dr^2 - r^2(d\theta^2 + \sin^2\theta\, d\varphi^2) + f dt^2$

where $f = 1 - \frac{2m}{r}$ m any constant of integration

This shows that a region of space having this prop. could exist.

Procedure is to examine the props of such a region & then see if we know a region with analogous props —

Determine the path of a ptcl under grav.

To a 1st approx. ptcls move under an inverse sq. law (Newton's)

To further approx paths deviates slightly by an amount verified for the universe expt'ly ∴ This is the Law as now accepted.

Path of a ray of light — see math in Report + appendix to Space Time & Grav.

16/5/22.

In Vector Theory. force $X_1 X_2 X_3$ $x_1 x_2 x_3$

Divergence $\frac{\partial X_1}{\partial x_1} + \frac{\partial X_2}{\partial x_2} + \frac{\partial X_3}{\partial x_3}$ Try to generalize this

$\frac{\partial A_r}{\partial x_r}$ or $\frac{\partial A^r}{\partial x_r}$ represents the sum. but take $(A^r)_r$ an invariant Define the divergence as this.

It is the contracted covariant derivative. $A^r_{;r}$

$A^\mu_{;\nu} = \frac{\partial A^\mu}{\partial x_\nu} + \{\alpha\nu, \mu\} A^\alpha$

$A^\mu_{;\mu} = \frac{\partial A^\mu}{\partial x_\mu} + \{\alpha\mu, \mu\} A^\alpha$ contracted 3 index symbol with double suffixes.

not a tensor. μ is dummy

Evaluate. Γ using g.

$\frac{1}{2} g^{\mu\lambda}\left\{\frac{\partial g_{\alpha\lambda}}{\partial x_\mu} + \frac{\partial g_{\mu\lambda}}{\partial x_\alpha} - \frac{\partial g_{\mu\alpha}}{\partial x_\lambda}\right\}$

* these go out for $\mu\alpha\lambda$ interchange here. $* = g^{\lambda\mu}\frac{\partial g_{\alpha\mu}}{\partial x_\lambda} =$

(A) $= \frac{1}{2} g^{\mu\lambda} \frac{\partial g_{\mu\lambda}}{\partial x_\alpha}$ Now considers determinant

$\frac{\partial g}{\partial g_{\mu\lambda}}$ mult. each element by its minor

$\frac{\partial g}{\partial x_\alpha} = g g^{\mu\nu} \frac{d g_{\mu\nu}}{\partial x_\alpha}$

$\therefore$ (A) $= \frac{1}{2} \frac{1}{g} \frac{dg}{dx} = \frac{\partial}{\partial x_\alpha} \log \sqrt{-g}$

$\therefore \{\alpha\, \mu, \mu\} = \frac{\partial}{\partial x_\alpha} \log \sqrt{-g}$

use this above.

$A^\mu_\mu =$ — as above

$= \frac{\partial A^\mu}{\partial x_\mu} + A^\alpha \frac{1}{\sqrt{-g}} \frac{\partial \sqrt{-g}}{\partial x_{\alpha\mu}}$

change α to μ.

$= \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\mu} (A^\mu \sqrt{-g})$

$\sqrt{-g}$ can always be so got over by arranging coords. so that det $g_{\mu\nu}$ gives $-g = 1$

Prof. Weyl explains $-g$ as vol-q mesh system he calls $A^\mu \sqrt{-g}$ the vector density.

$\sqrt{-g}\, dx\, dx_2\, dx_3\, dx_4$ is an invariant – the natural volume.

mult by a vector A^μ

$\iiint A^\mu \sqrt{-g}\, dx\, dx_2\, dx_3\, dx_4$ is a vector

xss dividing by $dx_1\, dx_2 dx_3 dx_4$ (the vol. in Galilean coords) leaves $A^\mu \sqrt{-g}$ as a vector density.

This adds significance where quantities are concerned if intensities are concerned it is not to clear.

$A^\mu_\mu \sqrt{-g} = \frac{\partial}{\partial x_\mu} (A^\mu \sqrt{-g})$

$\mathfrak{A}^\mu_\mu = \frac{\partial}{\partial x_\mu} \mathfrak{A}^\mu$ reforms w vector densities.

$A^\nu_{\mu\sigma} = \frac{\partial A^\nu_\mu}{\partial x_\sigma} - \{\mu\sigma, \alpha\} A^\nu_\alpha + \{\alpha\sigma, \nu\} A^\alpha_\mu$

Contr. σ to ν

$A^\nu_{\mu\nu} = \frac{\partial A^\nu_\mu}{\partial x_\nu} - \{\mu\nu, \alpha\} A^\nu_\alpha + \{\alpha\nu, \nu\} A^\nu_\mu$

$= \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\mu} (A^\nu_\mu \sqrt{-g})$

$- \frac{1}{2} A^{\alpha\beta} \frac{\partial g_{\alpha\beta}}{\partial x_\mu}$

$\{\mu\nu, \alpha\} A^\nu_\alpha = g_{\alpha\lambda} [\mu\nu, \lambda] A^\nu_\alpha = [\mu\nu, \lambda] A^{\lambda\nu}$

$= \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\nu} (A^\nu_\mu \sqrt{-g}$

$+ \frac{1}{2} A_{\alpha\beta} \frac{\partial g^{\alpha\beta}}{\partial x_\mu}$

If $A^{\lambda\nu}$ is symmetrical i.e. $\mu\lambda\sigma\lambda\mu$ gives $\frac{1}{2} A^{\lambda\nu} \left(\frac{\partial g_{\mu\lambda}}{\partial x_\nu} + \frac{\partial g_{\nu\lambda}}{\partial x_\mu} - \frac{\partial g_{\mu\nu}}{\partial x_\lambda} \right)$ giving

There two are formulae for symmetrical tensors.

If antisymmetrical tensor use.

$A^{\mu\nu}_\nu = \frac{\partial A^{\mu\nu}}{\partial x_\nu} + \{\alpha\nu, \mu\} A^{\alpha\nu} + \{\alpha\nu, \nu\} A^{\mu\alpha}$

1 + 3 cancel + 2 vanishes by inner mult^{n} of a symm. + an antisym tensor

giving $A^{\mu\nu}_{\nu} = \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\nu}\left(A^{\mu\nu}\sqrt{-g}\right)$

Antisymmetrical tensors only.

$$\mathfrak{A}^{\mu\nu}_{\nu} = \frac{\partial}{\partial x_\nu}\mathfrak{A}^{\mu\nu}.$$

Theorem

The divergence of $G_\mu{}^\nu - \frac{1}{2} g_\mu{}^\nu G$ is identically zero

$G_{\mu\nu}$ is contracted R-C tensor.

raise suffix to $G_\mu{}^\nu$ contract

$G = G_\mu{}^\mu$

$G = g^{\mu\nu} G_{\mu\nu}$

This is a tensor eqn $\left(G_\mu{}^\nu - \frac{1}{2} g_\mu{}^\nu G\right)_\nu = 0.$

holding in any system of coords if it holds in any partic one of general applicn (i.e. not rect. coords)

Choose coords such that 1st deriv. of g's vanish

$\frac{\partial g_{\mu\nu}}{\partial x_\sigma} = 0$ i.e. if here take system falling under grav. where 1st derivs vanish but not 2nd derivs

By terms ①

$$G_\mu{}^\nu = G_{\mu\nu} = \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\nu}\left(G_\mu{}^\nu \sqrt{-g}\right) + \frac{1}{2} G_{\alpha\beta} \frac{\partial g^{\alpha\beta}}{\partial x_\mu} \quad ②$$

Cov. deriv. of 2nd term $-\frac{1}{2} g_\mu{}^\nu \frac{\partial G}{\partial x_\nu} = -\frac{1}{2}\frac{\partial G}{\partial x_\mu}$ ③

*

i.e. now $A + B = 0$

$$\left[\frac{\partial G_\mu{}^\nu}{\partial x_\nu} + \frac{\partial G}{\partial x_\mu} = \frac{\partial G_\mu{}^\nu}{\partial x_\nu} + g_\mu{}^\nu \frac{\partial G}{\partial x_\nu}\right.$$

$$= \frac{\partial}{\partial x_\nu}\left(G_\mu{}^\nu + \frac{1}{2} g_\mu{}^\nu G\right) = 0$$

This is a useful dodge to change suffix by a substn. operator]

$G = g^{\alpha\beta} G_{\alpha\beta}$

$$\frac{\partial G}{\partial x_\mu} = G_{\alpha\beta} \frac{\partial g^{\alpha\beta}}{\partial x_\mu} + g^{\alpha\beta} \frac{\partial G_{\alpha\beta}}{\partial x_\mu}.$$

* these cancel

$$\therefore \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\alpha}\left(G_\mu{}^\alpha \sqrt{-g}\right) - \frac{1}{2} g^{\alpha\beta} \frac{\partial G_{\alpha\beta}}{\partial x_\mu} = 0. \quad ④$$

Now consider 1st derivs vanish here we can cancel strike out the $\sqrt{-g}$'s –

Remember $B_{\mu\nu\sigma\rho} = \frac{1}{2}\left(\frac{\partial^2 g_{\mu\nu}}{\partial x_\sigma \partial x_\rho} + \frac{\sigma\rho}{\nu\nu} - \frac{\mu\sigma}{\nu\rho} - \frac{\nu\rho}{\mu\sigma}\right)$ + prods of 2 index symbols with 1st derivs going out remains 0^2 it still goes out on deriv

$G_\mu{}^\alpha = g^{\alpha\nu} g^{\sigma\rho} B_{\mu\nu\sigma\rho}$ this with ④ 1st term.

$$\frac{1}{2} g^{\alpha\nu} g^{\sigma\rho} \frac{\partial}{\partial x_\alpha}\left(\frac{\partial^2 g_{\mu\nu}}{\partial x_\sigma \partial x_\rho} + \frac{\sigma\rho}{\mu\nu} - \frac{\mu\sigma}{\nu\rho} - \frac{\nu\rho}{\mu\sigma}\right) \quad ⑪$$

Take 2nd term of ④ change $\alpha\rho$ $\kappa\sigma$ then ⑨ + ⑧ go out

$$\frac{1}{4} g^{\alpha\beta} g^{\sigma\rho} \frac{\partial}{\partial x_\rho}\left(\frac{\partial^2 g_{\alpha\sigma}}{\partial x_\beta \partial x_\sigma} + \frac{\sigma\rho}{\alpha\beta} - \frac{\alpha\sigma}{\beta\rho} - \frac{\beta\rho}{\alpha\sigma}\right)$$

Interchange α & σ β & ρ for 1 & 2nd term, add.
& α & ρ β & σ for 3rd & 4th & then add.

Giving:

$$\frac{1}{2} g^{\alpha\beta} g^{\sigma\rho} \frac{\partial}{\partial x_\mu} \left(\frac{\partial^2 g_{\alpha\beta}}{\partial x_\sigma \partial x_\rho} - \frac{\partial^2 g_{\alpha\sigma}}{\partial x_\beta \partial x_\rho} \right)$$

This is same as (II) by changing suffixes.

$$\frac{1}{2} g^{\rho\nu} g^{\sigma\alpha} \frac{\partial^2}{\partial x_\mu \partial x_\rho} \left(\frac{\partial g_{\sigma\alpha}}{\partial x_\nu} - \frac{\partial g_{\nu\alpha}}{\partial x_\sigma} \right)$$

Put β for ν & β for σ.

$$\frac{1}{2} g^{\rho\sigma} g^{\alpha\beta} \frac{\partial^2}{\partial x_\mu \partial x_\rho} \left(\frac{\partial g_{\alpha\beta}}{\partial x_\sigma} - \frac{\partial g_{\sigma\alpha}}{\partial x_\beta} \right)$$

which is identical

$\therefore$ the identity holds generally.

+ signifies :—

Think of div. of a vel.

Eqn of continuity: div. vanishes.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0.$$

This theorem proves something in world inherently permanent.

$$G_\mu^\nu - \frac{1}{2} g_\mu^\nu G$$

20/5/22.

Energy tensor of matter

$T^{\mu\nu} = \rho_0 \frac{dx_\mu}{ds} \cdot \frac{dx_\nu}{ds}$

mix. contrav. vector, contrav. vector → contrav. tensor. (Contrav. Tensor.)

ρ_0 = invariant density (i.e. that observed by an observer moving with it)

$\frac{dx_\mu}{ds}$ is the velocity.

Consider in full. coords — to get idea of what $T^{\mu\nu}$ is.

ρ = dens. u v w velocity : $\frac{dx}{dt}$ $\frac{dx_2}{dt}$ $\frac{dx_3}{dt}$.

$\rho = \rho_0 \left(\frac{dt}{ds}\right)^2$ where $\left(\frac{dt}{ds}\right)$ is Fitzgerald's factor)

Result: (1) increase of mass by this factor.
(2) increase length
diminish volume : density is altered by $\left(\frac{dt}{ds}\right)^2$.

$$\therefore T^{\mu\nu} = \rho \frac{dx_\mu}{ds} \frac{dx_\nu}{ds} = \rho \frac{dx_\mu}{dt} \frac{dx_\nu}{dt}$$

$$= \sum \begin{matrix} \rho u^2 & \rho uv & \rho uw & \rho u \\ \rho vu & \rho v^2 & \rho vw & \rho v \\ \rho wu & \rho wv & \rho w^2 & \rho w \\ \rho u & \rho v & \rho w & \rho \end{matrix} \quad (A)$$

Since matter is composed of many mols of varying vels. put Σ before determ^t

Methodically $u = \bar{u} + u_1$,
u_1 motion rel. to centre of mass
$\bar{u}$ motion of centre of mass.

$\rho \bar{u}^2 + \rho u_1^2$

these are the components of stress.

$\rho u_1 v_1$ &c denoted usually p_{xy} & is the reaction per unit across any plane per unit of area.

A becomes.

$$\begin{matrix} \rho \bar{u}^2 + p_{xx} & \rho uv + p_{xy} & \rho u & \text{rel. vel. to centre} \\ \rho \bar{v} w + p_{yz} & \cdot & \rho v & \text{of mass.} \\ \rho \bar{v} \bar{w} + p_{zx} & \cdot & \rho w & \\ \rho u & \cdot & \rho & \end{matrix}$$

$\mu = 1$ $\mu = 2$ $\mu = 4$

Consider $\frac{\partial T}{\partial x_\nu}^{\mu\nu} = 0$ subscript for $\mu = 4$

$\frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z} + \frac{\partial \rho}{\partial t} = 0$ Eqn of Continuity. Cons. of Mass. (A)

$\mu = 1$. $\frac{\partial \rho u^2}{\partial x} + \frac{\partial \rho uv}{\partial y} + \frac{\partial \rho uw}{\partial z} + \frac{\partial \rho u}{\partial t} = -\frac{\partial p_{xx}}{\partial x}$

$+\frac{\partial p_{xy}}{\partial y} + \frac{\partial p_{xz}}{\partial z}$

or $u\left(\frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z} + \frac{\partial \rho}{\partial t}\right) + \rho u \frac{\partial u}{\partial x} + \rho v \frac{\partial u}{\partial y}$

$+ \rho w \frac{\partial u}{\partial z} + \rho \frac{du}{dt}$

() goes out by B. Denote remder by $\rho \frac{Du}{Dt}$

Eulers Eqns (Hydrodynamics)

$\therefore \rho \frac{Du}{Dt} = -\left(\frac{\partial p_{xx}}{\partial x} + \text{—}\right)$ Cons. of Momentum

Nobody forces in Gal. coords hec. no grav. field.

$\therefore$ Hydrodyn. formulae embodied in $\frac{\partial T^{\mu\nu}}{\partial x_\nu} = 0$.

Thm. $T_0^{\mu\nu} = 0$ Holds in any coords in flat space time

Divergence of energy Tensor is Zero.

Same as $T^{\nu}_{\mu\nu} = 0$

or $\operatorname{div} T^{\nu}_{\mu} = 0$.

Gen Todays has been indep^t of the geometry & $g_{\mu\nu}$ by introducing matter without defining it.

Take view that T_μ^ν is a fundamental something in $g_{\mu\nu}$ - Its div vanishes $\therefore$ identify it with $G_\mu^\nu - \frac{1}{2} g_\mu^\nu G$ whose div vanishes & none other is known.

$\therefore$

$$\therefore -8\pi T_\mu^\nu \equiv G_\mu^\nu - \tfrac{1}{2} g_\mu^\nu G \qquad (C)$$

for mnth's sake put in -8π. This is ~~not clear~~ what we have named matter.

The perceptual world by 'natural selection' & the mind must have some element of permanence

Hence the above tensor

$0 = G_\mu^\nu - \frac{1}{2} g_\mu^\nu G$.

$0 = G - \frac{1}{2} \cdot 4 G$

$= -G$

$G_\mu^\nu = 0$

$G_{\mu\nu} = 0$ The law of Gravitation.

This region is a vacuum

We yet known why so much of space is empty.

In non Galilean coords there will be body force $\therefore$ the hydrodyn. Eqns under forces should be evolved.

$$T^\nu_{\mu\nu} = \frac{1}{\sqrt{-g}} \frac{\partial}{\partial x_\nu}\left(T_\mu^\nu \sqrt{-g}\right) - \frac{1}{2} T^{\alpha\beta} \frac{\partial g_{\alpha\beta}}{\partial x_\mu} = 0.$$

Dropt out $\sqrt{-g}$ $(= 1)$ in rules

Tensor Calc. deals with intensity. " density Calc. " " Quantities.

Density Eqn corresponding } is $\mathfrak{T}_\mu^\nu = \frac{\partial}{\partial x_\nu}\mathfrak{T}_\mu^\nu - \frac{1}{2}\sum^{\alpha\beta}\frac{\partial g_{\alpha\beta}}{\partial x_\mu} = 0$.

$\frac{\partial}{\partial x_\nu}(T_\mu^\nu)$ vanishes in Gell. coords. when no field of force

but now it

$= \frac{1}{2} T^{\alpha\beta}\frac{\partial g_{\alpha\beta}}{\partial x_\mu}$

$= (\rho X \quad \rho Y \quad \rho Z \quad 0)$ representing body forces approximately

Types of terms $\rho \quad \rho u \quad \rho u^2$

$u + w^2$ are very small in all hydrodyn. applications

∴ take ρ i.e. $T^{44} = \rho$.

$= \frac{1}{2}\rho \frac{\partial g_{44}}{\partial x_\mu} = (\rho X \quad \rho Y \quad \rho Z \quad 0)$

$\frac{\partial g_{44}}{\partial x} = X \qquad \frac{\partial g_{44}}{\partial y} = Y \qquad \frac{\partial g_{44}}{\partial z} = Z$

$\frac{\partial g_{44}}{\partial t} = 0$ in old idea where mass is not created or destroyed. Now by idea of inc. of mass with vel. there shd. be a term there other than 0.

$\frac{1}{2}\frac{\partial g_{44}}{\partial x} = X = -\frac{\partial \Omega}{\partial x}$ Ω = potential.

$\frac{1}{2}\quad = Y = -\frac{\partial \Omega}{\partial y}$

$\frac{1}{2}\quad = Z = -\frac{\partial \Omega}{\partial z}$

$g_{44} = -2\Omega + \text{const.}$

$g_{44} = 1 - 2\Omega$ by considering $\Omega = 0$ at ∞.

Thus $g_{44} = (1 - \omega^2 r^2)$ where ωr = the force.

In gen. field.

$ds^2 = -(1-\frac{2m}{r})^{-1}dr^2 - r^2 d\theta^2 - r^2\sin^2\theta\, d\phi^2 + (1-\frac{2m}{r})dt^2$

$g_{44} = 1 - \frac{2m}{r}$

In more generalized theory forces act not only on the mass (T^{44}) but on the momentum attraction, etc, etc.

$G_\mu^\nu - \frac{1}{2}g_\mu^\nu G$ The Energy Tensor has a direct geometrical interpretation. See Phil Mag. recent number.

Consider $G_{11}^E - \frac{1}{2}g_{11}^E G$ represents the Gaussian curvature of a 3-dimensional section of the world ⊥ to the x_1 direction.

2 dimensions Gaussian curvature is $\frac{1}{k_1 k_2}$ an invariant where k_1, k_2 are radii of curv. in 2 dims.

G is the Gaussian curvature in 4 dimensions

If a 4-dimens. figure is drawn in 5 dimens

$G = 2\left(\frac{1}{K_1 k_2} + \frac{1}{K_1 k_3} + \frac{1}{k_1 k_4} + \text{—— 3 terms more}\right)$ 6 terms II

= the Gaussian curvature.

A spherical 4 dimens. figure drawn in 5

each term is radius.

& $G = \frac{12}{R^2}$ i.e. $R = \sqrt{\frac{12}{G}}$ Radius of curvature

$G_{11}^E - \frac{1}{2}g_{11}^E G$ case gives $R = \sqrt{\frac{6}{G}}$ since only 3 terms as in II

Consider $(G_{\mu\nu} - \frac{1}{2} g_{\mu\nu} G) dx_\mu dx_\nu = 3$ (ε)

contravariant expression — locus. Take pt $(\rho_1, 0, 0, 0)$

$$\left(G_{11} - \tfrac{1}{2} g_{11} G\right) \rho_1^2 = 3$$

$$G_{11} - \tfrac{1}{2} g_{11} G = \frac{3}{\rho_1^2}$$

Then ρ_1 is the radius of spherical curvature of 3-dimens. section of world.

but ρ_1 is radius of the quadric. (ε) in x direction. i.e. its radius is always perp. to rad. of spher. curv of the world in the corresponding dirn.

If quadric (ε) is a sphere

$ds^2 = g_{\mu\nu} dx_\mu dx_\nu = R^2$ (eqn of sphere.

then $G_{\mu\nu} - \frac{1}{2} g_{\mu\nu} G = \frac{3}{R^2} g_{\mu\nu} = \lambda g_{\mu\nu}$.

where $\lambda = \frac{3}{R^2}$

adopted by Einstein for

$G_{\mu\nu} = 0$

$G_{\mu\nu} - \frac{1}{2} g_{\mu\nu} G = 0$ Infinite world becoming Euclidean at ∞!

If instead of 0 put a very small quantity $\lambda g_{\mu\nu}$

$G_{\mu\nu} - \frac{1}{2} g_{\mu\nu} G = \lambda g_{\mu\nu}$

The rad. of curvature of world in any dirn is homogeneous + isotropic — i.e. constant in all dirns.

23/5/22. (1)

Eq. for Eq: $G_{\mu\nu} - \frac{1}{2} g_{\mu\nu} G = \lambda g_{\mu\nu}$

hence $\left(G_{\mu\nu} - \frac{1}{2} g_{\mu\nu} G\right) dx_\mu dx_\nu = \text{const}$ (2) is the quadric of curvature

$\lambda g_{\mu\nu} dx_\mu dx_\nu = \text{const}$ is necessarily a sphere.

$\lambda = ds^2 = \lambda g_{\mu\nu} dx_\mu dx_\nu = \text{const}$

What is a sphere — physical idea involved — the standard of symmetry. O is the figure you draw with a pair of compasses. Extend to 4 dimensions — still symmetry.

Hence universal tendency to curvature — i.e. form of any unit of material (drop of water) tends to conform to the locus in the space. i.e. spherical — under its own gravity only.

(2) has no real rad. of curvature if value is taken in time coord. Hence there is no radius of time & an electron (e.g.) is presumably to go on for ever.

Structure building

Consider lattice systems of a crystal. Similarly in space time.

Take A^μ as relation between two pts whose coords differ by δx_μ. μ serves not to represent 4 measure nos. Assume there is an equivalence between relation between 2 pts a, b and two other pts c d — Take then a b & c d are neighbouring pts.

A^μ at x_μ and $A^\mu + dA^\mu$ at $x_\mu + dx_\mu$ (3)

$$P_{\nu+d} A^\mu = -\Gamma^\mu_{\nu\alpha} A^\alpha (dx)^\nu$$ sum of 16 terms all infinitesimals

not a tensor.

(1) A^μ will be identified with δx_μ $A^\mu = \delta x_\mu$

(2) (3) is a tensor asymmetrical in $\nu + \alpha$ (parallelogram law)

② is the axiom of comparability of approximated relations

displace vector round circuit & diff. one recalls the difference being also a vector.

$$\delta A^\mu = \int_C dA^\mu = -\int_C \left(\Gamma^\mu_{\nu\alpha} A^\alpha\right) dx_\nu$$

$$= \tfrac{1}{2}\iint \left\{ \frac{\partial}{\partial x_\sigma}\Gamma^\mu_{\nu\alpha} A^\alpha - \frac{\partial}{\partial x_\nu}\left(\Gamma^\mu_{\sigma\alpha} A^\alpha\right)\right\} dS^{\nu\sigma}$$

by Stokes Theorem.

$\tfrac{1}{2}$ appears because in summation each term appears twice.

Integrand. $A^\xi\left(\frac{\partial}{\partial x_\sigma}\Gamma^\mu_{\nu\xi} - \frac{\partial}{\partial x_\nu}\Gamma^\mu_{\sigma\xi}\right)$ change to ξ.

$$-\left(\Gamma^\mu_{\nu\alpha}\cdot\Gamma^\alpha_{\xi\sigma} + \Gamma^\mu_{\sigma\alpha}\Gamma^\alpha_{\xi\nu}\right) A^\xi.$$

then $\delta A^\mu = \tfrac{1}{2} A^\xi dS^{\nu\sigma}\left(\frac{\partial}{\partial x_\sigma}\Gamma^\mu_{\nu\xi} - \frac{\partial}{\partial x_\nu}\Gamma^\mu_{\sigma\xi} + \Gamma^\mu_{\sigma\alpha}\Gamma^\alpha_{\xi\nu} - \Gamma\right)$

a tensor.

$$= B^\mu_{\xi\nu\sigma}$$

Thus we have discovered a tensor describing the construction of the world having made one assumption only - i.e. comparability of approx rels.

Contract it

$$B^\xi_{\mu\nu\sigma} = \frac{\partial}{\partial x_\sigma} F^\xi_{\mu\nu} - \frac{\partial}{\partial x_\mu}\Gamma^\xi_{\sigma\nu} + \Gamma^\xi_{\sigma\alpha}\Gamma^\alpha_{\mu\nu} - \Gamma^\xi_{\nu\alpha}\Gamma^\alpha_{\mu\sigma} \quad (A)$$

Put $\xi = \sigma = \beta$

$$G_{\mu\nu} = \frac{\partial}{\partial x_\sigma}\Gamma^\sigma_{\mu\nu} - \frac{\partial}{\partial x_\nu}\Gamma^\beta_{\mu\beta} + \Gamma^\beta_{\alpha\beta}\Gamma^\alpha_{\mu\nu} - \Gamma^\beta_{\nu\alpha}\Gamma^\alpha_{\mu\beta}$$

call $\Gamma^\sigma_{\sigma\mu} = \Gamma_\mu$

Symmetrical in $\mu\nu$ except 2^{nd} term.

∴ separate it.

$$G_{\mu\nu} = R_{\mu\nu} + F_{\mu\nu}$$

symm. antisymm.

$$F_{\mu\nu} = \tfrac{1}{2}\left(\frac{\partial}{\partial x_\nu}\Gamma_\mu - \frac{\partial}{\partial x_\mu}\Gamma_\nu\right)$$

"If a curl is a curl it must be the curl of a vector."

From (A) contract with respect to $\xi\sigma$

$$\frac{\partial}{\partial x_\sigma}\Gamma_\nu - \frac{\partial}{\partial x_\nu}\Gamma_\sigma$$ giving nothing fresh.

Introduce (as a matter of pure math only for present) an interval - ds

Displacement $dx_\mu : A^\mu$ has a length l

given by $l^2 = g_{\mu\nu} A^\mu A^\nu$

$ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu$

whether l is like length in physics is to be seen later

dl^2 due to displacement thro dx_σ.

$$dl^2 = \left(A^\mu A^\nu \frac{\partial g_{\mu\nu}}{\partial x_\sigma} + g_{\mu\nu} A^\mu - \Gamma^\nu_{\lambda\sigma} A^\alpha + g_{\mu\nu} A^\nu\left(-\Gamma^\mu_{\lambda\sigma} A^\alpha\right)\right) dx_\sigma$$

$$= A^\mu A^\nu dx_\sigma\left(\frac{\partial g_{\mu\nu}}{\partial x_\sigma} - g_{\mu\xi}\Gamma^\xi_{\nu\sigma} - g_{\xi\mu}\Gamma^\nu_{\mu\xi}\right)$$

$$= A^\mu A^\nu (dx)^\sigma \left(\frac{\partial g_{\mu\nu}}{\partial x_\sigma} - \Gamma_{\nu\sigma,\mu} - \Gamma_{\mu\sigma,\nu}\right)$$

covariant vector

3 vectors

invariants.

∴ tensor of 3rd Rank.

Call it $K_{\mu\nu,\sigma} = \frac{\partial g_{\mu\nu}}{\partial x_\sigma} - \Gamma_{\nu\sigma,\mu} - \Gamma_{\mu\sigma,\nu}$

Interchange suffixes

$$K_{\mu\sigma,\nu} = \frac{\partial g_{\mu\sigma}}{\partial x_\nu} - \Gamma_{\mu\nu,\sigma} - \Gamma_{\sigma\nu,\mu}$$

$$+ K_{\nu\sigma,\mu} = \frac{\partial g_{\nu\sigma}}{\partial x_\mu} - \Gamma_{\nu\mu,\sigma} - \Gamma_{\sigma\mu\nu}$$

add last 2 + subtr 1st.

$$K_{\mu\sigma,\nu} + K_{\nu\sigma,\mu} - K_{\mu\nu,\sigma} = 2[\mu\nu\sigma] - 2\Gamma_{\mu\nu,\sigma} \quad (B)$$

Christoffel symbol

Σ 3 tensors is a tensor, call it

$$S_{\mu\nu,\sigma} = (B)$$

$$\tfrac{1}{2} S^{\sigma}_{\mu\nu} = \left\{\mu\nu,\sigma\right) - \Gamma^{\sigma}_{\mu\nu}$$

$$\therefore \Gamma^{\sigma}_{\mu\nu} = \left\{\mu\nu,\sigma\right\} - \tfrac{1}{2} S^{\sigma}_{\mu\nu}$$

Hence see that $*B$ contains ord. B (R.C. tensor) as well as terms in $S^{\sigma}_{\mu\nu}$.

Call an Intensor one fundamental in world.
" ord. tensor " containing something we have introduced arbitrarily.

Gauge System is the choice of the $g_{\mu\nu}$'s
In Physics only one gauge system is possible.

World must contain its own gauge system
i.e. be self gauging
∴ it should contain a tensor of 2nd rank.
We have found one 2^{nd} rank tensor.

$$ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu = {}^*G_{\mu\nu}\, dx_\mu dx_\nu.$$

$$= R_{\mu\nu}\, dx_\mu\, dx_\nu.$$

$$\therefore \lambda g_{\mu\nu} = R_{\mu\nu}$$

∴ λ is universal constant.

$*B^{\rho}_{\mu\tau}$ gen. R.C. tensor

$R_{\mu\nu}$ Contracted $= R_{\mu\nu} + F_{\mu\nu}$ giving

$\int = R_{\mu\nu}\, dx_\mu\, dx_\nu$ (D) since anti symmetric part is not concerned

Consider the average radius of an electron — what determines its size. Its locus is of form of (D) - i.e. a quadric : of form $ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu$

(with a biquadratic answer the purpose? It could be formed thus $*B^{\beta}_{\mu\nu\alpha}\, *B^{\alpha}_{\sigma\tau\beta}\, dx_\mu dx_\nu dx_\sigma\, dx_\tau$.

something not vanishing - But it is likely that a more simple expression plays a much more important part in physics

All Geometry + all mechanics comes from $R_{\mu\nu}$
The anti sym. part $F_{\mu\nu}$ is obviously responsible for the electromagnetic phenomena of the Universe.

(Questions of quanta etc. not yet solved by this math. treatment?)

Thus all physics bifurcates into two parts
from + mech. and electro mag. phenom.

$$f_{\mu\nu} = \frac{\partial F_\mu}{\partial x_\nu} - \frac{\partial F_\nu}{\partial x_\mu} \quad (a)$$

we had $F^{\sigma}_{\mu\nu} = \left\{\mu\nu,\sigma\right\} + S^{\sigma}_{\mu\nu}$

$\Gamma_\mu = \Gamma^{\alpha}_{\mu\alpha} = \left\{\mu\alpha,\alpha\right\} = \delta^{\alpha}_{\mu\alpha}$ simple vector

$= \frac{\partial}{\partial x_\mu} \log\sqrt{-g} + k_\mu$ Subst. in (a)

(a) $= \frac{\partial k_\mu}{\partial x_\nu} - \frac{\partial k_\nu}{\partial x_\mu}$ Curl of vector.

$F_{\mu\nu}$ has 6 terms reducing to 4 being anti-symmetric since $F_{11} = 0$ & $F_{12} = -F_{21}$

There are the 4 elect. mag. pots. (F, G, H, Φ)
Identify these with $(-F\ -G\ -H\ -\Phi) = K^\mu$ scalar vector
In galilean coords. $= K_\mu$

$$-\frac{\partial F}{\partial y} + \frac{\partial G}{\partial x} = F_{12} = +\alpha$$

$\alpha\beta\gamma$ curl of FGH

$$F_{14} = -\frac{\partial F}{\partial t} - \frac{\partial \Phi}{\partial x} = X$$

$$\rightarrow \mu \begin{vmatrix} 0 & -\gamma & \beta & X \\ \gamma & 0 & -\alpha & Y \\ -\beta & \alpha & 0 & Z \\ X & Y & Z & 0 \end{vmatrix}$$

Show these to be tensors.

$$K_{\mu\nu} - K_{\nu\mu} = \frac{\partial K_\mu}{\partial x_\nu} - \left\{\mu\nu, \alpha\right\} K_\alpha$$

$$-\left(\frac{\partial K_\nu}{\partial x_\mu} - \left\{\nu\mu, \alpha\right\} K_\alpha\right)$$

Hence a tensor

Maxwells Eqns in Tensor form.

$$\frac{\partial \gamma}{\partial y} - \frac{\partial \beta}{\partial z} = \frac{\partial X}{\partial t} + u$$

Curl of mag force = displacement current + ord. current.

$$\frac{\partial X}{\partial x} + \frac{\partial Y}{\partial y} + \frac{\partial Z}{\partial z} = \rho$$

Take $\frac{\partial F_{\mu\nu}}{\partial x_\nu}$ from determinant above.

$$\frac{\partial \gamma}{\partial y} - \frac{\partial \beta}{\partial z} - \frac{\partial X}{\partial t} = u$$

$$\frac{\partial X}{\partial x} + \frac{\partial Y}{\partial y} + \frac{\partial Z}{\partial z} = \rho$$

$$\therefore \frac{\partial F_{\mu\nu}}{\partial x_\nu} = (u\ v\ w\ \rho) \quad \text{(I)}$$

Embodies first set of Maxwell Eqns in new form.

$$\frac{\partial Z}{\partial y} - \frac{\partial Y}{\partial z} = \frac{\partial \alpha}{\partial t}$$

$$\frac{\partial \alpha}{\partial x} + \frac{\partial \beta}{\partial y} + \frac{\partial \gamma}{\partial z} = 0$$ because there is no such thing as a magnetic charge.

$$\frac{\partial F_{\mu\nu}}{\partial x_\sigma} + \frac{\partial F_{\nu\sigma}}{\partial x_\mu} + \frac{\partial F_{\sigma\mu}}{\partial x_\nu} = 0 \quad \text{(A)}$$

from determinant $\frac{\partial \gamma}{\partial z} + \frac{\partial \alpha}{\partial x} + \frac{\partial \beta}{\partial y} = 0$

$$+ \frac{\partial \gamma}{\partial t} + \frac{\partial Y}{\partial x} - \frac{\partial X}{\partial y} = 0$$

(A) is an identity – put in K's + everything goes out.

$$\text{(II)} \quad F_{\mu\nu} = \frac{\partial K_\mu}{\partial x_\nu} + \frac{\partial K_\nu}{\partial x_\mu}$$

2nd set of Maxwell Eqns in new form.

(I) is not a tensor. Substitute $F^{\mu\nu}_{\ \nu} = (u\ v\ w\ \rho)$

contrav. vector call it $J^\mu = u\ v\ w\ \rho$

$$F^{\mu\nu}_{\ \ \nu} = J^\mu$$

$$F_{\mu\nu} = \frac{\partial K_\mu}{\partial x_\nu} - \frac{\partial K_\nu}{\partial x_\mu}$$

Both in tensor form holding rigorously + hence Einstein's grav. laws does not affect elect mag. theory

Others whether galilean coords hold or not the props of light etc can be deduced from above

Tensor Density:

$$\frac{1}{\sqrt{-g}}\,\partial x\,(F^{\mu\nu}\sqrt{-g}) = \mathfrak{J}^{\mu}$$

or $\frac{\partial}{\partial x_\nu}\mathfrak{F}^{\mu\nu} = \mathfrak{J}^{\mu}$

Differentiate $\frac{\partial \mathfrak{J}^{\mu}}{\partial x_\mu} = \frac{\partial^2 \mathfrak{F}^{\mu\nu}}{\partial x_\mu \partial x_\nu} = 0$

terms cancel in pairs.

This is Law of Conservation of elect. charge

In ord gal. coords. no distinction between $\mathfrak{J}^{\mu}$ + $\mathfrak{J}^{\mu}$ + law is

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} + \frac{\partial \rho}{\partial t} = 0$$

Empirical laws for Energy tensor.

$$E_\mu^\nu = -F_{\mu\alpha}F^{\nu\alpha} + \frac{1}{4} g_\mu^\nu F_{\alpha\beta}F^{\alpha\beta}$$

$P = v\gamma - w\beta + \rho X$

mechanical force component.

Q ..

R ..

S = $Xu + Yv + Zw$ mechanical force

is $\perp^r$ to dir. of motion of charge.

Streams in Ether - elect. mag. momentum + el. mag. energy as in Maxwell's Thy. are thus formed

$$T_\mu^\nu = G_\mu^\nu - \frac{1}{2} g_\mu^\nu G$$ Gen. law of Cons. of Energy

Nature Dec 23/22. p. 854

Criticism from English Times of 2 lectures delivered by Einstein in 1920 + 1921. Many of E's followers in England have been inclined to abandon the conception of the aether but E states "according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether... Space without ether is unthinkable... there would be no propagation of light... But it may not be thought of as... consisting of parts which may be tracked through time".

T^{ν}_{μ} includes E^{ν}_{μ}

Contract T^{ν}_{μ} put $\mu = \nu = \beta$

$E = E^{\nu}_{\nu} = 0$ identically.

but $T = \rho_0$ the invariant density.

Hence T^{ν}_{μ} is not entirely composed of E

According to Maxwell a electron could not exist; the charge wd. dissipate at once.

Hence another form of energy must exist besides elect. mag. energy.

G_{μ}

Cons. of energy

MISCELLANEOUS · DATA ·

Archiv der
Deutschen
Seewarte.
Hamburg 1921.
Brennecke.

Baltimore.

Lectures on Navigation.

Aeroplane Serial.

Philosophical
Magazine

4669

Archive Deutschland.
Gg. 14. 18
acton. c. 34. 350.

Dryden.

Stiff in opinions, always in the wrong,
Was everything by starts + nothing long:
But in the course of one revolving moon
Was scribbler, painter, statesmen and buffoon.

Lord Rbt. Cecil of Winston Churchill. 27/1/22.

Who is Lord Rbt Cecil? "one foot in the middle ages and the other foot in the L. of Nations" in reference to Viscount Grey. I will never desert Macaulay.

Winston Churchill of Lord Rbt Cecil.

Haldane R.B.
The Reign of Relativity.

180.c.92.21. (21.1627)

1921.

27/10/21.

Data sent to G.H.D.

Sci. Abstracts

1. Frazil + Anchor Ice. Agitate water at 32°. If rod +000° above 32 nucle forms.
J Murphy - Can. Sl. News. 29. Mar. 1920.

2. Twilight Phenom. P. Gruner (Archives des Sciences. 42 p. 32-46 July 1916
45 5-37 Jan 1918
Sky colourings ant + pm. due to diffuse reflection not diffraction alone.

3. Warmth of Dawn Theory. O. Meissner. (Phys Zeit 19. Sept. 1918.) Time of min. temp + sunrise connected thus May to Sept former 30 min after sunrise. Spring + Autumn 15 min after. but in winter 10 min before.

4. Antarctic Ice Cap. D Mawson (Nature 102 Dec 19. 1918) Large shelf - mechanics of flow diff. from that of small mass. Static pres. at base may reach 1 ton per sq in. + accum. of ground heat may raise temp above that of upper layers - hence plastic base to thick shelf. at Gt Ross Barrier + Shackleton Shelf if pres. rate of flow had been constant the present boundary left centre in 7th century.

5. Buoyancy of Frazil Ice Crystals H T Barnes R.S. Can. Trans. 11 June 1917. Stokes law

adapted shows rate of seis thru water <
0.1 cm/sec. hence lack of much buoyancy.

6. Locating Submarine faults. By earthquake waves from different obs^{ns} points:
O. Klotz. R. Soc. Can. Trans 12. J. Sept. 1918.

7. Strength of Rocks in Earths Interior L.V. King.
(J. of Geol. 25 oct.-nov 1917. (FDA + J.A.B.)
Resistance to flow increases with hydrostatic pres. i.e. depth. Isostacy must take this into account. Continental elevations & those existing are poss.

8. Obs. on Ocean Temps in Vicinity of Ice
(Waidner & J.J. Cronoc - Bur. Standards Bul 10 Feb. 1914) H.T. Barnes "characteristic pics" in temp near ice is not corroborated. Str. variations in temp & in salinity are found erratically when ice is present & often no such change in pres. pics.

matter from edges. Jeans finds discontinuity when density is ½ that of water. Assuming density increases with age young stars behave like Laplacian model, old ones like Roche's; the former are represented by spiral nebulae, latter by binary stars.

Cosmogony, Geophysics, etc.

References obtained from "Science Abstracts." (except (4.)) 15·8·21.

1. Rotation as a Factor in Cosmic Evolution – J.H. Jeans – Roy. Astron. Soc.
MN 77 – pp 186–199. Jan 1917.

Increasing rotation may break up a mass in 2 known ways. (1) Poincaré–Darwin:– Mass flattens, becomes ellipsoidal, pear-shaped, throws off satellite. (2) Laplace–Roche:– mass flattens & sheds a ring of matter at equator which ultimately breaks up into satellites. J.H.J. gives mathematical analysis of general cases of which he finds the above are special cases. [References to Poincaré, Darwin Sir Geo. & Roche are probably given.]

2. Cosmogonic Theories & Motion of Tidally-distorted Masses (Pt. I.) – J.H. Jeans
Roy. Astr. Soc. Mem. 62. pp. 1–48. 1917.

Examines Planetesimal Theory of Moulton & Chamberlain, showing conditions under which it is applicable & the alternative theories. States it not impossible for Solar System though not the most probable origin.

3. Present Position of Nebular Hypothesis – J.H. Jeans. Scientia Oct. 1918 also in
Roy. Astr. Soc. Canada. J. 13. pp 215–227 May 1919.

Hypothesis of Kant (1755) & Laplace (1796) is shown quite inapplicable to our Solar System, but may possibly be accepted for the much greater problem of evolution of Universe. Poincaré's investigations with homogeneous incompressible fluids point to a regular sequence of sphere, spheroid, ellipsoid, pear-shaped figure, & binary star followed by fission of larger member & gradual formation of a cluster. Roche's work on case of density increasing toward centre led to his lens-shaped model shrinking by throwing off matter from edges. Jeans finds discontinuity when density is $\frac{1}{4}$ that of water. Assuming density increases with age young stars behave like Laplace's model, old ones like Poincaré's the former are represented by spiral nebulae, latter by binary stars.

4. The Origin of the Earth [Planetesimal Theory] Thos. Crowder Chamberlain 1905?
A small, very readable book treating in a non-mathematical way the critical features of the Solar System, failure of Laplace's Neb. Hyp. to satisfy the requirements, the theory of Spiral Nebulae, effect on rotation of infall of planetesimals, juvenile shaping of earth, ideal stress-strain diagram on a semi-elastic sphere + its interpretation as applied to the Earth.

5. Origin of Earth - E. Belot. Observatory. No. 537 pp. 127-131. March 1919.
Earth + 4 satellites of which moon was outermost generated by impact of a cylindrical gaseous vortex with a nebula through which the system gradually passed in a relatively south-north direction. 3 stages (1) nebulous (2) igneous - ceasing at the crit. temp. of water. (3) diluvial or geological. The 3 great periods of mountain building + Earth movement when the 3 inner satellites fell inwards onto Earth.

6. Resonance Theory of Origin of Moon - H. Jeffreys - Roy. Astron Soc. MN 78 pp. 116-131 Dec 1917.
Production of a semi-diurnal tide so greatly magnified by resonance as to lead to the rupture of the mass is impossible in the case of a homogeneous incompressible mass, but is possible if mass be assumed heterogeneous. Analysis points to increase of actual speed + decrease of speed needed for resonance in the latter case - hence resonance theory is considered highly probable.

7. Evolution of Solar System - H. Jeffreys. Nature 101 pp. 447-449. Aug 1918.
Summary of conclusions arrived at by Jeans + H.J. in support of tidal disruption theory.

8. Birth of Moon - W. H. Pickering. Nature 104. Jan. 1920. p. 479.
Earth's crust formation took place probably 20 times as far back as Darwin's estimate of moon's age. Hence suggestion of W.H.P. that during the interval moon's mass circulated as a cloud of fragments producing small tidal effect not modifying earth's primitive rapid rotation of about 4 hrs. Thus less gravity in tropics, hence is explained capacity for flight of prehistoric monsters. Moon solidified probably in middle of Cretaceous Period - hence huge tides + convulsive + volcanic activity associated with that Period.

Life & Art as expressed in Architecture of Churches of Europe 500 – 1500 AD.

Dr Prior - Slade Professor of Fine Arts -

14.10.21. 500 - 1500 period of mediaeval archit.
Basilica of Ravenna (500) internal beauty only
Milan (1500) external beauty - beginning & end.
Amiens (1400) int & ext.
1150 - 1400 med. art flowered forth in ft. churches of Paris, &
500 - 1000 experimental tentative
1000 - 1500 Romanesque & Gothic
Centres - Cologne, London & Paris
Med. thought & requirements shaped Gothic architect
not essentially French.
No architect in pres. sense - Ecclesiastic clerk
& master mason.

From Egypt - masonry wall -
" Greek - pillar
" Etruria - arch.
Rome - curved wall (apsidal)
These 4 were the starting point in 500 AD

4.11.21. Development of stone vaulting.
First stage was plain semicircular arches.
False roofs to keep out snow, etc while interior was being built - necessity of keeping stone arches from rising above, in larger diagonal ribs led to finding stable forms of flattened arches & instead of simple single vaulting the more elaborate forms were introduced the vaulting ribs converging to several centres - & increasing in number from the pillars - final stage fan-vaults as in Kings Ch.
Originally rib-vaulting was structural - later it became ornamental & hid the actual beams & structural supports.

11.11.21. Development of Gothic Apse.
Simple curved wall around high altar at end grave. Need for chapels led to introduction of apsidal aisle & apsidal aisle with chapels off it. Lighting difficulties small lancet windows insufficient - led to flying buttresses for wall & roof support while leaving space for windows.

18.11.21. English monastic cathedrals [1080 Durham] on thro 12th - 13th - 14th centuries uninterruptedly. French cathedrals, high & compact dominating the cities as the centres of religious & secular life in 11th cent. During 12th & 13th in France not much building due to internal national troubles.

25.11.21. The rise & decay of Gothic Sculpture.
With the period known as the Perpendicular Gothic Art reached the peak of its perfection - Stone has become alive with a soul of its own - the forces of gravitation are overcome & stones are forced up like spray. Then it ceased to be creative & the work of development & was imitated in miniature for tombs & decorations whole parts being made wholesale & sold by firms for inclusion in the buildings - The overdoing of canopies, porches, arches, niches & figures detracted from the noble simplicity - Gothic art & inspiration had worn itself out.

The Graphic Art of Painting - Dr Prior.

24.1.22. Painting as a vehicle of conveying the thought- or vision of one man to others - just as a poem, a building or a sculpture but more powerful than the latter two & older. The graphic art of expressing something by outline & form, light & shade & colour. Colour & form inseparable in ordinary mind.

Outline.

1. Near East alhambra - purely decorative
2. Byzantine mosaics - (Ravenna) a creed & solemnity of religion.
3. Glass - blues creed

13th century Italy new ideas - Assyi pictorial power of colour - foremost of St Italian use of graphic painting

Put into frames like a poem in a book.

Mystical effect of L de V.

Masters frieze pescoes & Mic. Ang.

Vivid living groups of Titian.

Airy spiritual landscapes.

Graphic art - stirs led to collections, private & public

Ic to thus advanced the decorative function

Rembrandt - light & shade

Religion - chiefpreoccupation i.e. magic talismanic

Spanish caves & crypts

2 - mystic - Byzantine

3 spiritually emotional, ritual.

4. academic standards.

Material side 1. graphic - truth & deceipt.
2 aesthetic formality - public opinion
2. commercial.

English art falls in - these categories but not art in general i.e. Gothic as Greek impos

1. Magical & mystical
2. Dramatic fancy of painter added naturalism
3. Aesthetic.
4 Commercial

Shifts from decorative to narrative in graphic strug

Book by McCall.

1. Olympians - God & his world all edealized (Fra Ang. Titian
2 attitude of rebel ag. world - storms battles
M Angelo. Titanic devils etc.
3. Mystic (Botticelli)

Italian Painting 1330-1430

Birth of painting - directed by Church & controlled

Masolinio etc discovered powers of features & - for emotion or thought -

Lippo Lippi etc. discovered the beauty of beautiful things

Tactile representation as mind things

Florentine nature - freedom & beauty led from shop-like painting (Madonnas by 100's) up to individual ones.

Giotti & fra Angelico all grown crypt burying reincarnation of human nature

15th Cent. Actuality attained next step - behind actuality - to thing of art for arts sake - rhythm & music

What Reformers were in N. Europe Artists were in Italy.

Neo classical - church owned craft.

Serious Madonnas - & martyrs.

Then happy & natural

Later sadness

Florentine - effective shape more important than - surface adornment as distinct from Byzantine & Indian.

Perspective -

Leading to Raphael - a Renais. decorator
Later 15th cent deeper things of life.
Tragedy + classical features - less
simplicity of joy -
Florentine despotism drove H. art away.
Padua &c take up H. spirit of individuality
Mic Angelo last of H. & peak of
16th century art - divine painter
prophet of art. + Sculptor
Explosion of human form -
Working for Popes & Princes -
Mona Lisa - triumph of spirit.
Georgoni - super-artist equal
beauty either relig. or pagan.
This is Cinque cheato.
+ Raphael - Transfig. or Parnassus
Athens seniors art - goes to Hellenist-ic
conscious + academic - so also
H. goes with its acrobatics into
Italian academicism.
Venician - gorgeous pageantry.
Titian - 60 yrs painting - central repres. of
what we call art of painting.
Titian "splendid gentleman"

Mic Ang. - Prophet of life 15th + last —
" music + melody that intellectual can appreciate

Ren. art passes to north —
1564 M. Ang. dies, Galileo born
Shakes "

The Graphic Art of Sculpture 3/5/22.

Gothic + Renaissance sculpture rose out of the decaying Roman art just as it had risen from the decadent Greek sculpture. There are 2 waves of awakening effort, rising art, climax of genius + spirit, passage from creative spirit to dexterous mimicry + fall - to be seen in the Gk + Gothic sculpture. i.e. Climax of Gk the Venus de Milo - Climax of Gothic of Mic. Angelo. Vitality + power derived from influx of northern barbarians seen in sculpture Commercialized sculpture shows deterioration of unique creative power (Happy Virgin of Amiens as opposed to "Mother of God" Virgin of earlier date) overdoing of sentiment in Gk - Sleeping Ariadne in Gothic - Carcassonne Cath. many with Book of Christ "

5/5/22.

Sculpture reduced to a low ebb for 600 yrs 500 to 1100 A.D. Byzantine reliefs - very stiff + formal + symbolic - doves + peacocks represent souls of blessed - ugly beasts etc. rep. devils + wicked. + struggle of good + evil, +c. Revival of graphic sculpture began not in Italy + S. France but in crosses in N. Britain + Ireland - influence of missionaries seen in subjects - but a new vitality is in the form + later the influence of the Norsemen is seen in the subjects decorating the X'n crosses. Then as architecture developed on the continent + in Britain the art of sculpture began to revive + to shake loose from stereotyped designs.

9/5/22.

In half a dozen places in France, N. Spain + Eng. the carved figure in relief suddenly emerged into the rounded statue figure - At first forming a part of pillars as at Lincoln(?) + Chartres. The revulsion from demons + beasts is followed by angels etc. See the beautiful angels in deep relief over W. door of W. Minster Abbey - This is Gothic art nears its climax - The Bon Dieu of Amiens + Notre Dame in Paris represent the highest point of Gothic sculpture dignity, grace, expression, power. Of height of Greek sculpture in head of Hermes - the pediment figures. Appolo, Zeus etc Venus de Milo. Then came a time when dexterity for its own sake marks the decline of the creative art - see Golden Virgin of Amiens etc.

12/5/22

The special feature of later Gothic development in England was effigies + tombs - recumbent figures - knights lying in attitude suggesting readiness to leap to their feet at the Last Trump. also some altar screens. The Flemish art took the form of reredos's of great beauty + symbolism - these things were made for export + found their way all over Europe. Then Italian sculpture began to revive + the Florentine art took a form of its own, but influenced by the Flemish.

16/5/22.

Sculpture art centred in London in 13th, in Paris in 14th century:
The Renaissance Art in Florence in 15th Century was essentially a personal thing - no longer done by an artisan, craftsman but by an "artist" recognized by the Florentines as a peer among men - + given a place in court + palace with Princes. This first renaissance artist was Michael Angelo. It was a delight in the beauty + joy of things natural - happy playful babys + boy angels, etc. But before M. Angelo died The laws of freedom due to a desire to imitate Classical style had set in + so M.A. is also the last of the gt. Renaissance painters + sculptors.

19/5/22.

The art of sculpture next became applied to elaborate groups for fountains etc - The Barock period - 17th century In France there followed the Rococo period - elaborate brick-brac + church furniture + domestic decoration - stucco modelling in imitation of stone sculpture - The master of the Barock is Bernini - the patron of the Rococo in Louis XIV. In England - Wren, Inigo Jones, etc revived classical standards - In memorial statues see James II by Admiralty + Addison in Westminster abbey in Roman apparel - Also the elaborate graphic pictorial tombs as in Westminster Abbey etc.

22/5/22.

"Modern" sculpture lacks creative imagination - it picks fragments from the débris of classical civilization + adapts them to something which is not the expression of the age as were the classical sculptures the expression of the ancient world + the Gothic (Amiens front) sculptures the full expression of the age which produced them. The Renaissance sculptor was also a craftsman + developed the science of casting. See Cellini's autobiography describing his moulding in clay of the Perseus with Gorgons head then covering it with thin layer of wax + encasing in more clay fully supported to resist pressure, this is baked + wax runs off, then lowered into a hole in the ground - air escape holes being allowed for, + then the bronze is melted (it wd not melt at first + he lay down to die of disappointment + overwrought nerves, but tried again) + it boiled over + filled the interspace. The present sculptor is the clay modeller while engineering firms carry out the castings. There is further a modern invention

whereby the clay model is placed in a frame & the distance in to it from each point on each face is determined & the marble block is mechanically drilled so that an exact replica is produced and as many as desired.

26/5/22.

Modern English sculpture is chiefly monumental & the effort at naturalness - in clothing & posture is evident. There are some very fine tombs & public statutes - not appreciated by general public today - except outstanding things like allt. Memorial. Best English sculpture of 20th century is.
See Wellington monument in St. Pauls.
In France this realistic sculpture reached its height in Rodin.

Prehistoric Art in Spain. — Burkitt.

31.10.21. Drawings of animals in cave walls - very good outlines. Thought to be as talismans against evil. Neolithic age and also stone & bronze age decorations. Caves in barren hilly part of Spain.

History & Fiction — Prof. Trevelyan.

12.11.21. Difficulty of combining the two results generally in modern thought in the mouthes of ancient characters. Great pioneer in making history live was Sir W. Scott.

Modern Drift in Astronomy — Prof Sampson Astron. Royal Scotland

12.11.21 The modern drift in Astron. as in Physics is "toward the light". — see Pract. Astron notes book.

Greenland. — Dr Seward - Botanist.

14.11.21. Great fossil flora beds on S.W. side where the basalt lies on the Archaen. Solid ice cap to within few miles of coast in S.W. S - S.E.

The Last Roman Historian — Dr Mackail Oxford.

Ammianus Marcellinus.

18.11.21. In 590 A.D. a faithful account of the condns existing throughout the decaying Empire was published by him. Mackail does not think much of Constantine & said the rise & the fall of the Roman Empire were the 2 great unsolved problems of history. His theory of the decline was that of natural change, not due to moral decadence in any special sense.

Development of Houses of Parliament Westminster — Thos Wilson. Director of Works & Bldgs - Worsted.

24.11.21. At Westminster Ford.
Shrine of St. Erasmus - religious
Primitive judicial seat - secular authority
Centre of commerce & industry.
Palace of Westminster grew up gradually -

Meeting place of King + his nobles, Commoners below the bar brought their pleas - they were sent by King across to Abbey Chapter House to deliberate + report by a chosen Speaker. Hence chapter house was place where British constitutional govt. came into existence. Later recalled to Palace + given St Stephens Chapel for their assemblies - Hence custom of bowing to Speakers Chair came from respect of site of original altar. + on removing to the new St Stephens Hall, the habit was contd.

Dante Prof. Oakey.

Idea of true nobility based on deeds + character only.

25.11.21 Recent Excavations in Greece Mr Casson Fellow of New Coll. Oxford.

During war at Salonica in trenches building he found remains which led him to return for summer 1921. Found burial mounds, pottery, urns, implements carvings, etc of great interest + city gates with early christian Biblical inscriptions on them.

Imaginative Prose Walter de la Mare

25.11.21. Difficulty in defining prose. Tremendous influence of individual imagination in everything - We dwell in a world of our own making, whether it be sunny + bright or ominous + gloomy.

28.11.21 Bilingual Inscriptions of Picts + Scots on stones in Aberdeenshire. Strange hieroglyphics in series of upright + sloping dashes forming the alphabet of Picts + Celtic words of the Scots giving account of the King's authority.

Star Charts on great Slabs of granite + Solsticial circles in Scotland. Former were inverted so that if rubbed with a skin the impression on skin was a diagram of heavens right side up - Hence astronomical printing press.

30/1/22 Underhill's Painted Slides of English Stone Os.

1- Menhir. 2- Dolmen -

3 Cromlech. 4. Trilithon

1. Dartmoor
Group in Rudrie in O.

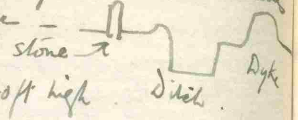
Stanton Drew Somerset 6 mi S. Bristol
Stone O. → not "Stone town of druids!
Drew is Normandy family name.

Rollright- Stones N. Oxfordshire.
Circle + sunrise stone in field in line of Summer Solstice King Stone.
Stones are local here + at S. Drew.
To S.E a dolmen like group. Seen that a circular hole in a stone of O as seen from centre. Diam of O: 2 ft.

Stanton Harcourt Oxfordshire.
Berkshire "Wayland Smith's forge" or Cave - probably a burial place -

Sarsuen Stones on S. Downs [Marlborough]
Avebury. Wiltshire nr Devizes
Largest O in England

Village built within great ring of monument stones
ditch & dyke around enclosure —
Stones > those of Stonehenge.



They are Sarsen stones up to 20 ft high.
Silbury Hill 130 ft high 110 ft at top &
largest artificial hill in Europe —
2 avenues of stones from SW & SE.
Stonehenge. small but impressive.
Stones carefully cut - narrow thin oblongs.
Stones mortised & tongued throughout.
Heel Stone outside ⊙ is unhewn - on axis
toward sunrise at Summer solstice.
Sir Norman Lockyer - 1700 BC. from
astron calculation.
other evidence from excavation - green Cu. stain
on stone - no other metal ∴ stone implements only
bronze age followed - this corresponds to 1700 BC.
Stones trimmed by pommelling with stone hammers
& finished with stone chisel —
Smaller stones are volcanic & from Wales or
Ireland probably - not nearer -
Burial barrows in neighborhood - long ones
antedate Stonehenge - round ones contemporary.

Sir Wm Ridgeway: warning against too much
reliance on vague speculations regarding
both age of these circles and any mystical
halos about them — possibly only 400 BC
when Aristotle wrote of the Iberians raising
stones over their dead in the west. He scorns
idea of elaborate astronomical interpretation
Certainly nothing to do with druids.

The Aurora Green Line in Spectrum of Night Sky.
Lord Rayleigh. Proc. R.S. Jan 2. 1922. Fainter near
Newcastle than in S. England & reported stronger still in
California at Yerkes — The aurora line differs in degree
and in kind from that of Arctic regions & occasionally
temperate latitudes. Latter shows predominant Nitrogen
lines so far absent on ord. nights - when the green line
of λ 5578 is recorded 2 nights out of 3. Its intensity
does not seem to be related to amt. of magnetic
disturbance or to transit of spots over suns centre.
Efforts to determine origin of this line succeeded only in
proving it was not Krypton.

Mineralogical Society - Jan. 10. A Russell
discovery of pitchblende at Kingswood Mine, N. Devon.
It occurs in a north & south lode associated with
chloanthite - also native bismuth. Possibly econ. value.

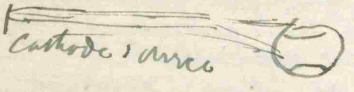
1/2/22. Via Valeria Mr Gardner - Archaeologist

From Rome N.E. mountainous. peaks 10,000 ft
150 mi. to coast.
part older than 300 BC - Claudius - begun by Valerian 400 BC
Tombs along roadside.
Stone work along steep slopes -
Nero's road diverged southward
Horace country.
Bridge arches { fine ones on Via Appia 2,000 yrs old
Nero's milestone.
ft 1900 ~~meters~~ up & 1900 ft more in 3 miles
highest pass 4,000 ft. up great snowy peaks.
Polygonal masonry - Etruscan temple
Draining lake Fucinus J. Caesar proposed it. — Claudius began it
Tacitus - 30,000 men 11 yrs to tunnel thro mt.
~~Collapse~~ — disaster — Trajan also tried
1870 French engineers accomplished the task
& now villages & cultivated fields are there

Aurora Spectrum - Lord Rayleigh. Cavendish 9/2/22

Auroral max. intensity on an irreg. curved zone N + S. about Spitzbergen Lat -

This done in lab with magnetized iron sphere



Theory of pencil of cathode rays from disturbed area as sun.

Way found first photographic results - aurora like neg band of N. in a discharge tube

Lines in violet + blue like N. (neg. pole)

Specially them line in yellow green w the typical aurora line very nearly coincides with the Krypton line.

Green aurora line in night sky.

No N lines but faint solar spec - due to moonlight

Height of aurora by triang 100-150 Km ofs strange no He line in the spectrum -

Lens 3" focal length aperture 1.9.

Czecho Slovakia by Attaché

Botany Theatre 10/2/22.

Embraces Bohemia, Moravia + portion of Carpathian region bounded by Russia, Poland + Germany on E. S. + N.W. Well drained magnificent mt scenery - very fertile + plains highly cultivated - intensive scientific agriculture - vast mineral wealth - self-supporting in food - great beet-sugar export trade in Europe. Industrially it comprises 80% of the industries of the former Austro-Hung Empire - this including 100% of its china + jewelry, 92% glass, + so on - 2nd to England in no. of cotton looms per population has been for 500 yrs under Austrian dominion [On March 24th 1622 the last representative of Bohemia was in Camb. - the hero who came to marry James 1's daughter + latter brought him over from Newmarket - Dr Giles.]

Jugo Slovakia by Dr — Attaché.

17/2/22.

Embraces Servia, Bosnia, Dalmacia, Montenegro + Slavia etc. Great mineral wealth only partially developed - also oil prospects. Greatest plum growing country in world with prune industry + swine - 2nd maize producing country in Europe + 5th in wheat - Transport system very poor as yet - partially through war devastation - fine harbours. Finances in very low struggling state - no help from Britain + adjacent markets of Germany, Hungary, etc. open. People gradually learning to trust each other + work for common good instead of reverse feeling kept alive intentionally for centuries by Austria. In some wild parts patriarchal conditions exist with intertribal feuds, cattle raids, etc.

Marine Biology of a Tropical Island

Mr Potts - Philos. Soc 20/2/22.

Islands clustering round Australia + N.Z. are part of Polynesian Continent, but islands further east + N.E. are volcanic + coral + their vegetation has been brought from the western lands + islands

Samoan islands volcanic with coral reefs protecting coast against Pacific Trade & Monsoons - Various kinds of coral according to whether exposed or sheltered latter beautifully branched - Rapid growth of $CaCO_3$ pillars Carnegie Inst. researches showed a theft of coral grew from 5 lbs to 60 in 18 mos - Sea-anemones, sea-urchins, crabs & many kinds of fish abound, also a green worm about or more long comes out of the coral once a year to breed & is harvested for food. Very fine curved bay used as U.S.A. naval base - Also a sausage-shaped organism which eats the coral or has strong gastric acids digesting some constituents - it is exported to China for soup -

Rumania.

Attaché -
24/2/22.

People were Dacians conquered by Rome & retaining their Latin characteristics & language, now for first time united all under one King instead of under Austria, Turks, Russia etc. etc. Said to be the wealthiest European country - Cereals, lumber, liquids, oil nat. gas, & mineral wealth, gold etc etc including rare minerals. Magnificent Carpathian Mt. scenery & on Danube. Ovid died in exile there at Constanza. Visited by English travellers since 1580 — Orthodox Church but total religious freedom to all sects. Free education throughout. Five universities.

Natural History of Mt. Everest Region.

Mr Wallaston -
27/2/22

Expedn went up into Tibetan plain to N.E. of Mt Everest. Trees & flowers to 15000 ft up there some bare salt-lake regions with very little vegetation - Herds of Yaks & their shepherds - Temples in remote parts. up to 17000 ft. Then they descended well wooded valleys into Everest Region, flowers, etc. Glorious views of Mts glaciers & valley torrents.

Charles Dickens - Prof. Quiller-Couch
1/3/22

Dover picture of Westminster Hall with young Dickens running in with first printed page of his work. Ascribed his popularity to fact that what he wanted was what the people wanted i.e. humanity seen thro human eyes - not cynical, not hypocritical, never condoning evil or indonciling - in anyone, never failing to respond to simple goodness - wealth of his imagination & creative ability - take away any character & you know he could create another equally typical & unique at same time. Dickens visit to U.S.A. not only to see for himself but also to try to get proper copyright laws. He told them that Sir W. Scott might have lived his last years in comfort of mind & estate if a proper system of copyright had existed in England. 8/3/22

Dickens essentially a great man - Tasso said the word Creator only applicable to God & to the Poet. i.e. creative imagination - Virgil, Dante, Shakes. & Dickens
10/3/22.

Dickens was the master of improvisation - e.g. Pickwick but his conscience - as in case of all gt. artists - worried him & urged him against his genius to make an effort to form a plot. Hence in Tale of 2 Cities, & Oliver Twist & Martin Chuz. There is a stereotyped plot which he introduces over & over again with variations - & he is over influenced by the stage. The opening of Martin Chuz in his worst bit of writing & gives Q-C. the "feeling of shame produced when a loved parent misbehaves in public" The sales fell so rapidly that in consternation Dickens forsook his plot & improvised - the transfer to America of the scene - producing the best part of the whole story

This influence of the stage on Dickens is understood by considering his boyhood - robbed of any of the artistic influences of nature & beauty - so early experienced by most people & starved in body, mind & soul - his one joy being an occasional visit to the Drury Lane gallery. The mark of Greatness may perhaps be said to be the careless indifference & disregard of past mistakes & trivial weakness over which the world lingers & talks. Shakes. can afford to be careless of his plots & indifferent to criticism for his characters are pre-eminent, so too Dickens has made men & women whom we know though generally we forget the part they play in the tale - it does not matter in the least. But Dickens had all the restlessness of soul of all gt. men - the spirit of Ulysses - a striving after new accomplishments & greater efforts towards greater triumphs.

24/5/22.

The world of Dickens is a crowded city. He knew nothing of English country life, delight in nature, in sport, in seed time & harvest. His world has no formal religion in it - he ignores the clergyman, cathedrals, churches generally. His world is uninfluenced by the great religious movements & controversies of his age, or by the progress of science & scientific thought, likewise by politics. His is not a world of ideas or of character development - it is a static world of people who are and remain as he made them. The first essential of a true artist is sincere belief in his own creations & to Dickens his characters were his companions & friends. He saw humanity as he did because he possessed in unbounded degree the greatest of all virtues - charity.

The Antarctic Manual 1901 Univ. Lib. NA. 5-59.
Geo. Murray F.R.S. Preface by Sir C.R. Markham F.R.S.
Contains complete Ice nomenclature
Notes on Low Ocean temps & ice J.Y. Buchanan F.R.S.
Lowering of F.P. by presence of dissolved NaCl.
The no. expressing the % by weight of Cl in the Soln. expresses on Celsius' scale the depression of the F.P. of the Soln. below that of distilled water - and by consequence the temp. at which pure ice begins to melt in the same solution.
Sea water follows this rule approx.

Freezing temp of sea water	-2.0° C	-1.5° C	-1° C	-0.5° C
% by wt. of Cl.	1.940	1.445	0.963	.475
Difference	0.060	0.053	0.037	.025

This law holds for sea water containing not more than 4% dissolved matter.
Ref. to Arctic Ice by Weyprecht Die Metamorphosen des Polareises - Wien Monatsh. Perles 1879.
Young ice forming in an opening between solid masses of fresh water ice contains a concentrated amount of brine mixed with the ice crystals hence even at -35°C it is pasty & viscous not brittle.
When sea water ice is melted the saltness of the water produced will vary with the depth of layer the lower layers having formed more slowly being freer from the chlorine

The average Sp. gr. of sea water is 1.025
the Sp. gr. of sea ice — upper 5 cm. - was 1.017
" " middle 9 cm. - " 1.009
" " lowest 5 cm " 1.008
These corresponded to salinity 2.5, 1.3, 1.2 % respectively.

Buchanan believes the ice crystals are pure ice & their saltness is due only to adhering brines from which it is impos. to free them - Ice & Brines J.Y.B. 1887 Proc. R.S.E. XIV. p 129 Nature XXXV p 516 608 and Nat. XXXVI p. 9.

Reliability of & method of using Abs. Wt. hydrometer for sp gr determination of sea water at sea.

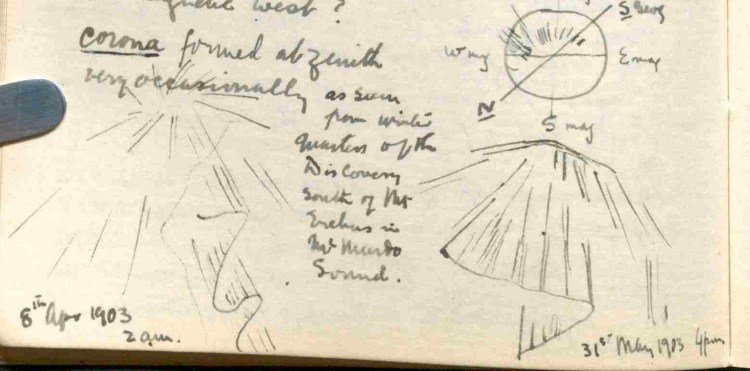
Application of calorimetry to Hydraulics Proportion of water from each of two sources uniting in one stream by consideration of their respective temps.

"Fohn" hot intermittent puffs of air in mountain regions. due to compression on descent from high alts Switzerland. West of Scotland. Antarctic.

National Exped^n 1901-4 Physical observ^{ns} & discussions for Roy. Soc. Sym. - 3.90.135.

Log of auroral displays 1902, 3 Maximum in mid winter June & July, at about 2 a.m. almost exclusively in geographical eastern sky i.e. magnetic west?

Corona formed at zenith very occasionally as seen from winter quarters of the Discovery South of Mt Erebus in Mt Hooper Sound.



"Terra Nova" Reports - Brit. Antarctic Exped^n 1910. Geology - fossils of Ross Sea region & Mt Buckley & Beardmore Glaciers (Scott & Wilson)
Dr Seward (Camb) remarks on value of specimens of glossopteris leaves - as fixing geological age - i.e. Buckley Island probably Permo Carboniferous

2/3/12. Karl Pearson - The Grammar of Science. 340.c.91.3
Causation, says J. S. Mill, is uniform antecedence. Science is Sci. there is no first cause inferable but a series ad ∞ is the field of conceivable knowledge.
Proof in the field of perceptions is the demonstration of overwhelming probability: Logically we ought to use the word know only of conceptions & reserve the word believe for perceptions. "I know that the angle of the circum. on any diam. of a ○ is a rt. angle" but "I believe that the sun will rise tomorrow."

Economic Problems of Democracy Dr Hadley Ex Pres. Yale -
Traced change in national outlook in U.S.A. on problems of immigration, state control, tariff, &c. Strong appeal for free trade as necessary basis of international understanding & friendship.
Sir A Shipley moved vote of thanks saying it was a Christ's Col. man who founded Emmanuel Col. & an Emm. man who gathered the money & books to start Harvard & a Harvard man who founded Yale.

The Miracles of Lourdes.

Dr Woodward (R.C. chaplain) Arts School.

To say the supernatural or miraculous never happens is to be unscientifically prejudiced.

1858 a young Lourdes girl saw several consecutive visions of N.D. de L. in a grotto & thousands were attracted by her accounts & by the healing powers of the spring water which then began to flow. They build the Ch. & about 1880 to obviate much undue exaggeration about the cures they opened a medical bureau to wh. any qualified Dr. or Surgeon of any or no creed & any nationality may go for short or long periods, under oath to call nothing a miracle wh can be explained by any natural means. Their signed statements & case-records are made public & the signatories include leading Frs, Belg, etc, etc. doctors & many of the "miracles" seem undoubtedly to be such. % cures is very small & includes many creeds & races but the spiritual uplift & encouragement is the main thing & seems universal amongst the pilgrims.

The Republics of Central & South America

Prof Shepherd of Columbia

There are 20 of which 1 is negro, 1 (Brazil 7 U.S.A. geographically) is of Portuguese origin, & 18 are of Spanish origin. Failure to comply with recognized international standards of protection of travellers & aliens property &c, maintainance of law & order. Hence they are only on the border of international status recognition. They are very suspicious of U.S.A. - the Colossus of the North. because of its unexpressed imperialistic aims. It has stepped in along Caribbean coast & forced a control for the sake of stabalizing finance, trade, &c. but all efforts to get Pan Americanism on a broad basis of agreement has failed on the part of the U.S.A. the 19 republics drawing closer to one another & looking more suspiciously at U.S.A. The Monroe doctrine very vaguely understood in U.S.A. but elevated in public mind to a principle - though an elusive one - No European interference in affairs of the Am. republics either invited or uninvited - Hardly an unselfish principle since U.S.A. reserves the right to interfere with her smaller neighbours - but as a Br. statesman said when asked what right Br. had to hold Egypt replied "In order that Her Majesty's Govt. may be in a position to give authoritative advice to the Khedive." Just how far the Monroe Doctrine is binding on U.S.A. is not known for if its claims were violated south of the Amazon he doubted if Washington would feel it incumbent on her to press an objection. The 18 republics have opposed the N.D. because of their feeling that in it the U.S.A. was forcing a restriction on their liberty but now that most of them have signed & entered the League of Nations they have automatically acknowledged it since it forms (though badly worded) Art. 21. of the Covenant of the League.

The Victorian age. Rede Lectures.

Dean Inge. 9/5/22.

Tremendous progress during the age. Great men of letters & of deeds. Ruskin a platonist. Tennyson the Gt. representative poet both of his time & a prophet of things to come. The age brought unequalled opportunities to Gt. Britain due to her Geog. position. but now that the Pacific is opening up & that Europe is wasted by war, the favour of fortune rests with America & Britain must play her part

Quotation from Ruskin in address by A.S.A. Hamilton Architect to Research Institute Toronto.

"Take it all in all a ship of the line is the most honourable thing that man as a gregarious animal has ever produced. By himself, unaided, he can do better things than ships of the line; he can do poems & pictures & other combinations of what is best in him. But as a being living in flocks & harmonizing out with alternate strokes & mutual agreement what is necessary for him in those places to get or produce the ship of the line is his first work. Just that he has put as much human patience common sense, forethought, experimental philosophy, self-control, habits of order & obedience, thoroughly wrought handiwork), defiance of brute elements, careless courage, careful patriotism & calm expectation of the judgment of God as can well be put into a space 300 ft. long & 80 ft. broad, & I am thankful to have lived in an age when I can see this thing done."

Rede Lecture contd.

no longer enjoying any special advantages over other nations - This is not a thing to be mourned but a fact to face. She was held in prestige among the nations of the world then - which her statesmen as a whole do not now enjoy. The Elizabethan & Victorian ages are the twin peaks in which the highest in our civilization culminated.

Royal Colonial Institute Meeting

T.R. Glover. on Romance of Canadian history - Kingston - U.E. Loyalists' etc. Parkman's History better for people here to read than Sir Gilbert Parker's

Viscount Peel: the position in India today calls for the best men to enter the Indian Civil Service - the development in its governmental system & the history of its institutions & civilization are of such interest.

Physiology of Life in Andes. Prof. Barcroft. 21/5/22.

2 Cambridge men 1 Edinburgh + 3 U.S.A. men went to Peru last November to study the effect on lungs & blood of high altitudes. 12000 - 14000 ft up are villages & mining settlements. west slope of Andes very arid & snow line is 16 or 17 000 ft. up. The natives carry 40-100 lbs of metal up steps in mine pits 600 ft deep. Huge chests with ribs bulging sideways short lived. whites living there become very florid through lack of oxygen. Increased rate of pulse on exertion or in high altitudes does not mean more blood circulated per minute but more labour reqd to maintain ordinary circulation. He thinks the chances of the Mt Everest party are very slim.

Sir Rbt. Ball : Dr Starry Realms. II.32.11. 16/5/22

It is the infinitesimal calculus that has given to mathematical science its potent grasp over some of the inmost recesses of nature. By this invention of Newton + Leibnitz, this subtle + exquisite contrivance, we attack these problems in detail. Is there not in this a striking analogy to the great principle of Darwin? As the infinitesimal calculus of Newton has led us to a knowledge of the physical laws which regulate the Universe so the infinitesimal calculus of Darwin has afforded the solution of the profound problem presented by organic life.

It must have been with prophetic insight that Cuvier exclaimed "Shall not natural history some day have its Newton?" At the time these words were uttered the Newton of Natural History had been born and his immortal work has revolutionized knowledge.

True Depth of Deep Sea soundings corrected for Ships drift: etc.

1. G.V.D. Quest.
2. Capt. Alington - R.N. Office. Silver St.
3. Ref. Archiv der. Deutschen Seewarte Hamburg. 1921. Brennecke.
4. Kelvin: Pop. Lectures & Addresses - III. Navigation Macmillan & Co. 1891.

Geological Effects of Cooling of Earth
Isostacy - Planetesimal Theory, Stresses of ocean bed etc. leads to theory that deepest parts of ocean should be associated with low values of gravity:
Dr. H. Jeffreys M.A. D.Sc. St John's Camb. P.R.S. C.A. 1921-22 p. 122.

Notes on Phys. Props. of Deepsea Bottom samples.
Sven Oden: Upsala - R. Soc. of Edin. 1915-16.

Ref. to International Reports on Pedology

"Deep Sea Deposits": Challenger Reports by Sir John Murray.

Self registering Accummulation Balance
B.A Keen - Journal of Agric. Sci VII Pt 4. p. 406

Modern Problems of Political Philosophy.

De Sorley - 17/10/22.

The study of the State: historical, ethical, geographical, political.

Difficulties in definition - not autonomous eg. recognition of a higher authority as in church in middle ages + in League of Nations today.

State as distinct from nation - wrong use of latter word - i.e. changing nationality is impossible in case of state. international law is really inter political laws. a nation is a group of men who have or think they have a common history, ideals + future.

A state is an artificial arrangement whereby the individuals recognize certain duties to the state + expect certain rights to be guarded for them by it and the state recognizes certain duties to the individuals composing it + expects certain obligations to be fulfilled by them.

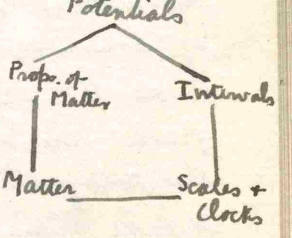
Theological Aspects of the Theory of Relativity.

Prof. A.S. Eddington.

at Emmanuel 20/10/22.

Science + Religion are to be compared to two neighbouring states influencing + interacting on one another. Are they antagonistic or is there an Entente cordiale between them? The former state is just going through a period of revolution on a first class scale.

The theory of relativity has altered our fundamental conceptions of the universe, by supplying the connecting link in a chain of ideas previously ab loose ends but now inseverably bound together into what he terms "the viscious cycle of physics". Thus Einstein embodies all the laws of the Universe into one generalized eqn whose terms are mathematical symbols denoting what are known as Potentials



Potentials are defined in terms of space-time Intervals. Intervals are measured by clocks or scales being material things matter is defined in terms of its

properties: one of density, 3 of momentum and 6 of state of strain. And these 10 quantities which completely define matter are embodied in the equation of potentials. This was the great discovery of Einstein.
Hence in this closed cycle is bound up all the laws of the Universe and its manifestations. There is no way in or out

Now consider a hypothetical universe obeying all the laws of the cycle. What is to distinguish it from any other universe? There is such a thing as our sense of actuality which alone distinguishes between the real and the hypothetical and this demands recognition of consciousness or mind. But we know this actual universe existed before finite minds came into being - hence the recognition of Mind. Thus far science takes us & it is left for the individual by his spiritual experiences to colour Mind for himself as God the Father, the Logos, the Invisible King. etc.

With regard to the position of an individual in the 4 dimensional universe, life seems to imply the consciousness of the moment Now - a moving point on the life-line graph. But further man is not only conscious of being but of becoming i.e. there seems to be a dynamic quality about his consciousness of actuality. The idea of a future life is not made apparent by the Relativity Thy. on account of the fact that there is no such thing as absolute time & hence we cannot conceive of a future life having no element of time in it. The heaven of the Revelation of St John is only slightly more attractive than that of the Revelation of Sir Oliver Lodge - a future life is only desirable if there be a purpose in it & we cannot disassociate the conceptions of a purpose & of time present & future. However the inherent dynamic quality of consciousness already mentioned may possibly be the basis of an argument in favour of a spiritual life, real & individual beyond the space-time Universe in which we spend our finite lives.
There is truth, falsehood & nonsense - We can respect the man who holds onto the first or onto the second if he sincerely mistakes it for the first - but we can have no respect for the man who deliberately holds onto the 3rd.

Bertrand Russell's name for nonsense or nothing."

Eddington discriminates between laws such as Gravitation (our 3 dimensional interpretation of the curvature of the Universe in 4 dimensions "If curvature conveys anything to the mind of the non-mathematician, it probably conveys the wrong idea") for the laws not yet fully comprehended but known as the Quantum theory. It looks very much as though the latter were a fundamental laws of the Universe as distinct from the former.

Charles Dickens (Concluding lecture

Prof. Sir A. Quiller Couch.

25/10/22.

One glimpse into a realm of life remote from his own reveals more to the eye of genius & stimulates more imagination than close & intimate contact with that type of life to the ordinary man. Thus Shakes. & Dickens wrote of things of which they had almost no personal knowledge as though born & bred in that atmosphere.

Dickens made a great mistake in ever descending to the dangerous practice of taking off the characters of his relatives, friends, acquaintances or of public men - especially when he had such a fecund imagination & could invent at will a score of men or women to live for ever in the minds of his readers. Thus his parents whom he had but little cause to respect should nevertheless not have been pictured in Mr Dowley etc. though Dickens certainly does not hold them up to ridicule or dislike. Also Leigh Hunt was much hurt at the hard hit in Skimpole. a man never generous & always dispirited by those who read. Similarly with other people including a judge who was removed by the Home Sec. as a result of Dickens representations.

Consider Little Dorrit the one pure character in the prison world whom Dickens by the command of truth is forced to show to be not entirely untainted by her environment for she thinks it hard that her father should have suffered for so many years in prison & then have to pay his debts to the last farthing as well. Even so unhealthy early environment always leaves some mark on character - & perhaps on the ground of his early disadvantages we must try to account for & forgive Dickens lack of fair play in attacking people on a plane upon which they

would not hit back - ie. by literary caricature. There are only 2 rules for honourable attack (1) Make sure of your facts (2) Attack a man on his own ground. Then if he is beaten, he is beaten + there can be no excuses as to unfair advantage.

The British characteristics are (1) religious + moral righteousness (2) common sense (3) hearty laughter. These have made the nation great + it is these 3 but especially the 3rd that Dickens strove to keep alive in the minds of his readers.

There have been + are critics of Dickens who say his style of prose is not good. Certainly some of it is not good - also some of Shakes - with all his in measure for measure - but these are the exception + Dickens at his best is beyond all criticism. Leo Tolstoy to whom as a foreigner one would think the conversations of many of Dickens characters would be unintelligible, stated that Dickens had created men + women who had become to him as real as personal friends.

In the world of genius like recognises like + great men of our own land + other lands as their stately ships pass by dip their flags to the genius of Charles Dickens.

The English Elegy. 8/11/22.

A tradition of elegy lasting to our own day namely classical allusion: nature, trees, flowers birds, sheep, shepherds. everything animate or inanimate weeping + mourning with the gods + goddesses over the death of someone. It began with the early Gks. + blossomed with theocritus in Sicily. Milton's Lycidas, Tennyson's In Memoriam Cowleys lament over his college friend; Adonis for H. Clough? Thyrsis? Keats Shelley &c and Grays "Elegy" of simple country people not an exception to the tradition because an actual embodiment of it.

Read all the Classics you can lay hold of in the original or in translations for in them are embodied most of what is best + finest in the thoughts of mankind.

The survival of the Elegy with its heathen gods + mythological allusions seems to point to a something lacking in our present conception of religion.

Hermas - A simple Christian of the 2nd century A.D.

Hulsean Professor
Dr Barnes
Peterhouse Nov 5/22.

Very little known of Hermas except that he was brother of Bp. Pius of Rome + that he wrote a book much quoted + thought of in the days of the early persecutions called The Shepherd - from it we gather that he was a Greek from Arcadia + himself a peasant shepherd - sold into slavery to Rome - bought by Portia a Xtian lady from whom he learned Xtianity. He foresaw the time of trial ahead of the Ch + he feared lest his brother might not stand firm. His book is that of a simple peasant visionary. consisting of 2 visions, 3 prophecies + several parables. The name of Xt is never mentioned.

The book was considered inspired by many but just failed to be included in the New Testament.

Shakespeare Lecture-Recital

Sir Johnstone Forbes Robertson

26th Nov./22

Shakespeare the greatest tragedian of all time. Othello, King Lear, Hamlet, Macbeth are unequalled in any language.

The historical dramas were popular because from them the people learned the history of their own country. Strange that Sh. never gave to his audience the Magna Carta scene for example. (The farewell of Buckingham in Henry VIII was recited.)

Othello & K. Lear seem to go together because both are purely domestic - no supernatural elements. no poetry of metaphor & allusion not directly bearing on the scene in question. (Final speech of K. Lear & of Othello recited.)

Macbeth & Hamlet are coupled because each has the supernatural throughout & the main characters are in a way similar for each vacillates & wants external confirmation for his opinions. each breaks forth into poetic soliloquies on subjects philosophic & meditative not always bearing directly or indirectly on the scene in which it is set. (The courtyard scene between Macbeth & Lady M.cB was given & Hamlet's To be or not to be.)

Is the Theory of Natural Selection Adequate?

Dr J. C. Willis - Cambridge.

The Nineteenth Century

Oct/22.

The idea of evolution long ante dates the Christian era but was never established as a recognized theory until Chas Darwin accomplished this by inventing "the very simple & beautiful mechanism of Natural Selection" "to explain the method in which it effected its results. This mechanism, commonly called Darwinism, has proved inadequate without modifications & additions which have almost obliterated the original theory. That it should be completely abandoned in favour of another theory is the opinion of the Author. Major Leonard Darwin quotes Chas as saying "evolution is the great thing not natural selection".

The study of geographical distribution shows a direct connection between Age & Area - & once granting this hypothesis prophecies made on this basis have in every case proved correct when the data was obtained - e.g. the islands near New Zealand (Chathams, Kermadecs & Aucklands distant 375 E, 720 N, & 1905. miles respectively) & once connected by land bridges across wh. the older flora made their way until the subsidence of the bridge. Thus the flora found both in N.Z. & the 3 islands are the ones most widely distributed

in N.Z. & those not found at all in the islands are less & widely spread over N.Z. & similarly with ref. to the relative distances of the islands.

A kindred hypothesis goes by the name of Size & Space - i.e. no of species in a genus and the area covered. In the statistics to avoid irregular errors genera are grouped in tens. Thus Age, Area & Size go together of which Age is called the active factor "which allows time for the really active factors to produce their effects".

Of the 12571 genera of flowering plants 4853 are composed of one species only 1632 of two species, 921 of three & then the curve bends round less steeply  "a hollow curve like that of the side of a cargo steamer or that obtained by trying to force a bow into the angle of a wall"! Not only does the grand total of all flowering plants show this beautiful hollow curve but every single family in it does the same & so do numerous families of animals as well.

Natural selection cannot explain this. "Its real place is at the birth of species. Nothing can come into lasting existance without the permission of Natural selection but this nat. selection ceases to occupy its old causal position. It simply determines whether or not a given form shall survive.

The fact that the same "hollow" curve is shown in evolution & in geographical distribution by both plants & animals & by every family alike (the variations are no more than one would expect from the great variety of minds that have been at work in their grouping & the great variety of accident to which living things are subject) goes to show that evolution has worked upon lines that are much the same throughout. The evolutionary clock having been wound up to run in a very definite manner.

The Worlds 6 greatest men (H.G. Wells)

1. Christ. 3. Aristotle. 2. Mohammet 4 Asoka
5. Roger Bacon 6. Abraham Lincoln.

References to Isostacy. (from G.S.)

Michelson : Rigidity of Earth
J. of Geol. Vol XXII. 1914. p. 97.

Barrell : Str. of Earth's Crust. ditto p. 209.

Hobbs : Isostacy - J. of Geol. 1916. p 690.

References to Cosmogony (from H. Jeffreys)

Jeans : M.N. R.A.S. vol 77 p. 186.

Jeffreys : M.N.R.A.S. " p. 84.

Jeans : Problems of Cosmogony.

Jeffreys : M.N.R.A.S. vol 78. p. 424.

The Foundations of Wireless
Sir Oliver Lodge - 18/2/23.

Historical sketch - Clerk Maxwell - Fitzgerald Hughes, Crookes, Lodge, Hertz, Rati, etc Marconi. Gradual development of detail: units - terminology. His own experiments - about 1875-80 on leyden jar sparks - coherers etc. his prophecy of signalling - addresses to B.Assocn + Roy. Inst. & conversations with Fitzgerald. Hertz great discovery + paper + later work of Marconi.

Concluded with remarks of rare literary beauty on aether. Analogy of knowledge of spectrum - great Hertzian waves, heat waves, infrared, visible range, ultra violet, X rays, γ rays - now working in one continuous spectrum even so we may hope that in the realms of Knowledge & of faith we increase understanding of Nature & the facts of reality. (do not let your hypotheses blind you to facts) may lead to the uniting of these two

into one continuous & harmonious whole.

Influences on Persian Art.

Mus. of Class. Archaeology
22/2/23.

In late B.C. times the Sasanians conquered parts of Persia & the influence of their art & literature can be traced up till about 200 or 300 A.D. Victorious angels carved in spandrils of stone archways — floral designs, legends & manuscript illuminations etc. The hunter who pinned the bird by the ear to the ear of a deer with his arrow by first slightly wounding the ear. This picture is gradually changing form. Camels give place to horses, etc appears & reappears in Persian designs

In early A.D. times the followers of Mani who branched off from Christianity developed a high state of art — Biblical stories or scenes after their own interpretation of them. Almost all destroyed by time. Only a few bits of MS. unearthed a few yrs ago in a deserted ruined city in Persia. Mani taught that Buddah, Zoroaster, Christ & himself were divine teachers. St. Augustine was a Manichean convert to Christianity & urged the destruction of their pernicious books & drawings — They believed the material Universe was all bad — Light & darkness — good & evil — alone existed fundamentally. Devil made man — we hoping to imprison a few particles of "light" in a body essentially evil & ∴ under his control for ever —

The Times
March 1923
Report of Chancellor of Exchequer

WAR BURDENS.

BRITISH EMPIRE CASUALTIES.

—	Men enrolled.	Killed.	Wounded.
United Kingdom	6,211,427	743,702	1,693,262
Dominions and Colonies ..	1,605,527	140,923	357,785
India	1,679,416	61,398	70,859
Total ..	9,496,370	946,023	2,121,906

EXPENDITURE DURING THE WAR.

The figures of expenditure during the war by the United Kingdom are only available for complete financial years. The Exchequer issues between April 1, 1914, and March 31, 1919, were £9,590,000,000, and the money was raised approximately as follows :—

From direct taxation	£1,820,000,000
From indirect taxation and other sources of revenue ..	910,000,000
By borrowing at home ..	5,500,000,000
By borrowing abroad	1,360,000,000

WAR LOANS TO ALLIES AND DOMINIONS

(excluding Relief and other post-War Loans).

—	Capital only.	Capital and unpaid interest to March 31, 1922.
	£	£
France ..	453,000,000	584,000,000
Italy ..	382,000,000	503,000,000
Other Allies	659,000,000	841,000,000
Dominions ..	150,000,000	150,000,000
Total ..	1,644,000,000	2,078,000,000

LOSSES AT SEA

(British Empire).

	£
Value of shipping (at about £70 a ton) and cargoes lost by enemy action	750,000,000
Tonnage	8,000,000 (gross tons)
Civilian lives lost at sea by enemy action	22,000

WAR PENSIONS.

(United Kingdom.)

	£
Expenditure from August 1, 1914, to March 31, 1923 (partly estimated)	470,000,000
Estimated capital liability from April 1, 1923	832,000,000

MANDATED TERRITORIES.

Expenditure on Mandated Territories from Parliamentary Votes from April 1, 1919, to March 31, 1923 (partly estimated)	153,000,000

OTHER EXPENDITURE.

(Resulting from British participation in the War.)

Some important items of expenditure by the United Kingdom which appear to fall under this description are :—

	Partly estimated between April 1, 1919, and March 31, 1923.
UNEMPLOYMENT.	£
Total expenditure by the State and local authorities, including existing commitments	400,000,000
HOUSING.	
Total capital cost to the State and local authorities of the houses erected under the Assisted Housing Scheme and Private Builders' Subsidy ..	225,000,000
LIQUIDATION OF WAR COMMITMENTS.	
Railway and Canal Agreements	203,000,000
Ministries of Munitions and Shipping	36,500,000
Compensation for damage by enemy action	5,000,000
Coal mines deficiencies	48,000,000
Bread subsidy	101,500,000
POST-WAR.	
Relief and reconstruction and other post-war loans (capital and interest due on March 31, 1922)	33,000,000
Occupation of Constantinople ..	20,000,000

GERMAN SHIPPING.

Amount credited to Germany and debited to the British Empire on Reparation Account in respect of merchant shipping :—

	Gold marks.
1,852,413 gross tons valued at ..	249,704,000
	£
Or at 20 gold marks to £1, about	12,485,000

A further debit will be made against Series "C" bonds, in accordance with Article 6 of the Spa Agreement and Article 12 of the Agreement of March 11, 1922.

No German Colonies have been assigned to the British Empire. State property in Mandated Territories passes without payment to the Government exercising authority in those territories under Article 120 of the Treaty of Versailles.

Summary of Antarctic Exploration

from 9th.

Ship	Commander etc.	Date	Region
Erebus & Terribus	Sir J. Ross	1843-6	Ross Sea.
Beaufoy & Jane	Weddel	1823	Weddel Sea 74° S.
Discovery	Capt Scott	1901-02	Ross Sea
Antarctica	Nordenskjold + Capt C A Larsen	1902-4	Lost in Weddel Sea.
Pourquoi Pas	Charcot		Charcot Land. W. of Graham Land
Nimrod	Shackleton Priestley	1907-09	Ross Sea. S. Mag. Pole + 97 mi of S. Pole.
Terra Nova	Scott Priestley Debenham + C.S. Wright	1911-13	Ross Sea - to Pole.
Fram	Amundsen	1911-13	" - Pole.
Aurora	Mawson	1914	Adelie & Q. Mary Land east of Enderby Land
Scotia	Bruce J.H.H. Pirie Rudmose Brown	1903-4	
Endurance / Aurora	Shackleton Wordie, James Stenhouse	1914-16	Weddel Sea.
Aurora		1914	Ross Sea
—	Filchner	1914	Weddel Sea
Quest	Shackleton	1921	Weddel Sea

Quotation from "The Forerunner" by Merejkowski

Leonardo da Vinci: O divine Justice of Thee Thou Primo Mover! To no force hast Thou permitted lack of the order and quality of its necessary effects. O Thrice-Marvellous Necessity!

Knowledge of a Thing engenders love of it; the more exact the Knowledge, the more fervent the Love.

Perfect Knowledge of the Universe and perfect Love of God are one and the same thing.

Great Love is the daughter of great Knowledge.

Dr Astbury on Materialism - 27.4.24.

all advance in knowledge of Matter & the Laws that Operate in Nature — Evolution, Gravitation, atomic structure Light theories - lead us face to face with greater mysteries. Sir J. Larmor on Eth may. thy & Q. Thy - Said Hold onto the ends of these 2 good chains & search for the connecting links - Similarly with Sci. & Religion - 4 Gt possessions Religion Philosophy Art & Sci. cultivate all - the Gt Realities are the conceptions of Ultimate. Eles. Love, justice, truth, beauty, goodness holiness.

Picture of human progress - Nt pass precipice of ignorance & superstition

by JBS Haldane

what is true
ent — rational
. As man
spirit will
more and more
ical application

Summary of Antarctic Exploration

from 9/11.

Ship	Commander etc.	Date	Region	
Erebus & Terribus	Sir J. Ross	1843-6	Ross Sea.	
Beaufoy & Jane	Weddel	1823	Weddell Sea	74° S.
Discovery	Capt Scott	1901-02	Ross Sea	
Antarctica	Nordenskjold + Capt C A Larsen	1902-4	lost in Weddel Sea.	
Pourquoi pas	Charcot		Charcot Land. W. of Graham	
Nimrod	Shack / Pries			
Terra Nova	Scot / Priestl / + C.S. W			
Fram	Amun			
Aurora	Mac			
Scotia	Bruc / J.H.H. / Rudmo			
—	Fil			
Quest	Shac			

Quotation from "The Forerunner" by Merejkowski.

Leonardo da Vinci: O divine Justice of Thee Thou Primo Mover! To no force hast Thou permitted lack of the order and quality of its necessary effects. O Thrice-Marvellous Necessity!

Knowledge of a thing engenders love of it; the more exact the knowledge, the more fervent the love.

Perfect Knowledge of the Universe and perfect love of God are one and the same thing.

Great Love is the daughter of great Knowledge.

Quotation from Nature May 24/24.

Sci & the Future. a review of "Daedalus" by J B S Haldane & "Icarus" by Bertrand Russell.

"The scientific spirit is that which finds out what is true and attempts to act on what it has found out — rational imagination and imaginative reason. . . . As men of sci. grow more numerous, the sci. spirit will spread and as it spread it will make more and more difficult the foolish use of the practical application of science.

Materialism by Dr A S Eve, CBE. FRS.

---

mists or phantoms on all sides, traveller with a great faith, some hope & a tremendous purpose & perseverence & courage struggling up — to what — an unknown splendour — Straight is the way & narrow the gate harder than for a camel to thread the eye of a needle — In my Father's house are many mansions. There are no words to express it The stars of the morning sang together & the Sons of God shouted for joy

---

Visit to Cambridge, Mass. May 2nd - 29th

Dr Harlow Shapley, Director Harvard Obs'y.
" F.A. Saunders, Prof Physics, Jefferson Lab.
" Leyton (Holland) Harvard Obs'y.
" Baxter Chem. Rare Earths.
" Lamb " .
Miss A.J. Cannon. Obs'y.
Prof. King - Photo. Lab Obs'y.
Prof. Marx - Engineer. Steam Pressure authority anti-Callendar tables.
Prof. Daly - Geology
Gratton - Economic geol. + mineralogist
Palache - petrographer
Pierce - Cruft Lab. oscillatory crystals. + rel. of sound.
Bridgman - High pressure research
Franklin - Mass. Inst. Tech. [Time + Quantum Th.

Quotations from "The Legacy of Greece."

Religion by W.R. Inge. "The dramatic fancy which creates myths is the raw material of both poetry + science"
"... trust in reason which rests really on faith in the divine Logos, the self-revealing soul of the universe."

see Haldane's Philosophy of Humanism p. 92.93.

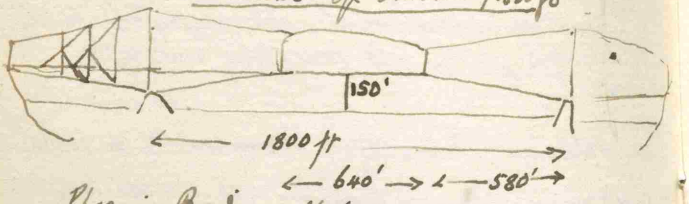
Natural Science: D'Arcy W. Thompson F.R.S. "We take pleasure in the beauty of a statue, shall not then the living fill us with delight; and all the more if in the spirit of philosophy we search for causes and recognize the evidences of design. How will Nature's purposes and her deep-seated laws be everywhere revealed, all tending in her multitudinous work to one form or another of the Beautiful". (Quotation from Aristotle's "Historia Animalium".

Self mistrust. Dante Inferno I.

My soul is by vile fear assailed, which oft
So overcasts a man that he recoils
From noblest resolution, like a beast
From some false semblance in the twilight gloom.

Practical Spec. Analysis - Meggers, Kiess, Stimson
Sci. Papers Bur. of Standards No. 444. July 29, 1922.

Dimensions of Quebec Bridge



Phoenix Bridge collapsed 1907
Dom. Br. Co. central span fell. Sept. 1916.
" " " Completed bridge Sept 1917.
Opened to trains Dec. 1917.
Design of K-structure Phelps Johnson
developed by G Hermek D Uffan.

Water Power in Canada.

Engineering Journal of Can. July 1924.
Estimated Total water power of Canada - 40,000,000 h.p.
Total developed water power 3,227,414 h.p.
At Niagara: Hydro Electric Power Commission of Canada (1) Elect. Development Co. Plant 164,000 h.p.
(2) Ontario power Co. plant 208,000 h.p.
Canadian Niagara Power Co. plant 109,000 h.p.
In Quebec. 3 sites on St Maurice river 547,000 h.p.

Numerical Coincidences.

$(10a+b) + (10b+a) = 10c+d$

$(10c+d) + (10d+c) = 99$

$64 + 46 = 110 + 18 + 81 = 99$

$41 + 14 = 27 + 72 = 99$. Do it in any scale £:s.d. or h.m.s.

Magic Square - odd no of places - always to right upper or up impos - to underneath square -

Pascals Δ.

Proof of result independent of a, b, c. Thus by A.T. Cochlan
$100a' + 10b + c$ Can be written $100(a+c) + 10b + c$ ①
where $a' = a + c$
Reversed $100c + 10b + a + c$ ② Subtr. ② from ①
+get $100a + 0 + -a$ write this as
$100a - 100 + 90 + 10 - a$ Reverse + add.
$100(10-a) + 90 + a - 1$
$1000 - 100a + 100a - 100 + 180 + 9 = 1089$

Thus
$$\begin{array}{r} 754 \\ 457 \\ \hline 297 \\ 742 \\ \hline 1089 \\ \hline \end{array}$$

Similar proof for 4 digits etc.
+for £.s.d £12.18.11
or $.c. $9999

Express all numerals from 0 to 6 using 2 twice.

$2 - 2 = 0$

$\frac{2}{2} = 1$

$\sqrt{2 \times 2} = 2$

$\sqrt{\frac{2}{0.2}} = \sqrt{2 \times \frac{9}{2}} = 3$

$2 \times 2 = 4$

$\sqrt{\left(\frac{1}{0.2}\right)^2} = 5$

$\sqrt{\left(\frac{1}{0.2}\right)^2 - e^{i\pi}} = 5 + 1 = 6$

Wordsworth.

I have felt a presence that disturbs me with the joy
Of elevated thoughts; a sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns
And the round ocean and the living air
And the blue sky, & in the mind of man:
A motion and a spirit that impels
All thinking things all objects of all thought,
And rolls through all things.

Browning.

Progress is the law of life, man is
not Man as yet.

The Debt Settlement — Atlantic Monthly Sept. 1926.

Hon. Philip Snowden.

Relative Cost of War. (1913 dollars - Bankers Trust Co. N.Y.)

	Gross Cost per Capita	Gross Cost % Nat. Wealth	Average annual Cost % National Income	Battle deaths % Population
Gt. Britain	524.8	34.5	36.9	1.44
France	280.2	19.4	25.6	2.31
Italy	124.6	20.6	19.2	.92
Russia	44.0	13.1	24.1	.98
U.S.A.	176.9	8.7	15.5	.05

	Taxation per capita in dollars	National Income per cap in dollars	Prop.n of Nat. Income absorbed by Taxation %
Gt. Br.	86.94	374.74	23.2
France	39.07	186.98	20.9
Italy	19.04	99.17	19.2
Belgium	24.83	146.06	17.0
U.S.A.	69.76	606.26	11.5

Italy's Debt.

	to Gt. Br.	to USA.
Original loan	£ 460.10^6	£ 339.10^6
Present total	570.	420.
Total payments to be made	254½.	495.

France's Debt

	to Gt Br.	to USA.
Total Debt	£ 647.10^6	£ 805,000,000.
Amt. to be paid	775.10^6	1,369,000,000.
i.e. Interest	128.10^6	564.10^6

War debts owed to Gt. B. £2,000 10^6.
On these debts G. Br is paying
out of her own Taxes † £100 10^6
Expected from Italy 4 10^6
" " France $12\frac{1}{2}$ 10^6
" " German Reparations 15 10^6 } £$33\frac{1}{2}$ 10^6
" " smaller nations 2 10^6
Paying to U.S.A.
Deficit £38 10^6
Due on internal debt borrowed
to lend to allies (same as above *) $4\frac{1}{2}$ 10^6
100_1 10^6

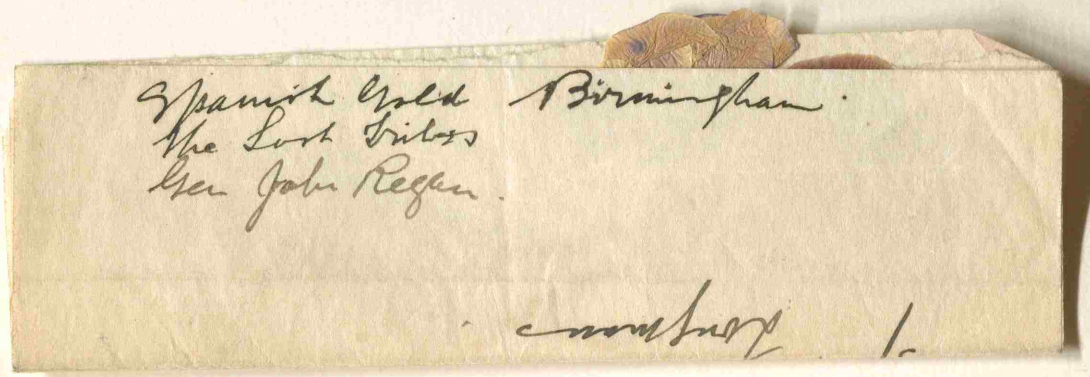
Usa. will be getting from all her
debtors approx per yr. 120 10^6
Total German reparations on
Dawes scheme 125 10^6
But actual reparations
can scarcely exceed 50 10^6
all of wh. † as much more
is being taken by Usa.

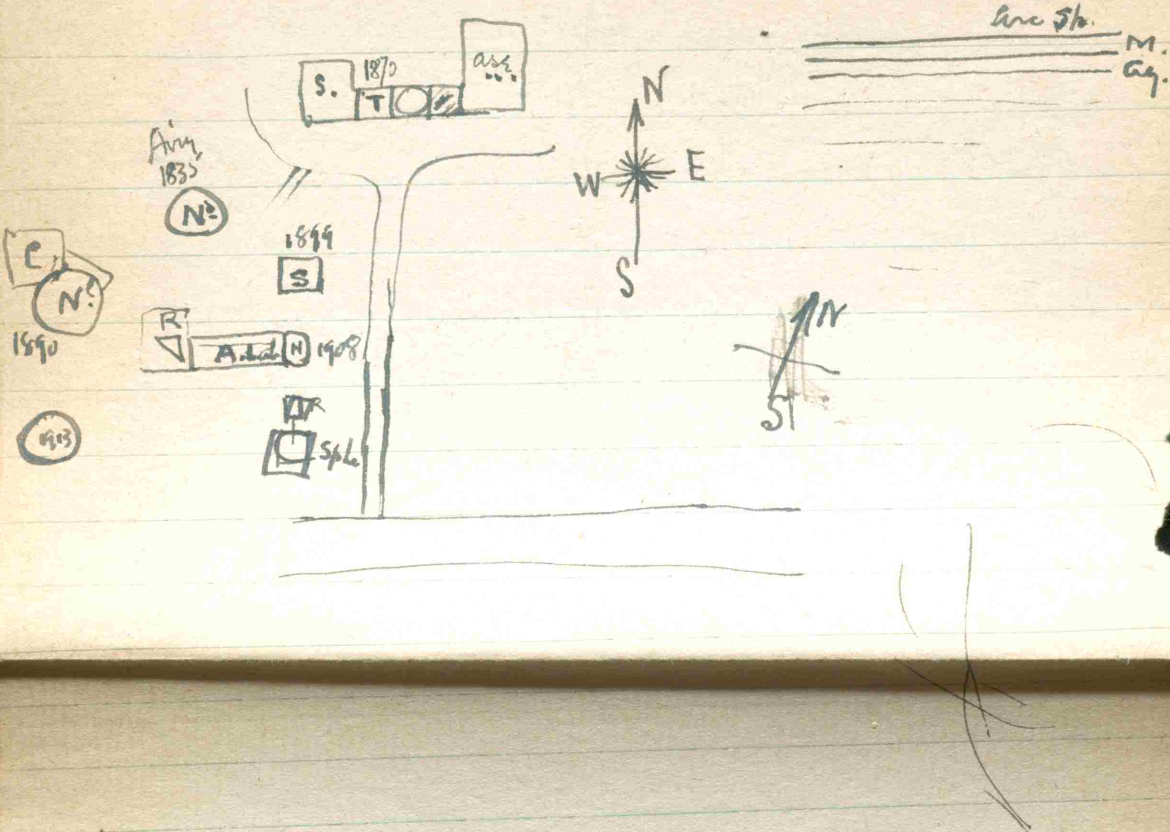
Federal Trade Commission data.
Wealth of Usa. $ 550,000 . 10^6
" " G. Br. $ 24,000 . 10^6
Usa annual increase $ 55,000 . 10^6 ie doubling in 10 yrs.
Usa. national income is increasing yearly by
the sum of the total amount of the debts
owing to her by her European debtors.
Usa. national income 1923 $ 70.000 10^6
annual increase 10.000 10^6
G.Br. national income £ 3.600 10^6

Wherever we tread
'tis haunted holy
ground
Ground where the Sires
have quelled the Foe
Of generations of
Illustrious men

Childe Harold
Canto III. 88.

Spanish Gold Birmingham.
The Lost Tribes
Gen John Regan.





S.
1870
T
1835
N°
1899
S
R
1908
1890
N
W
E
S
M.
Ag.

Experiments in use in Cavendish Apparatus made by W.G. Pye.

7234 Viscometer £5.10.0.

7235 Torsion Bal. 2-12-6.

7288 Steam Soap Bubble for Surface Tension. £2.7.6.

7300 Levelling Screws. (3 for 9/

7955 Unbreakable galvo's (cheaper & more accs than wooton) £3.10.0

9940 Searle & Pyes Spectrometer £6-6.0

9950 Sonicometer £3.5.0.

8965 Water Volameter. 16/6

Look up Mss. for Steam Soap Bubble - S. Tension
Viscometer.

S. Tension

Searles – Goniometer angle measure
" " type Spectrometer refr. indices of solns.

Micrometer Verniers

refracting scale.
Geom pt + groove base –

(Newtons rings.
Total Reflection
Woods Phys-Optics)

Ord Coll. for ∥^l^ beams –

~~[illegible]~~ Soap bubble.
Camb Phil Proc – Vol 17 Part 3

Erebus Terribus	Sir J. Ross	1843-6.	Ross Sea.
Belgica Jane	Weddel	1823	74° S. Weddel Sea.
Discovery	Capt Scott.	1900-02.	Ross Sea.
Antarctica.	Nordenskjold Capt C A Larsen	1902-04.	Lost in Weddel Sea.
Pourquoi pas	Charcot		Charcot Land - W. of Graham's Land.
Nimrod	Shackleton Priestley	1907-09	Ross Sea. S. Mg. Pole 97 nm of S. Pole
Terra Nova	Capt Scott Priestley, Debenham + E.S. Bright	1911-13	Pole.
[illegible]	[illegible]	1911-13	Pole - [illegible]
[illegible]	[illegible]	[illegible]	[illegible] East of Enderby Land.
Scotia.	Bruce J.H. Pirie Rivers Brown	1903-4	
Endurance	Shack.	1914-16	Weddel Sea.
Aurora	Stenhouse	1914	Ross Sea.
—?—	Filchner	1914	Weddel Sea
Quest	Shac.	1921.	Weddel Sea.

ALEXANDRA CHAMBERS,
7, KING STREET,
ST JAMES'S, S.W.1.

Returned with many thanks - by

G. T. W

to

M. G. S

and

G. V. B.

15th Dec/22

Johannsen Distrib Curve of size of beans

Could not shift the peak of curve by taking progeny of the extreme types –

Regeneration of leg by newt leads to but not by frog – red as absurdity on Nat Selection

Thus D's mech hyp cannot account for all the facts –

La Marckian Hypothesis –
(Generally Vitalists)
Response to need –

Darwin was broader than the neo Darwinians accepted inheritance of acquired characteristics

This hyp broke down –
Germ plasm not affected by later condns

Physiology demands the Vitalist to prove that no machine will do what body does

but mechanist cannot get answer to causes

Darwin performed the greater task of forcing people to believe in evolution by giving a mechanical explanation of change of forms –

Later blood test showed less diff betw Man & Anthropoid Ape than betw Cattle & lower monkeys

Criticism of D's Mech Hyp.
Variation & Nat Sel or surv of fittest
but not of Evolution
unfit fit

Nat Sel. eliminates the unfit does not affect the fit

Variation

eliminated

Dog scratches itself when tickled like flea
even if brain removed - i.e. spine severed -

Helmholtz - each nerve fibre starts in a
1842 nerve cell in the central system -

1850 - cut a nerve fibre + the portion away
from cell degenerates + stains
differently + ∴ possibility of tracing the
in + out ones -

ganglion nerve cells for
sensation of nerves -
[illegible] motor nerves

Nerve message not current elect
bec rate is 1 m per sec in frog
4 " " " man

Galvani — Elect. prod in body
Volta — current elect with dissimilar metals

Message is a state change slowly
propagated

- pt. rises to max + falls again
as stimulus passes

2 signals sent too fast will not both go -

(Analogy w Lilly's work on [illegible] waves ?)

(1) Mechanistic Hypothesis - Life expl. as Phys + Chem
(2) Vitalistic

Pragmatic argument favors (1) since it alone has
led to advance in knowledge -

(1) Evidence Physiological
(2) Theory of Descent
(3) Facts of Development -

(1) Elements of matter only ones in body
Conservation of mass -
Respiration - Oxygen + Combustion -
Conservation of Energy complete -
Synthesis of urea possible in lab
Nitrogenous complex product [illegible]
Effect of thyroid gland product on developing
tadpoles -

Cellular Composition of body
5 categories -

Nervous system - lines of communication -
nerve fibres
2 kinds of nerves - leaving back bone by
2 roots - one is sensation (in)
" " motive (out)
Reflex action (headless snakes - motion if touched
but only due to outside stimulus.
Many actions in our body are in no sense
dependent on consciousness

Vienna — Kammerer.

Pavaloff — Petrograd —

mice experiment

300 trials reduced to 5 in 6 generations

Prompt then he admitted it does not

prove vitalism.

J. S. Haldane of Vitalist physiologist in Oxford.

Subdivision of frog egg

mechanism with mechanism

Reich
Sleich
Breich ? 1907.8 Gifford Lectures —

All development —

His final decision is Mechanistic

after years of Considering it Vitalism —

Index.

Miscellaneous Notes.

1923—

A. D. Douglas.

$F_0 = \frac{Q}{R^2} = \frac{6\ 10^{10}}{R^2}$ $\therefore R = \sqrt{6 \cdot 10^8}$

$= 2.5\ 10^4$ cm

$= 250$ metres

on low side probability.

$\frac{Q}{R} = PR = F_0 R = 5\ 10^8$ volts.

Q = excess of + ions inside cloud

P = surface density = 120 E.S.U.

Aurora Theories (1) Cathode rays.

(2) Lindemann neutral rays.

Atmospheric Moisture Dr Shaw - March/24.

Max^{m} v.p. depends on surface curvature

m.v.p + density of sat. aq. vap. are indep^{t} of everything but temp.

I. Methods involving obs. of aq. vap. by hygroscopic substances

(a) Absolute (i) chem. hygrometer

pull air of given vol. thro a U-tube of deliquescent substance - good for large quantities.

ii Volumetric method. Const. pres. absorption hygrometer devised by Dr Shaw. 2 min to measure to $\frac{1}{10}$ %

Tilting tube method of Tyndall -

(b) Empirical method - Hair hygrometer if well calibrated + used within narrow temp. limits

Paper hygrometers - Paper on spring suspension

weight changes - $\frac{1}{10}$% accuracy.

Electrical resistance.

Refr. index of glycerine - changes with concentration by absorption of water.

II. Dew point - chill till condensation only accurate to 4th unless very many precautions taken - then to $\frac{1}{20}$ %

Thermal hygrometers

Physiological loss - Human body gives off 63 gms H_2O/hour.

Wet + dry bulb - Assmann instrument

Standard now in Eng. + Canada.

Clock work draws up air at given rate, change wick with graduated pipette

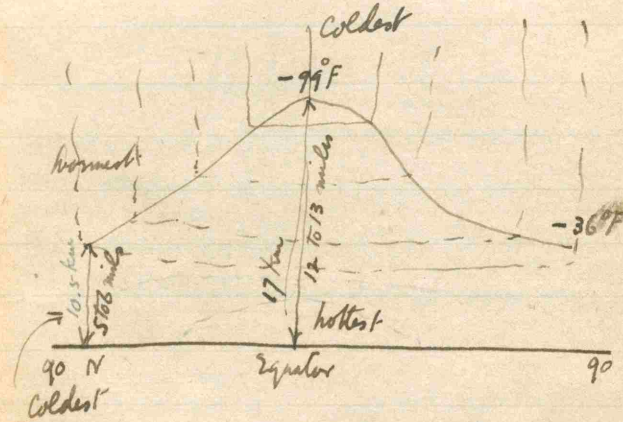
Rapid + accurate to $\frac{1}{10}$ %.

Rate of change of resistance of hot wire due to cooling in ans of diff moisture.

Structure of the Atmosphere

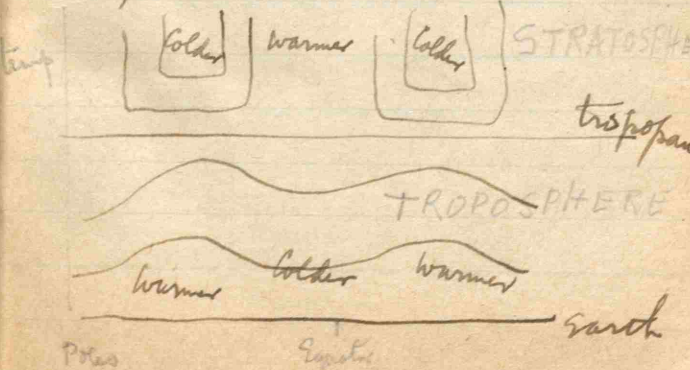
Mr J. Patterson
Dom Met. Dept. Jan/26

Troposphere - Temp grad. -3°F per 1000 ft.



Cyclones - centre cold outside warm.

Anti cyclone " warm " cold.



...ng was given by Mr. John Pat-
terson, M.A. of the Dominion Mete-
orological Department, Toronto,
on the Structure of the Atmosphe...

...of Meteorology from the lore or
...ne position it holds amongst
...alley was the first to plot
...urves of equal barometric pres-
...relation of pressure to winds.
Thus the prediction of weather
...ious for several days became
...rtainty at all times, due to
...re centres, these being some-
...and sometimes moving westward
...times stationary for several
with a velocity up to 50 ...er hour.

...tmosphere was described as it
...from aeroplanes and by data
... The highest record is
...es. A temp-
...25 miles above Italy.
...miles above Canada, and of
...The Troposphere is the re-
...up to about 11 km. in which
...t and circulation takes place
...ate region, whose boundary is
...atosphere where there is no
...n height, but only with latitude
...osphere being above the tropics
... The twilight limit is 75 km.
...a 100-180 km.; the region of
...auroral arcs form at 250 km.

The lecture of the evening was given by Mr. John Patterson, M.A. of the Dominion Meteorological Department, Toronto, on the Structure of the Atmosphere.

The gradual development of Meteorology from the lore or superstition of the ancients to the position it holds amongst modern sciences was outlined. Halley was the first to plot the trade winds and monsoons. Curves of equal barometric pressure were shown illustrating the relation of pressure to winds, to temperature and to moisture. Thus the prediction of weather conditions from charts of conditions for several days became possible, though subject to uncertainty at all times, due to the erratic motion of the pressure centres, these being sometimes stationary for several days and sometimes moving westward with a velocity up to 50 miles per hour.

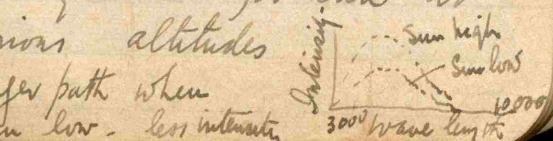
The structure of the atmosphere was described as it has been revealed by observation from aeroplanes and by data from instrument balloons and kites. The highest record is from a balloon which ascended to 23 miles above Italy. A temperature of -70°F was recorded 15 miles above Canada, and of -133°F 10 miles above the tropics. The Troposphere is the region of the atmosphere extending up to about 11 km. in which temperature decreases with height and circulation takes place and clouds are formed. Above this region, whose boundary is called the Tropopaus, is the Stratosphere where there is no forther temperature gradient with height, but only with latitude the coldest portion of the stratosphere being above the tropics and the warmest above the poles. The twilight limit is 75 km. up; the region for shooting stars 100-180 km.; the region of auroral draperies 100-200 km.; auroral arcs form at 250 km.

The proportional amounts of the various gases which constitute the atmosphere vary with altitude - nitrogen and not hydrogen and helium appearing to predominate in the stratosphere.

The temperature conditions as affecting aeronautical work were discussed and in conclusion the circulation of the atmosphere was described as the greatest transportation system accomplishing the stupendous task of shifting a million million tons of air in two or three days from one region 1000 miles in diameter to another region, at the same time carrying perhaps 1000 million tons of water to deposit them upon the Earth as rain or snow. The source of all this energy is the Sun.

Scattering of Light. Dr L. V. King.
Oct 1924.

Each molecule when a light disturbance comes along becomes a small doublet with 3 unequal modes of vibration along 3 mutually ⊥r axes. Hence unequal scattering effects + partial polarization.
No. of mols per c.c. in ages is 10^{19}
but from the absorption of light in space, i.e. the scattering due to mols. of nebula throughout space the density of matter in "empty space" is estimated at least to be 100 mols/c.c.
Early work by Rayleigh on the extinction coefficient in our atmosphere - theoretical - The actual determination is from intensity curves for sun at various altitudes longer path when Sun low - less intensity



Ratios of Salt Content of Oceans Rivers, Animals & Man.

1924. Dr Mac Callum

Relative Proportions.

	Na	K.	Ca	Mg.
Sea Water	·918	·038		
Medusa jelly fish	·848	·048		
Sea water	100	3.0	3.5	12.0
Medusa	100	3.5	4.1	11.4
Dog Blood plasma	100	6.0	2.5	0.8
Man "	100	6.1	2.7	0.85
Laurentian period of Sorgue (as in ovum)	100	207.	11.8	19.0
Murray's Av of 13 Rivers	100	38.	600.	
Lake Superior	100	97	1000	

Sea animals have the concentrations of the ocean in wh. they are living

Land animals have the concentrations of the sea at the times when their ancestors

first left the sea for the land.

Dog fish is representative of shark family & was assoc with it in the ocean to Silurio Cambrian times.

Cod fish arose in Cretaceous from a fresh water ancestor - the bow fish - since then salt water inhabitants

Whales arose from ancestors common to it & the pig & horse in Eocene

i.e. 30×10^6 yrs of ocean life.

The propr of salts in ocean & in blood of the above animals are approx. the same.

The Lobster has much less Mg but has been less no. of Geological ages in the ocean.

This is true of all recent ocean animals.

Na concentration increases in ocean

Mg. " increases less rapidly as some Mg & much Ca form limestone &c

K in ocean forms glauconite.

Ancestors of vertebrates had the salt concentr of the ocean at their time.

are composed of over 100 H, over 200 C + many Fe, O etc. ∴ very large + will not pass thro porcelain, but if latter be steeped in or impregnated in Na oleate or Quinine or Strychnine or 3 or 4 other things then the haemoglobin mols pass thro very readily.
No satisfactory theory.

→ Lining of intestines acts like a complicated membrane. Guinea pig fed only on yolk of Egg died in 3 days dec. The outside layer of cells bounding intestine greedily absorb the yolk mols & pass them in to cavity but next layer of cells does not act fast enough & hence a tremendous pressure inside lining as more yolk is sucked in by endosmosis against the accumulating pressure & inflation which finally results in rupture of the outside layer of cells - (ie self destruction)

Osmosis

Extension Lectures on Modern Physics

Jan 14/25. Faraday & Electricity

Dr A. S. Eve.

Electrical age - matter made of + - elect.

M. Faraday - 1791 lived 76 yrs.
blacksmith son - [illegible] to
bookbinder - Roy. Inst. founded
by Rumford - Davy in charge
succeeded Davy at R. I.!
Silly Billy - Sailor King Wm 4
gave F a pension £ 300.

amber magnetite
St Augustine "City of God"
asks why amber picks up
straw + lodestone iron?
Gilbert explained magnetism.

elect charges [illegible]
lines of force or [illegible]
between charges

1800 Volta Zn & Cu Cell.

Faraday. mag. effect of
current.
hence galvanometers -
1. mag. effect.
2. Heat
3. Chem decompos. Electrolysis.
Copper plating in cell in lantern
Hence unit of cur quantity.

Leyden Jars Capacity discovered ~~by Faraday~~ in Leyden - Studies by Faraday
for different materials
Wimshurst connects to Galvo
gives cur. connect to L. Jar
& get charge stored.

Solenoid (draws in core
& cats iron filings.

Faraday lines & get current
from a magnet -

Arago said he decomposed water with a magnet - afterward retracted.

There must be Motor.

Turn coil in earth's field - or move magnet in or out.

Mag-force in space.

Induction coils at A.C.

Current as motion of electrons

Transformer - same due to changing magnetism

Attach bell to 2ndary + screen off effect + then separate primary further + increase effect with core.

Amperes theory - mols in core each with its electric going about + acting as current coils -

The first men are those who combine regions of thought -

Franklin lightning same as other elec - laughed at + rejected by R.S. afterward F was made F.R.S.

Faradays Disc

Move Cu between poles of a magnet & get current.

Reverse process gives motor

Electromagnet

Discs falling in jaws of electromagnet

Disc jumps up when curr is turned off

Why?

Heavy glass made by Faraday

Put coils of wire round glass. + plane of polarization rotated.

Clerk Maxwell + Radiation Theory.

Lucretius iron filing + lodestone mag field – a propd space in neighbourhood of mag –

Electro field

Explain natural phenomena of matter in terms of el + mag field –

Induced cur. in Secondary on beg galvo. in corner + beg El. mag – + primary –

Transformers –

Props of A.C.

in coil – alternate mag field

Al disc held by 3 cords disc floats above coil. + gets hot even + boil dry

Clerk Ms Zn/Pt Cu & Zn in acid gives cur.
Put on mag field & wales rotates

If a jelly medium – a twist in jelly – i.e. effect through space –

C.M. b. Edin
Camb while Faraday was experimenting at R.I. London

Gt Eqns

$$\frac{\partial \gamma}{\partial y} - \frac{\partial \beta}{\partial z} = K \frac{\partial X}{\partial t} \qquad 1860$$

$$\text{curl}(X\,Y\,Z) = -\frac{D}{Dt}(abc)$$

Condenser. Leyden – Henry. mag effect
Wheatstone showed
Spark like multiple. – i.e. oscillation –
Boys revolving lenses
to show sparks

Kelvin – energy in oscillation discharge goes off into space

1888 Hertz –

Pick up effect
20 ft away –
saw small spark pass in his detector.

El field
mag " } mutual Ir

more Ir to both with vel c –

Lodge's Coherer –
Glass tube with filing betw 2 brass plates – four coherers until a spark begins in neighbourhood then it coheres (4 bell wires)
Valves have replaced this –

Transmitter – Capacity & transformer – oscillation obtained –

Marconi – Capacity – long wire with knob + earth as plates of transmitter – long range at once obtained –

insert a capacity wh. controlls frequency –

Earth.

22	octaves	Radio waves. $2\,10^{4}$ –
9	"	Infra red 10^{-3} – 10^{-6} m
$\frac{1}{2}$	"	visible light 7000 – 4000
4	"	U.V.
13	"	X –
7	"	γ –
67 +		

Dimension of atom (little aerial)
1.5 Å – 1.0 Å –

Other laws additional to Maxwells – for atoms — Bohr &c

Neon disc. tube. gives 4 lines 1 red 1 orange 1 green
+1 u-v –
Very good

U.V. light exptals –

Tesla Coil
200 000 volts
Explore field with neon tube. P.D. according to orientation of tube.

Dr Keys.

J J T + Electrons

(1) Cell. Faraday Ions
all metals + H gas (Greek wonders)
go with current
other ions go against current.

(2) Charge on drop -
ground leak thro' air
explained by J J T.

J. J. T. b. Manchester
Camb. 2nd Wrangler
1st Smith's Prizeman
Lord Rayleigh then Cav. Prof.
1884 J. J. T. 27 yrs old
Appointed Cav. Prof.

J J T.'s "Recent Researches"

27

1895. Camb. B A for

research.

Conduction of Elect thro' gases.

1. Charge drop. Bring up red hot metal & it is discharged.

2. Match will discharge + drop or − drop
∴ + + − ions in flame.

3. Shine u-v. light upon thin plate of charged drop -

How long do + − ions remain separate in air?

4. Connect gas flame to + knob of Wimshurst machine & at other end of table an insulated B Burner Connected

to elsp.
If ions persist across room elsp stopped open

No of ions free in air normally - Dr Eve -

H-A. Wilson - ions in flame Current flows if pt terminus lie at extreme ends of a long flame. put on Cur + flame ions conduct it to small extent

Dip electrode in salt + so in C. no of + ions + get huge cur. in that dirn.

1896 JJ at Princeton on Conduction of Gases -

1902 JJ wrote his big book

Vacuum tube discharge
Exhaust long tube
gradually -
violet at Cathode
long pas. column pink
becoming bluish green
When gt. exhaustion by
charcoal + liquid air.

Where there is very low
gas pres ionization
increases rapidly by
collision (Townsend -

Theories of nature of
Cause of luminosity in
a discharge tube
Br Cathode rays are matter
Continental physicists said waves -
Crookes + JJ said Corpuscles

Helmholtz wrote to Hertz
1883 – waves in ether –

Cathode rays bombard minerals
& they fluoresce
or Geissler tubes with various
liquids –

Magnetic deflection of cathode
gt – discovery. rays –

Hence means of determining
the $\frac{e}{m}$ + v of a cathode
ptcl.

J.J. sent them into Faraday
ice pail on slop & found
neg. charge –

Effect of electric field
nill if condenser plates
outside glass tube
but J.J. put them inside
& got deflection.

v came out 18,000 mi/sec
i.e. 1/10 vel light upwards –
to $\frac{9}{10}$ or 170,000 mi/sec.

To get m – C T R Wilson
ions & the water vapour.

Hence e a unit of
elect charge – & m –
Millikan

Sir Wm Crookes –
high vacua –
wheel tube –

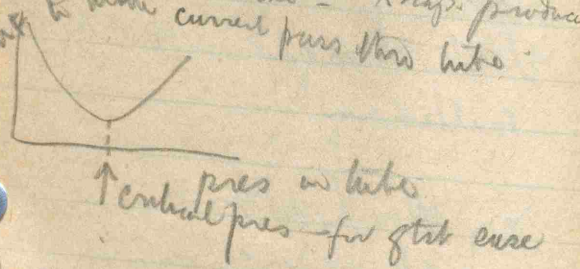
Bombard pt in centre of a
Crookes bulb & it gets hot.
& glows red.

Prof Reilly
Jan 4/32

Röntgen & X rays

25 yrs. X rays discovered.
1895 Accidental discovery of X rays
d. 1922 Holland.

Focus electrons in cathode stream on a pt & produce heat falling on metal. X rays produced



Röntgen notices fluorescence on a barium screen 9 ft from a covered tube.

pres. 10^{-6} atmos or less
E.M.F.

electron stops & gives up energy passing out as waves of pulses of energy in space.

1913 Coolidge tube.

indept of gas pres.

Heat & pt wire & electrons given off. put on a p.d & they hit the target & X rays go off.
Tube adjustments for gas pres.

X rays differ in λ & in intensity

(1) general radn.
(2) characteristic radn. depending nature of bombarded metal

Barkla

No satisfactory

method of measuring

dose -

at pres - amt rep'd to

make childs hair fall out

500 A to $\frac{1}{100}$ A°

K L M rad^{n} -

Cox & Callendar - took

X ray photo in Feb 1897 -

Cox Cal. E.R. McClung &

Pitcher 1897 Investigations

into heat &c - of X rays -

(1) fluorescence of screen -

(2) photographic plate affected.

(3) X rays ionize gas

& discharge elsp at a

distance -

(4) Absorption of X rays by

6" Al, 30" brick, 45" Pb

as shown by rate of discharge

of the elsp -

11/2/pr.

Bragg & Xtal Structure

Dr A.N. Shaw.

mol : fist = fist : earth.

Atom is short root to mol dimensions

10 cm cube

bisect in 3 dirns 8

" each $8^2 = 64$

Perform them 26 times & get to molecular dimensions.

Sir Wm Bragg first Prof Adelaide, then Leeds — London.

Prof Chem in R.I.

Observatories of Dr Eve in Cambridge.

No research until 40yrs old.

1910 Controversy as to whether X rays belonged to El Mag family.

Laue first got X-ray scattering from a Xtal —

Bragg Sr + Jr took it up

Interferences - water waves

Sound - forks -

of the flame in Stars 

very good —

Bragg - reflection from many plane, from distances apart of spots deduce spacing of Lattice.

Interference model from Xtal planes —

Stat intensity from most populated planes -

Geometrical game to fit all the observed plane distances with one Xtal Structure -

Graphite & diamond

∴ arrangement of atoms

∴ fundamental benzine ring.

Naphalene mol. has $C_{10}H_8$
+ each $C_{10}H_8$ is a unit
in the Xtal cell.
FeS etc etc all known

Equipment req. for this work —
Sun — crystals —

Many things are crystalline
wood, metals etc.

Complementary use of Xtal —
i.e. analyses of X rays by
a crystal — giving wave lengths.
Thus analyses of unknown
scatterer and to —

Similar from γ rays but
too faint often to get —

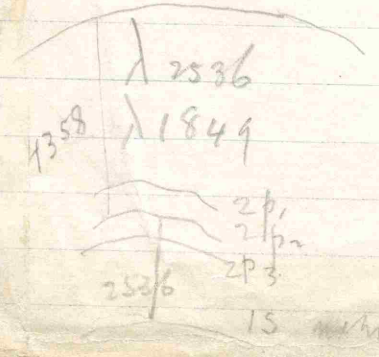
R. W. Wood. 9/1/25

Controlled energy transfer
from certain levels —
Hg. optically excited spectrum.

Resonance radiation is the
re-emission of same wave length
as sent in — i.e. intense glow
where arc light passes thro Hg vapour.

λ = 536

Magnack got 6 components
RWW gets 5 splitting into 10.
When a cool absorption vapour
is inclosed.
there broadening into 7 when
warmed —



Napthaline mol. has $C_{10}H_8$.
+ each $C_{10}H_8$ is a unit
in the Xtal cell.

FeS etc etc all known

Equipment reqd. for this work –
Sun – crystals –

Many things are crystalline
wood, metals &c.

Complementary use of Xtal –
1st. analysis of X rays by
a crystal – giving wave lengths.
Thus analysis of unknown
scattered radⁿ –

Similar from γ rays but
too faint often to get –

18/3/50 Curie + Radioactivity – E.S.B.

Rontgen 1885 fluorescence in discharge tube.
Becquerel. tried fluorescent bodies | to light

1896 Ur salt active without prev. exp
Date of disc. of ra.

Pitchblende – fract. crystallyn
of less soluble part – Radium
separated out + its At. Wt. 226

α β γ
α cut off by 1 sheet paper.
ER showed α of mass He + ++ charge
Scintillation method 1α 1 scint.
Same rate of disc as all temps. Seg Geol
Owens disc Th Em.
Th – Ra family
1911 Explanation began.
R.'s nuclear atoms.

General radioactivity K + Rb give
off β –

Tracks & Collisions
Pyes Projectiles -

Rutherford & the Atom

25/2/55 Prof J C McLennan

Renaissance Austin
150 years ago
Faraday & record of progress
Slump
1895 Renewed forms of activity
Last 30 yrs Ghost in Making —
E.R. one of the Giants

In Case when 2 discs made
① Röntgen rays
Matter discreet mols & atoms
Kelvin atom - smooth elastic sphere

At wt & at. Wt
Fractional wts led to idea of isotopes -
At wt of atoms of diff elements may be same - ∴ at wt. is no longer the ultimate test.
Lenard studied Cathode rays in Crookes tubes -
J.J.T showed that the same in mass & charg indepdt of gas in tube - ∴ electrons

Imagine 1 cm $\frac{1}{100\,000\,000}$ the sharing with 1 layer of atoms -

Diam of electron $\frac{1}{10^5}$ of atom
& atom 10^{-8} cm -
∴ JJT says atom is not a solid sphere
JJT atom sphere with electrons in it

R explained ionization + conduction of gases — 1897

End of Pt 1. of R's work

Becquerel disc. r-a of Ur —
R. found their conductivity the same as that from X rays or flames —

R made for the main road i.e. r-a substances —
α β γ rays
"α rays are the main things" R.
in 5 yrs he found them He atoms ++
1903

Owens + R found Emanation gas given off + 226 - 4 = 222 inert gas
Soddy + R condensed Em at liquid air temp

Ra Em → a deposit on walls
∴ Spontaneous transmutation of matter

Sir Wm Ramsay + Soddy got He spectra in sealed Em tube

43

Confirmed proof 1909 by R —

End of Pt 2. of R's work

Have work tracing families
Ur – Th, Ac → Pb

Characteristic speed of α from diff products —
R's mind grasped this as a set of projectiles of known speed
Use them to ionize

Barkla with X rays found no of electrons in atom roughly = ½ at wt.
Moseley —
At no. gave no. of electrons —
R sought max^m + charge —
Nuclear theory + central electrons about —

Used CTR Wilson method + studied β tracks + α tracks

1907-1912 R, Geiger, Marsden & Rods - Scintillation method of detecting single electron — or α-ptcl.
Marsden showed α deflected right back by gold leaf
∴ tremendous forces about atom.
Do nuclear charge he found the force necessary
+ thus measured charge on nucleus - charge 79 for gold
at no. 79
Closeness of approach

Charged ⊙ radius b.
α will not penetrate ordinarily.

Bohr positions of electrons in orbits
determine chem + phys prop
but R never touched this

He N going for nucleus -

He nucleus.
R's picture 4 protons
2 electrons -
Nucleus resultant charge
determines the element
Add 1 or more protons
+ equal no. of El -
+ charge remains same but
mass is diff
i.e. isotope.

R knocks out a proton
but goes further than
a head on collision would
produce - i.e. trigger action
+ disruption of nucleus if
nucleus is a mult of 4 + 2 or 3
14 elements
At no odd - peter proton shot out

i.e. odd nuclei are less stable -

Note even at. nos - are most common on Earth i.e. most stable -

These protons sometimes go forward sometimes back

∴ complex nucleus -

— compact He's -

Blackett has shown that the projectile ✗ stays in -

H comes out mass 1
Charge 1

He stays in mass 4
Ch. 2

∴ no 7
becomes no. 8
+ ya have made an isotope of Oxygen -

Once inside charged sphere + attract + ///

Spectra of nebulae
H, He Li all appearing -

In the beginning
protons + electrons
+ the forces -

Perchance proton + el -

1 gm H as proton + electron energy heat 2000 tons water to 100°C.

Wood instrument – bell, bucket
Li, Na, Cu, Ca
Spark thru

Order of H lines
attracts Baker.

1	2	2	3	3	4
1	4	4	9	9	16
2	8	8	18	18	32
2	+8	+8	+18	+18	+32
He	10	12	36	54	86
	Ne	Ar	Kr	Xe	Radon

Striation in H tube.
Electron snake →

Puppens + path balls
+ Wimshurst machine
Moseley –

Subdivision of energy –
Some experiments said yes –
Planck's quantum theory –
quite unequal but fundamental
bundles –
the higher the frequency the larger

Orbits of electrons –
models –

Aston + Isotopes

Dr Foster.

(1) atom - line spectra

(2) mol - dumbell 

Rate of rotation changes ∴ giving or absorbing light —

Boltwood - Ionium + Thorium

Ac mixed them + could not re separate them -

1st chemically identical.

radioactive props showed them different.

Mesothor + Ra inseparable

1910 Soddy

chemically identical

mass different

∴ pos - explains fact with

M being all whole nos -

Speculation later established

1911 R - gave nucleus the seat of Controlling factor for chem props is nuc. charge

3 things to consider

no of protons P

" " el. in nuc E

no of el - outside = at no = A

$+P-E=A$.

Li. $P=6$ $E=3$ $A=3$

Alternative $P=7$ $E=4$ $A=3$

There are isotopes

$+ m_1/m_2 = 6/7$

1912 Russel at Manchester

Compared spectra of Io + Th —

1913 El chem props the same
1914 R showed X ray spect
to be same for R&B, & Lead
Is Radio lead diff from
ord. Pb? not yet detected

Ur Pb. 206
Th Pb 208
ord Pb 207.2

1908 Richards exp
At wt of Ur Pb = 206.06

1923. JJT at Yale

Active & inactive Pb.

Isotops may have same
wt but be packed differently
in nucleus! spins different

RA props
JJT
Astons pos ray tube

Fosters transformer
City 60 cs 110 volts
to 10 000 volts
valve inserted to give
dir. cur 10000 volts
1/10 amp drawn

JJT neon etc.
Aston El. only found
not applied whole place
Krypton more isotope than
any other

No isotopes for O, C, N.

Loss of mass due to packing —
∴ not always necessary
to have integral mols
of H.

Ast. 10% mass of Sun is
H burning to He =
10^5 yrs.

Ur Pb. λ 4058
± .005 for old Pb.
acc to Merton, Oxford.

Thus line spec. differs for isotopes
but so slightly that almost
not measurable —
for mols — band sp. it is
determinable — for double lines
head the bands.

Eddington + Star Physics
at Gillson 18/3/25
Sci grows by theory + explan
Prominence of Camb. men —
me for the Kepler
Sr Newton — Watt
Maxwell —.
Asch, Dec 1882 Form
Sen Wranglers
(Camb men — Matts
+ poets
Greenwich 1906–13
Ah 31. Plumian Prof
after Sir Jo Lawson —
Almost all theoretical
3 branches

(1) Contribn to Gen Relativity.
1915 Einsteins Gr paper
1916. de Sitter.
3 papers + dsc.
then began - after exponent
Space time + grav -
Got 1st proof
29 May 1919 eclipse -
Eddington + Crommelin

1 pound of light
at 5c per unit (MLHPCo.)
$ 42 10^6.
120 tons per day of light from sun
1927 Math Phy of Rel -
Punch Twinkle twinkle little star
How I wonder where you are
Where I think I see you paint
Now I know that there you aint.
Twinkle twinkle little star
How I wonder what you are
You are less than ever fixed
I am more than ever mixed.

(2) Star Streams

(3) Interior of star
JH Jeans - evol. of stars
from spiral.

Dens. of a Sp. neb
luminosity $\frac{1}{10^{12}}$ of our air

Binary stars
Masses $m_1 + m_2 = \frac{a^3}{T^2}$
Observed range large of
$\frac{1}{2}$ S 5 5 S -

Spectra

Solar Spec.
1802 Wollaston prism hl
1842 Fraunhofer lines
+ others [illegible]

1849 Foucault.

1859 Rediscovered by Kirchoff

1860 Explained by G G Stokes

Classification - Secchi
4000

O B A F G K M N

~~[illegible]~~

20000 15000 5000

11000 4200 3100 Temps.

	Abs. mags.		~~[illegible]~~ Sizes	Sears.
M	1.6	10.8	3/5 S	
K	1.4	7.1	7/10	
G	0.6	5.3	1	
F	1.1	4.1	2.5	
A			6.	
B			10.	

Hence R's G & D Thy —

Inc. in temp but dec. in surface
area ∴ Luminosity more or

less constant

1906 AS E

grav. in
gas pres. not
temp. near in

gas pres. not suff.
unless temp were so gt
as to give 10^6 × known Emissi
other outward pres.
Radiation pres

1871 C. Maxwell's eqns
gave pres. of light
verified 1800 —

Rad. energy goes up at T^4

15 S	$RP = \frac{1}{25}$ GP
S	$\frac{1}{10}$
1.5	$\frac{1}{5}$
3	$\frac{1}{3}$
4.5	$\frac{2}{5}$
20	4/5

All this math based on Gas Laws

$L \propto M$

Prediction of diameter –
δ Orion 051″
1 inch 60 miles away.
1920 Michelson –
see letter by Mr Pease
to Ast. Jet 1923 –
.047″ . 215 10^6 miles
δ Boötes .020″
found .024″
19 10^6 miles
our Sun .75 10^6 miles –

$L \propto M + T$ surface –
Sun dens 1.33 water –
Loss of mass –
$E = mc^2$

63

Igus Energy raises
1 + 1 + 1 + 1 –

1925 Lecture on
Eddington

Age was 10^9 – Now 10^{-10}

All this math based on Gas Laws

$L \propto M$

Prediction of drams —
α Orion .051"
1 mile 60 miles away.
1920 Michelson —
see letter by Mr Pease
to RSL Feb 1923 —
.047" . 215 10^6 miles
α Bootes .020"
found .024"
19 10^6 miles
our Sun .75 10^6 miles —

$L \propto M + T_{surface}$.
Sun does 1.33 water —
Loss of mass —
$E = mc^2$

1 gm energy raises
30 10^6 tons to top of
Eiffel tower —
+ + — annihilating —
1 lb cheese
2 10^6 dreadnaughts
3000 miles —

Sun 4 10^6 tons/sec.
1.5 10^6 yrs Sun mass
$\frac{9}{10}$ prop. less heat
distance to earth 93
1 year 15 mos —

See Searles Tables of Stars.

Tidal Theory.
Collision 1 in 30 10^6 or 3 10^6 yrs
Age was 10^9 — now 10^{12}–10^{14}

Dr Benjamin Boss (Albany)

March 25/25

235°. Crown

Spiral Neb indicate Solar drift ↓ radial vel only — very few —

2 forces at work —

Van Maanen

knots outward

along arms with vels > light

If Hubbles dist is right.

He gets no vel. for stars in Glob. clusters. Through nearer

Dependence on Cepheid period

Hubble shows very little / abs. of mol scatter light in space —

55

Rast. Dr Benj. Boss —

28/3/25 —

Stellar motions & Str of Universe

Motions: ① Structure of star — both type and &c.

② structure of universe —

Rel. motions of near & distant objects

Appt drift back of near stars —

On average stars with larger motion are nearest

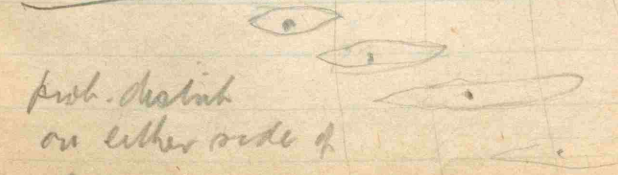
& likewise stars with str brightness are on average nearer

Hence a formula for distances.

Groups are to brightness

& groups are to motion —

dist



prob. deviation on either side of mean for group

1920. Kapteyn & Van Rhijn.

Luminosity Law

-12 -8 -4 0 +4 8

Density Law r^3

progressive decrease

10000 parsecs

1924 Sears.

Luminosity Curve

Dens. Curve

very like K + R.

Ratio 28 : 4 near Sun to far out on outskirts of space.

Velocity Law.

Radial. P.M. & Real motn

Solar Drift got as opp. of average star drift in P.M.

By R. vel. similarly. direction & rate of solar motion.

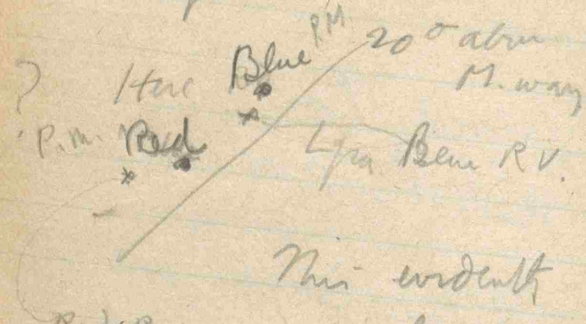
Giants & Dwarfs.

C H N R. ash. etc.

M & L.

D & J. Uncertainty

Apex – Betw Hercules
& Lyra.



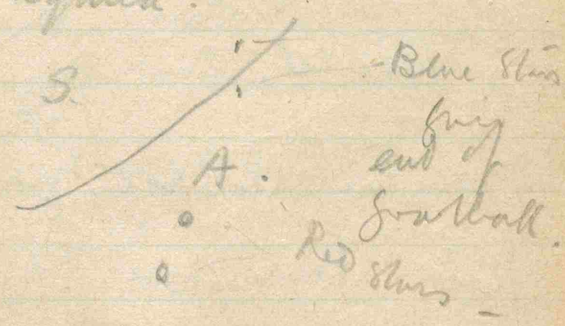
This evidently
Red R.V. a systematic
motion of blue & 20
stars –

Kapteyn 2 Star Streams –
2 swarms of bees –
wh meet & intermingle.

Schwartzchild clung to
one system – Ellipsoidal
theory: start them at a
pt together with their
actual dirns & vels &

After elapse of time distribn
wd be an ellipsoid
with 2:1 axes – &
a few stragglers.
If latter be included then
ellipsoid is larger & lower

This tendency is toward
Orion – & in opp
dir (betw. Serpens &
Aquila.



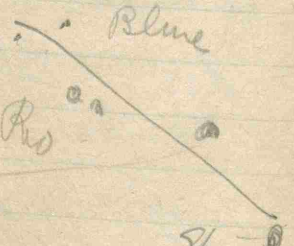
of – Solar apex –

1914 B. Boss.

Plot
Motions N
dim +
amb.

None in Up L. quadrt.

P. Motions



Sun's apex

Hyp. Vel.

Blues are low vel. Giants.
Reds have more vel.

Prof. Motion - Long axis
of football

Speculation -

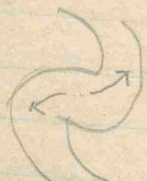
Spiral Nebula
Andromeda - 10^6 l. y. ∥r
Hubble.
Island Universes -

Is our M. W a spiral
Evidence from both of
heavens -

Nucleus of Sp. Neb.
looks like a football
i.e. ⊃ Axial Spreading
of ratio 2 : 1.

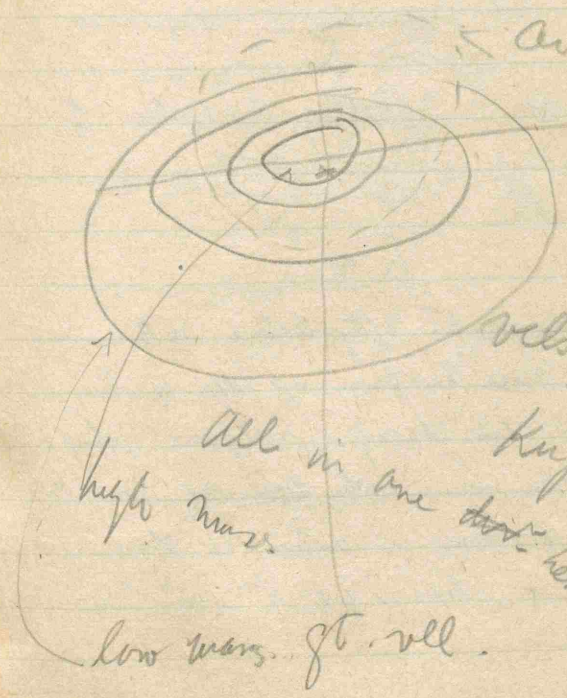
Condensations along arms
of Sp.
Van Maanen found
motion of nuclei out along
Sp. arms.
Hubble's dist means too

Gt. a vel. i. something wrong with. Van M or H.
[from Maaman. Monan]



2 preferred motion.
from nucleus — Of
pref. Motion of our stars out of
nucleus. if we form a spiral cluster
Immensity of
Universe —
Forming out of stars
Of our system in
one direc only
Our own Sp. net is
drifting in space

Mutual attrac. for
orbits.
External force
Connected with
Same force as in Spirals.



no massing of Spirals
yet detected. but if
in future it is found to be

If we give a grav. explan. of ext. force -
Some force from outside
is acting on our M.W. sys.
system -
(gravitation ?)

E.E.H. appalling conception of
the External force -

In conversation after lecture Dr Boss said that Oort had given up idea of the fastest stars being "foreigners" dropping in from ∞ - why from one direction only? Plot directions of motion of stars of any vel. + always get a skew curve -

Dr Siegbahn 26/2/25

$n\lambda = 2d_0 \sin\varphi_n$

gives place of

$n\lambda = 2d_0\left[1 - 4\frac{d_0}{n^2}\frac{\nu^2\delta}{\lambda^2}\right]\sin\varphi_n$

$\delta = \frac{e^2}{2\pi\, 0^2 m} \sum_{i=KLM} \frac{N_i}{\nu_i^2 - \nu_0^2}$

N_i = no of electrons in KLM

$\nu = \frac{1}{\lambda}$ $\nu_i = \frac{1}{\lambda_i}$ C.G.S. units

$\therefore \delta = \text{const} \sum \frac{N_i}{\nu_i^2}$

$= ct \cdot \lambda^2$ or $\frac{\delta}{\lambda^2} = \text{Const}$

(if $\lambda \ll \lambda_i + \nu \gg \nu_0$

then 2nd approx =

$n\lambda = 2d_0\left[1 - 4\frac{d_0^2}{n^2} k\right]\sin\varphi_n$

Rep. Orders for X rays. for metals
is nearly 1
$\delta = 1 - \mu$ $\mu < 10^{-6}$

Refraction of X rays with Fe + Cu anticathodes in glass prism only with large [illegible] angles —

$\mu = 1 - .000008125$
± 50

Pop Lecture

Q2 building stones of universe —

5 volts . 135, 820, 3570, 14800
P O N M L

82900 K volts to get to various layers of Hg atom towards reducing to Au (80) 79 —

Optical spectra is the language of the atom . 1st idea
X ray spec — is language by wh. they tell their secret structure
bec. optical spec like chem prop are from outside electrons .

K + L lines are of less λ as we pass to heavier elements

i.e. increasing freq with inc of at. no.

Absorption spec. of X rays [illegible]
K + L .. abs. bands
Ag + Bromine.

Diff. of energy of abs limits gives emission lines.

Hg Q2 el.		K	L	M	N	O	P	Q	X ray levels
no gabh	Siegbahn	1	3	5	7	5	3	1	= 25
	Bohr	1	2	3 4	3	2	1		= 17
no gel	Bohr	2	4 4	6 6 6	8				
	" Stoner	2	2 2 4	2 2 4	[illegible]				

JJK

Atomic physics

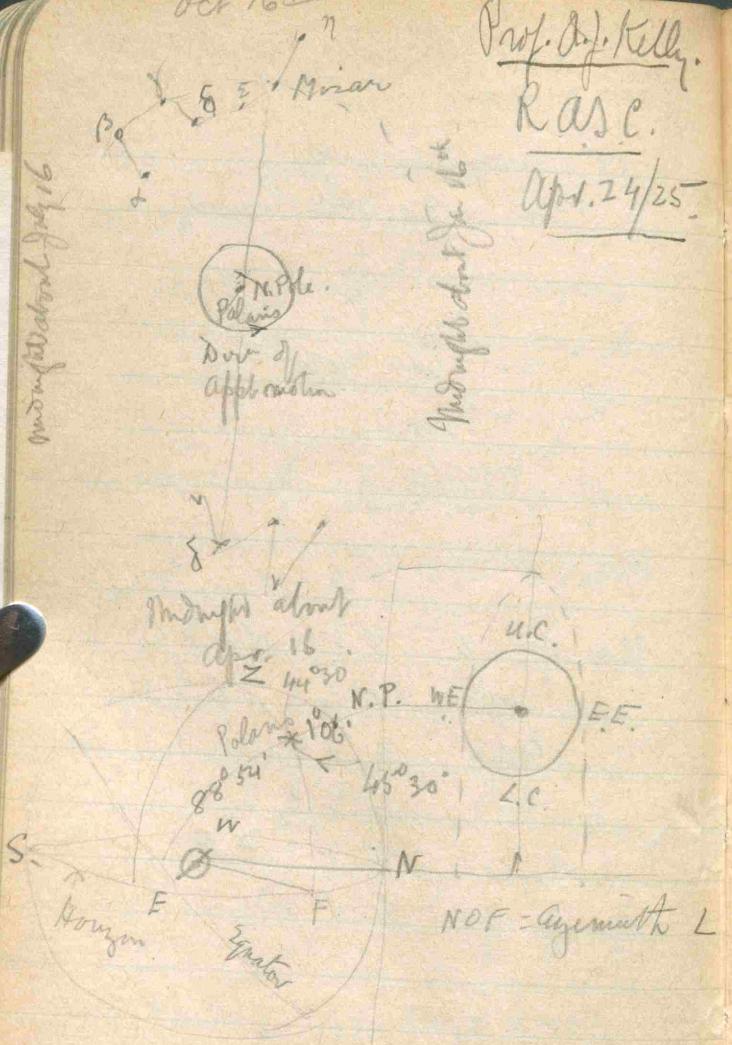
Atomic emotion

Oct 16th

Prof. A. J. Kelly.

R.A.S.C.

Apl. 24/25.



Up. Cul. when a star crosses N.P.-Z-S meridian

79

Plane surveying the art of making such measurement on face of earth that on drawing when scale the various features exhibit their proper relative

Horizontal plane tangent to earth i.e. plumb line.

Plane & Geodetic surveying

Where surface earth is plane i.e. local. i.e. several hundred sq miles

Where it is necessary to take curvature earth in - then Geodetic

1" in 76 sq miles.

$\Delta = 1\frac{1}{3}'' + 180°$ on curved surface.

100 sq miles.

Determ. of lines at azimuth or longitude.

"bearing" Compass reading

azimuth is True N reading

For a survey – Ref^ce Bearing of 1 side & dist along it the pt.

Ref to true meridian is essential.

Exploratory surveys – fix of control points by lat. long. of several pts & the in rough measurements – navigation dist & pos^n.

Instruments

1. Surveyors Compass
mag. meridian – declination is deviation from T.N.
16° W here.
Secular variation
2 – 2½ Centuries.
Diurnal variation 2 – 15'
Annual " fix in Summer than winter.

Affects of mag. storms & aurora render compass irreliable

nevertheless for survey where speed, not accuracy.

Hedley Dial for safety at angles.
Value of compass for surveying standing timber. offset.

Dec is Zero at Pt Arthur – Agonic line.
Dec is 22° E at Vancouver.

Culmination of Polaris when it is on N.S. line.

R.A. δ Cassiop. 1^h 28'
Polaris – 1^h 34'
Mizar 13^h –

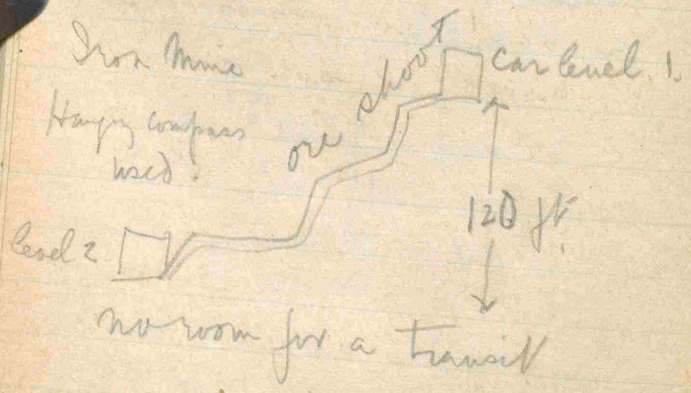
1^st when plumb line shows both Polaris & Mizar on Mer. 16' thus – plumb line is due N.
4' per day – 1^st 8 pm on July 6

Instead of plumb-line use Compass slit

Oct 16. Polaris is at Upr. Culm.
Apr. " " " Lower "

4' per day time moves round.
May 10. Culm. takes place at 10? pm.

Gimball hanging compass for mine work.



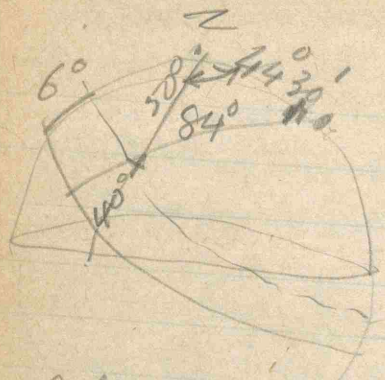
Transit Theodolite. ≡ transit

(1) Set transit on Polaris + its motion about cross hair gives about 5 mins. when motion in alt. but not in azimuth.

Elongation.
from elongation (1°32')?
to be added or −
to get due N.

Any other star not so good bec. being further from pole it moves too fast to get an accurate reading.

Obsn of Sun
say 9 am motion in alt + az about equal
50" per hour change in dec at this season



Solve spher. Δ for $\frac{A}{2}$

Solve for ↔ = 105° = Azimuth of Sun - i.e. 105° E of N.

Not very accurate because of uncertainty of exact dec. i.e. reduction to Greenwich. If Lat is not known use hour angle //

Or. Observe equal altitudes am & pm. ± ½ angle is dist S with correction for change of dec.

Observe in grad

pm. Since one cannot gauge centre of sun.

Difficulty of seeing crosshairs without so much illumination that star image (of less than 1st mag.) is obscured.

Several hours req'd for this.

∴ usual method is 1st i.e. E Elong. in Summer W. E in winter? ?

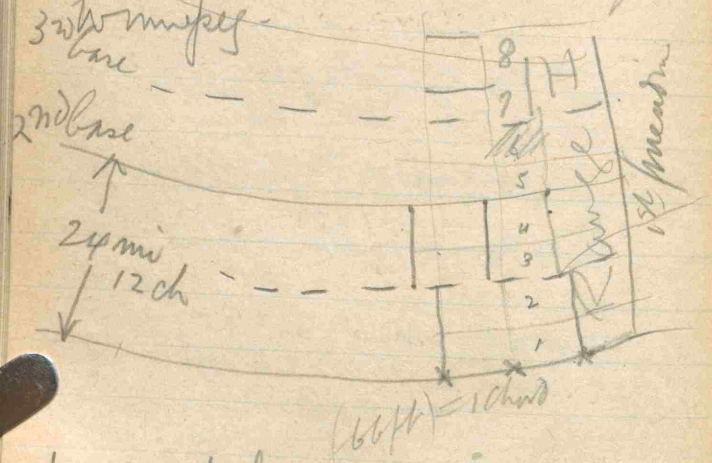
Tables solving Δ for various positions of Polaris.

Dominion Crown Lands –

Basis is 49th // International Boundary.

True meridian 1st to this line

Initial meridian 12 m W of



6 mi + 6 chains (road allowance) is the township chord

acreage 36 sq. mi. 6 mi × 6 mi

Township higher N would not be as great. base lines are drawn 24 mi. 12 ch.

True chords 6 mi 6 ch on each base.

½ way between are the the Correction lines –

& run True N from base & true S from 2nd base.

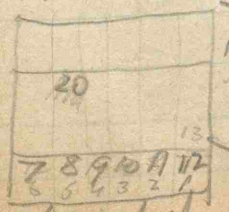
– called the jog.

Each tier is called a Range.

Townships numbered

To square the jogs start a new meridian 2

Each township 6 long. lines + rd. + 3 // ls + roads



1 section of land 1 mi sq. 640 acres

adjusted to coincide & found a 25" bringing effect.

dist between wires at bottom of shaft 0.2 inch Stn thro all surface due to action of old rails 100 ft away —

Curvature of earth makes negligible approach —

With Tunnel. no pt. on mt. where both portals could be seen.

Wells Col. Cor. Then 2° angle to under Presby Col.

Other tangs. W. to model City.

Began at both ends & met to 1/16th inch —

Photo theodolite

Col. Deville Surveyor Gen of Can. 1st promoter of this method of surveying —

Alt azimuth instrument correct to 1" arc.

Zenith telescope for Lat.

Chose 2 stars approx equal & opp Zenith dist. (Know approx your Lat to select stars)

Place in meridian

Reverse to other star

Mean gives Z

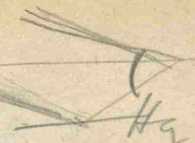
Take 20 sets of stars in all & get Lat. by 1/10" accuracy —

Lat. by Polaris at Culmination & correct by 1° 06'.

Lat by Alt of Sun at App. noon -
Sextant on upper limb.

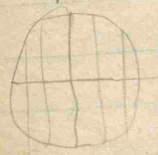
Correct for
// x + Refr^n

Sextant method -
Used at sea -
Dip angle necessary at sea ?
Make lower limb but natural horizon -
On land artificial horizon by reflection from Hg.



& get double angle of Lat.

Field transit for Time & then Longitude -
Observe Sidereal time -
Set for dec of star selected due to pass meridian at given hour -



½" Chronometer -
Record time on each 5 hairs -
Mean of 5 is the true Culmination time -
Chose fast moving star i.e. near equator -

Errors ① Level
② Collimation
Correct for ② by reversal
① by level +
Calculate [illegible]
Observe 6 stars
2 N of Zenith
2 near eq. + 1 N of Z
Get mean time thus
& subtr from G.M.T.
& this is the Longitude.

11/5/25

Dr Debye Zurich

Pot. $p = \frac{\Sigma e}{r} + \frac{(\mu)}{r^2} + \frac{t_1 t_2 t_3}{r^3} + \dots$

goes out since Σ = –   goes out since not symmetry of el. moments

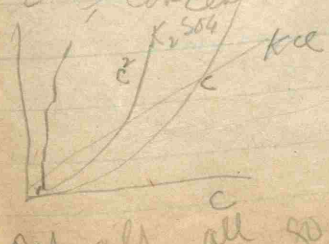
3 constants like stellar moments

$\Sigma e x^2$ 10^{-10} 10^{-18} 10^{-26}

order of constants

Coulombs law of attr of charges
Strong Electrolytes   V. H. Hoff + Waage
mass action law – osmotic pres law

θ = calc F.P. – actual
c = concentration

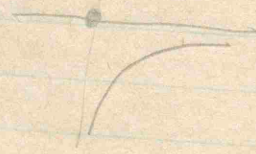


prop to c^{3} $La(NO_3)_3$

Actually all go on ....

High valency ions give
⊖ due to gtr forces
betw charges

Any ion tends to be
surrounded by ions of opp
ch : a mean ionic
atmosphere or ionic density
about it.



Pfc energy.

$\frac{e^2}{D\lambda}$ thickness of ionic layer

$\varphi \leftarrow \rho$ concentration
$\rho \leftarrow \rho$ number of ampl

Calculable from
Maxwell Boltzmann law
from ptls.

$$\frac{1}{\lambda} = \frac{4\pi}{DKT} \sum n_i e_i^2$$

dielectric const of water

For water $\lambda = \frac{3 \cdot 10^{-8}}{\sqrt{\rho}}$ cm

i.e. 100 × diam of ion — concentr

hence get ptls

+ Thermodyn. ptls —

Test Theory by solubility —

Activity $a = fc$
factor × Concentr

$a_1^{\nu_1} a_2^{\nu_2} a_3^{\nu_3} =$ true Const.

Work to bring ion from crystal
into water —

In KNO$_3$ sol Ag(I) will
be more sol than in pure water
bec of the ionic atmosphere on
the ion —

Conductivity $\propto \sqrt{\text{Concentration}}$
valency enters
Gives sq rt. law

t_2 Polar mol $\pm e$
tendency to alignment
in fields.
2 effects - charges in mol 10%
+ whole mol 90%
tend to align themselves

Dielectric
Polarization dec as Temp rises
$\phi \propto \frac{1}{T}$ or $\phi + \frac{\text{const}}{T}$

Electric moments are all of
order 10^{-18} as expected

Debye's Anomalous Dispersion
i.e. Change of fields for ν 10^{-9} sec

mols have not time to move
Polarization is due to
change of position of charges within
mol only

t_3 Moments of Inertia

Van der Waals 2nd approx
Good for low concentrations
$a \to$ const at high temps

all orientations of a mol are
not equally probable
mol tends to come to place
of max attr i.e. sq of el. field
is a maximum - this gives
the attn factor a in Van der W.

Use also optical props i.e. the
polarization effect i.e. index of
refraction - get t_3 10^{-26}

3000 flashes per sec

Dr Eve. Phys Soc Oct 1925

Compton 2 Geiger tubes for detecting selection of the $h\nu$

Dayton Miller + Simms drop

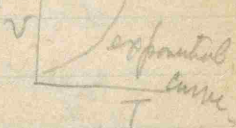
Millikan, Hot Spark

Chem. Colloq. Swietz

Quantum Theory of Radiation in Chemical Reaction.

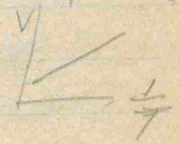
1. Sol^n 1 mole in 10^5 liters I in Sulfide action is instantaneous

2. Vel & Temp



Plot log v, T

$\log v = -\frac{1}{T} + \text{const}$



K.E. increase with rise of temp not sufficient to account

Arrhenius says only some (very few) mols are in a state to react chemically.

Crit State of a mol — ref. to the internal energy due to rotation & vibration etc

Spontaneous or explosive change one way or another from Crit. State.

Eq^n of statistical mechanics giving fraction of mols with a specified

Arrh'g unit energy. $f = e^{-\frac{\varepsilon}{RT}}$

Start from van't Hoff eqn ε = unit energy

$$\frac{d(\log k)}{dt} = \frac{\varphi}{RT^2}$$

$$d \log V = \frac{A'}{RT^2} + B$$

$$\frac{d \log V_0}{dT} = \frac{A''}{RT^2} + B$$

$$\log f = -\frac{\varepsilon}{KT} + S$$

$$= \frac{U}{T} \qquad f \rightleftarrows i$$

Arrhenius says ① let $V \propto f$

② There is a definite equilibrium between the no of mols in active & nonactive state

$$\frac{d \log f}{dT} = \frac{\epsilon}{RT^2} \quad \text{replacing } k.$$

$$= \frac{d \log V}{dT}$$

$$\log V = \frac{\epsilon}{RT} + \text{Const.}$$

Get ratio of 2 vels

$$\log \frac{V}{v} = -\frac{\varepsilon}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

hence calc ε = heat of activization

If $\varepsilon = 1000^{0}C$

$$f = 10^{-\frac{25000}{2 \times 1000 \times 23}} = 10^{-5}$$

$= 1$ in 10^5

= fraction in active state.

Prob. sources of error involved in Arrhenius assumptions -

Energy content may not be sole criterion for act state -

i.e. may depend on distribution of energy within the molecule

What agencies give f mols their extra unit energy & maintain the supply -

K E ? or Collision

Radiant Energy

Heat of reaction slowly dissipated

Monomolecular reaction

$N_2O_5 \rightarrow N_2O_4 + \frac{1}{2} O_2$

no effect by walls, collisions, range of concentration

10000 mols per cc or in room makes no diff — ∴ not collisions nor heat of reaction —

∴ radiant energy pres. in virtue of temp — v. small yet sufficient + very rapid stream —

Einstein says no such thing as monomol. reaction at ord temps —

Example of rad energy changing into energy of translation light on water heats water i.e. mols move faster —

1. Mols receive heat of activation from rad. energy

2. Calc freq. of that rad

$NL\nu = E$

Avogadros No —

Absorption of monochromatic

radn raises it to act state

action takes place + radn is emitted —

$NL(\nu' - \nu) = \Phi$ diff in original & final energy level —

Perrin abs^n & emission bands observed. fluorescence.

Blue abs^n Green emission —

NB The chemists call the regular law of fluorescence that the emitted ν is lower than the absorbed ν Stokes Law + Dr Maass says a few substances are known to be exceptions to this Law — i.e. $\nu_{em} > \nu_{abs}$.

See Woods Phys Op. p

Magdala red & other substances known to give a fluorescent spec. part of wh. is further to violet than absorbed λ

Prof Bower – Botanist. Glasgow.

Mechanical Problems of Plants

Plant – unlimited potentiality

1. Turgor of cell.

Water in cellular. 96%
4% mech. material of
cell walls + plasm –

Pith is under compression
outer tissue under tension

2. Thus Mutual Tensions –

3. Specific mech. tissues –

Metaphor. H. of Commons
H of Lords – resistant
latter yields to continuous pres
but stability is maintained –

Dicotyledon – like Oak
support, storage, conduction
+ adaptability to increasing demand

Hollow trunks – str. Transmission shafts
to avoid buckling – 1 ft at base
Bamboo – Ht 120 feet high

Similar construction in grass –

Manilla. 2 ft high –

$\frac{l}{diam} = \frac{500}{1}$

Salisbury spire – 400 ft hi
base shd. be only 1 ft dia.

Factor of Size –

manilla	500/1	
10 ft fishing rod	10 / ½"	or 250/1
Giant bamboo	120 ft / 1 ft diam	120/1

Flat expanse of leaves –
stem gives yielding

epidermis ties all
soft tissues together

vascular strands = framework

Arch system
forming a selvage.

Bast strengthening -

Roots - Concentration of resistant tissue at core.

Sclerenchyma -
fibre cells -

Kgs/cm²

Elasticity comp. to steel wire.

Breaking pt. inferior

Elongation - Greater -

Plant yields & recovers -

Spider in dense like
Rose in a gasometer

Teleology in plants.
& in engineering -

Violin construction.

Wavy grain -

Music the most delicate of all the arts

Elastic fatigue in metals

The reverse in violin wood

Vibration more easily taken up by wood with subjection to vibration - i.e. toning up & mellowing.

Soho - Selves violin tone and grow worse with use -

Physiological tragedy of a broken tree -

Trial & Error in plants Is the trial blind?

Prof Bower says he has no answer!

Dr Eve - The Divine Architect of Plants -

Variable Stars RASC
10/1/19.

Leon Campbell

Boyden Stn – Arequipa –

100 to 1000 fold –

Detection of variables 2 ways.
+ by spectra i.e. pres. of bright bands.

Likewise novae – diff by big

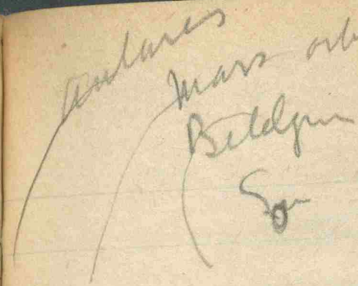
Miss Leavitt – 1000 variables in one field –

Her law – Brighter stars have longest period

Magellanic Clouds –

Pickering Classification
— irregular variables in region of Orion Nebula

mag range small
1^m rather than 7 or 8^m



Rel sizes

Irreg – near nebulosity

Shapley – Cluster dist

Σ Carinae region
one of finest in sky –

Novae – 36^h 11^m to 0^m
expanse of nebulosity st. mag

1901 1918 novae –

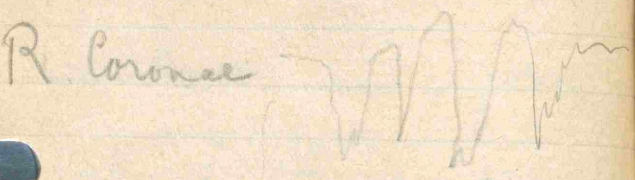
Eclipsing variable

Polarizing photometer

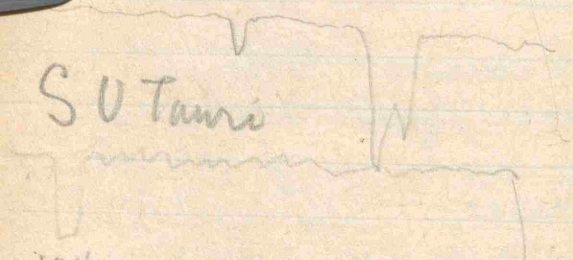
(Jupiter sat. eclipsing –

β Persei $2^d.867312$
period - known by about
1" each time -

R Coronae



S U Tauri



S S Aurigae

S S Cygni 8^m — 12^m $8^d 4^h$
1895 to date - most thoroughly
observed 213843 Cygni
Values observers use all together

30 000 obsns per yr.

Mira Ceti

Observed 300 yrs ago
Now studied agn
but will not be in 6 mos

Still stand on way up —

Decreasing long period
20 to 40 yrs -

400 - 500 variables on list
S. Afr. N.Z. India Japan, Canada

Dr Heymans — 20/11/25

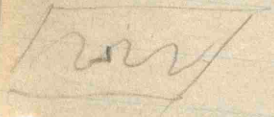
— cathode

— anode

⊣⊢ electrostatic field

1 El. mag. tangent (universally strong)

2 El. mag. — alternating current



Sinusoidal curve is the true scale (not linear but known)

10^{-8} alternating freq.

$\leftarrow 10^{-8}$ sec

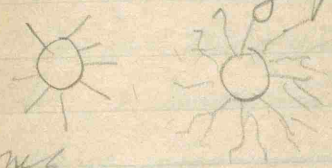
interval $\cdot 25 \cdot 10^{-8}$ sec. to $\cdot 1\ 10^{-8}$

2 milliamps current
$= 1.4\ 10^{16}$ electrons
per sec $\frac{1}{200}$ pass thro anode

115

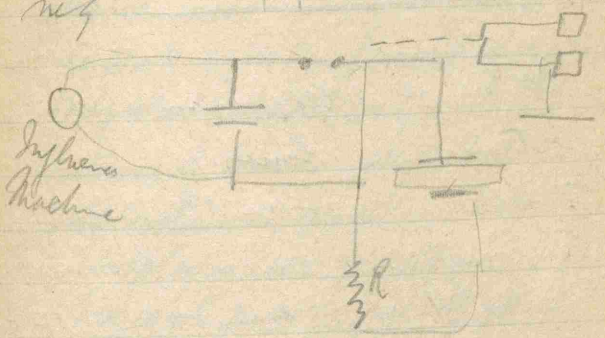
1.8. 10^{14} electrons

Lichtenberg figures



pos

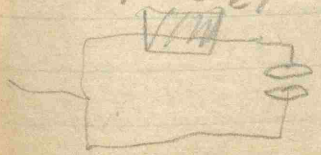
neg



Retard current slowly lead to one anode

Dielectric const D velocity $\frac{c}{\sqrt{D}}$

∴ diff in time in $\frac{D l_1}{c}$



$\frac{l_1\sqrt{D}}{c} - \frac{l_1}{c}$

$= \frac{l_1}{c}(\sqrt{D} - 1)$

Use this to measure P for
various substances
water. Alc &c.

Lichtenberg figures become
asymmetrical –

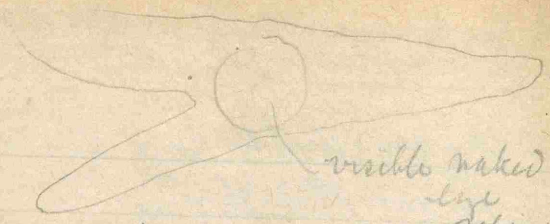
Dr Eve at Colloquium.
Interference lines
Talbots : eye + knife edge –
Gradingers : mica & b. burner
Newton & Stokes : water vap. condensed
or powder on concave mirror

9/12/25 – 17

Dr Henrdean

Milky Way (Aristotle thought it a meteor
of our own atmosphere –
Ptolemy & Democritus thought it small stars
Galileo – telescope proved it stars –
Life work of Sir Wm Herschel to disclose
majesty of milky way
Millions of stars –
Sun distance $92 \cdot 10^6$
Aeroplane 100 yrs to sun
Projectile fr mod. gun 9 yrs.
Tel. light $8\frac{1}{2}'$
α Centauri $4\frac{1}{2}$ yrs.
i.e. $5 \times 10^6 \times$ Sun dist –
Sidereal Universe – Milky Way.
diam 100 000 yrs.

Cygnus to S Hemisphere [illegible]
M.W. is 2 branched) –
Near stars by perspective
appears scattered over sphere



← 100 000 l.y →

width 1000 l.y.

M. W. slides with dark cloud.

40 000° C. luminous portion of dark one.

Betelgeuse. diam. 280 10^6 mi

27 10^6 × size of Sun

325 × S-diam

just > orbit mars

ρ = 1/1000 air — dist 220 l.y.

Mass Bet not much gtr than ☉.

∴ ρ — about like our extreme vacuum —

Sirius B — 60 000 pretty well proved

Best proof to date of Einst Rel Theory

Analysis of Spectrum elements: temp: dens. vel

1 giant to 100 dwarfs

Bohr Theory of Atom

Compton (Compt's) said we cd never know constitution of star —

Dwarf stars no corresp. lines Giants. Lines more or less dense

Cepheid variables are Giants
like Bet. + Antares
always + lines -
Among 1000 giant stars
1 is a Cepheid
Dispersed in Space + form
its framework ? — ? — ?

Light change a few days -
to go fr. max to min -
in Shorter period - days min
to max — perfectly regular -

VX Cygni 20 days -

VY Cygni
secondary max

$7\frac{1}{2}$ days

about 150 curves known
average Ceph 10 000 l.y.

δ Cephei Rad vel. curve
+8
-30 km

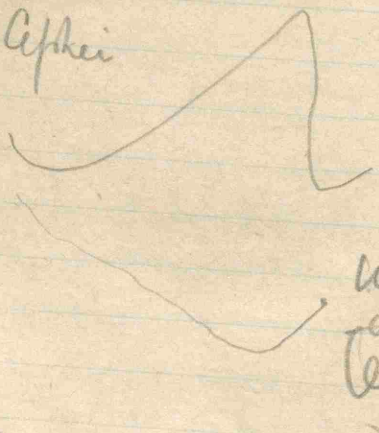

Light Curve


Hence real pulsation
expansion = brightest
Contraction = growing thin -

Great wings at max
intensity of lines + dec at min
∴ temp change
Great furnace - 20 000000 °C -
temp. change with pulsation
Probably a pulsation -

X Cygni

δ Cephei



Cepheids are all in Milky Way due to their gt dist.

almost no Cepheids in N half of milky way -
but as many faint stars in N as S branch

Is there ∴ some cause operative in one part of Universe? Unknown force -
Other unknown forces are postulated for star streaming
"unknown hand has set stars pulsating - &
together to animate them in other part -

Outside in N. Spiral Neb.
300 000 Counted -
Some so faint that Spiral Shape almost undetectable

Their drums 7 10 000 ly
± dist from us millions of ly.
Motion in Space
up to 1000 mi. sec -

Curtis Ven. drain 100 only.

Cepheids in 2 nebulae
20m. to 21 or 22m
reported from Mt W
+ light curves for
a dozen in each neb.
Same shape as Cepheids
in our own Galaxy -
Andromeda Neb -
dist. 650,000 l.y -
± 10,000
Exceptionals to dist of farthest
nebs -
50 x 10^6 l.y

Period hours - days -
Shortest 2h 36m

20 - 24 days apart
to observe Cepheids -
Ottawa the centre of the
research by International
Astron Congress -

our Galaxy 7 1000 10^6
< 2000 10^6

Van Maanen
seemed to indicate a
rotation of Spirals
early photos 20 years
doubtful -

Shapley –
Brightness & Period
via Magellanic Clouds
(larger than
Spiral nebs.

with 50 samples in our Gal.

P. T. M.

Shapley – T. P.

Mass must be taken
into account.

Crowther – vote of thanks

Dixon – Public meeting –
"Universe"
Race of Astron & Physics –

Ordinary Gen Meeting Work

James Stanton.
Reporter to Gazette

Viscosity Water
14/2/15 Dr Barnes.

Le Roux Comptes Rendus
180 p 914 (1925)
March 23

0°C.	0	0.0178
20	5	.0181
50		.0057

Rotating Cylinder method –
Dr Barnes' Thermal Turbulence method

4/1/26. Report of Kansas Meeting by E.S.B.

Dayton Miller —

Interprets his results as 95% ether drag
10 Km/sec abs. velocity is recorded + he
thinks the curves indicate a motion
toward a pt. in Draco of 200 Km/sec
[Draco extends from α $16^h 0^m$ — $20^h 34^m$
δ +51 — +81
cf. Strombergs centre of symmetry for
spirals Ap. J. June /25. at about $\alpha = 16^h$ $\delta + 55°$
with vel. 300 Km/sec.]
Miller gets a slight shifting of the
daily curve with sidereal time i.e. noticeable
monthly. The daily curve is due to the
changing inclination of the earths
axis to the direction of space motion.

St John

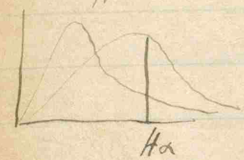
Pressure Shift is negligible.

Solar Lines.

	Eclipse heights	Rad. Vel. Total shift — Calc'd Einstein shift	Vel. in Sunspots inward Tangential.
Ca^+ H.K.	14000 km	+ 0.25	1.90
H	8000	+ 0.10	1.50
Fe		0.00	0.00
La		− 0.10 *	− 0.20

* These are convection currents — see notes on his former paper.

The black body intensity curves for
Sirius B + for the scattered light of Sirius A.
are different as B is less hot than A.



∴ continuous background
in neighbourhood of Hα
will be more intense
in B than in A.
whereas nearer violet
intensity ratio shifts to left for A.

Lag in appearance of fluorescent light
measured as 3.5×10^{-8} sec.
If spark + arc be started simultaneously
The spark lines appear 10^{-8} sec before the
arc lines i.e. the ionized atom is more
rapidly excited.
In H. the order of appearance of Balmer
lines is H_β H_α H_γ.

Palaeochem.
Kidney, thyroid gland of ancient org.
nucleus of cell
membrane arose to keep out
the ocean salts.
Primitive cell neither veg nor animal
© nucleus formed before
An. + veg. differentiation.
There are morphological
Chem. protoplasm
protein + chromatin varies
∴ none are organic seeds
23 yrs ago he found this
ancient existent chemistry in
the inorganic
Concentration % of Salts in Blood Plasma
Crab 2.78
Lobster 2.8
Dogfish 1.77
Frog .633
Birds .8–.9
Mammals .89–.92

Study ratios Na as 100
Cerebral spinal fluid v. Cat.
blood plasma

Pres. Sea Water 3.0 – 3.1 % Salt
Protovertebrates developed kidney to control
Limulus (Crab) Kidney has succumbed
to osmotic pres of ocean but
ratios are maintained.
Frogs + amphibia began in fresh water
+ a land life + sea ∴ low %
∴ Ocean has incr. % from < 1
to 3 or 3.1 since vertebrates
acquired their fixed %
Early Cambrian
blood plasma = fossil sea water
Joly – 200 atmosphere of water
350°C + gt pres. 1st condensation
+ evap. until temp 190° + water
gt pres. liquid remained
+ rocks decomposed + out came salts

in ratio.
Na K Ca Mg.
1.00 97.8 10.4 1.09

all carbon in lime & coal
derived from atmos CO_2

Concentration thus .1%
100
Living organisms take out the K
& due producing glauconite
Na & Ca not eliminated nor Mg
today.
100 3.6 2.8 12.1
Joly says $87 \cdot 10^6$ yrs age from
Na in sea.
now Lessing $160 \cdot 10^6$ – $240 \cdot 10^6$
whale, horse & pig have
common ancestors cetaceans
in ocean in eocene
5 10^6 yrs ago –
to $30 \cdot 10^6$
whale kidney has kept Na/K
constant

133

Comp of cells – not fluid
shows K > Na

100 287, 11, 19.

men who are acknowledged as leaders of thought in almost every line of knowledge - names which one has heard of & learned to respect cease to be names & become personalities
Thus every student in Canada knows the names of
Sir Arthur Quiller Couch, Gilbert Murray, T.R. Glover,
Sir J.J. Thompson, Sir Ernest Rutherford Sir Wm. Ridgeway.
They cease to be names, they stand out indelibly as living personalities to those who at Cambridge or Oxford or elsewhere have met & heard them.

It would be easier to teach literature after having sat spell bound under the words of Sir Arthur Q-C. watching each movement of that mobile face whose expression changes from humour to sarcasm, to interest, to admiration to a tender pathos preparing his listeners in advance of the tenor of his words. I heard him give four lectures on Dickens and can never forget the impression he gave.

It ~~would be~~ is easier to teach Physics after having studied it and seen it evolving in the Cavendish Laboratory, Cambridge, and after seeing J.J.T. & Rutherford both as lecturers and as experimenters - J.J. is one of the great outstanding men in England today - one of the greatest of Scientists, though his days of creative work are passing, and with one of the greatest & most all-round personalities I have ever met; Rutherford is a scientific wizard and to watch that mind working when faced by theoretical or experimental difficulties ~~was~~ is a revelation to any Student.

But if you would see the amazing heights to which the mind of man can reach & realize something of the almost audacious daring and profound imaginative qualities of a mind which is seeking to learn the secrets of Nature & lay bare the mysteries of the Universe in which we live,

Introduction

Aim of I.O.D.E. in establishing W.M. Scholarships – that each year there would go from Canada a certain no. of students to the Old Motherland – there to live & study for 1 or 2 years absorbing as much as possible of the great traditions & spirit & thought & outlook of St. Britain & returning to Canada with broader vision with deeper understanding & with a great determination to put the best energies of themselves into the building up of this Dominion of ours into a great & noble nation – a worthy daughter of a Mighty Mother Country.

Whether your Scholarship holders return to Canada to find their sphere of action in home life, or in public life as political men, perhaps, or lawyers, or as leaders in industry or commerce or ~~some profession such~~ as Educationalists', there is no doubt that their influence will be many times greater & their contribution to the life [illegible] more valuable that it could have been if the opportunity afforded them by your Scholarship had not been theirs – "I am a part of all that I have met" said Tennyson & your scholars will be forever richer & ∴ of necessity – more useful citizens because of you.

Speaking in particular of educational work, for of that I have some personal knowledge, I want to emphasize the importance of study abroad. Not for one moment do I want to imply that all who have studied abroad are ipso facto better teachers or more valuable citizens than those who have not had [illegible] knowledge – There are those who are naturally great souls broad in their outlook & cultured in mind, there are born teachers – & these will shine forth as the greatest assets of any country – their lustre dimmed by comparison with no one – But what I want to say is this, that the

then I bid you to look at Prof. A.S. Eddington the great Astronomer, Mathematician and Natural Philosopher of Cambridge. Surely in all Literature, History or art (unless perhaps it be in Music) there is nothing to thrill the intellect or fire the imagination to wonder & amazement as does the Science of today. Even though we can only understand parts of what these men say & write, we can catch a glimpse of the splendour of their vision & the immensity of their mind - & it is a revelation indeed - and something which I think every teacher should have - for teaching is often discouraging work - & unless the teacher ~~loses in mass~~ realizes the dignity of the human mind & its possibilities it is not easy to always throw the whole force of one's personality into stimulating, encouraging & enthusing the young minds which the teacher seeks to train.

ordinary Canadian, man or woman, has much to learn which Canada alone cannot teach and he or she will be an immensely better teacher & more valuable member of the community - as a result of contact with the best in thought & deed & tradition which the old Land can offer and does offer so generously in its great Universities.

The average student comes up through High School & into College & graduates after four years without having had much variety of outside experience. His view point - unless he be unusually independent of thought - has been coloured to a great extent by his teachers & professors, and the atmosphere of his own university has been the only air which he has breathed.

Now suddenly, put him in Oxford or Cambridge, let us say, for it is to these two centres that the majority of your scholars will gravitate — and what an awakening it is! First there is the strange sense of the reality of the PAST so difficult to grasp in a new country - History becomes a living thing, a thing a great sequence of life, not a few isolated facts of long ago unconnected with the life of today. The old buildings, so quaint & so beautiful, speak to the stranger & bid him read the history of his own forefathers in their grey stones. Their appeal may at first be met with mere curiosity but the longer your scholar lives amid such surroundings the more does curiosity give place to love and a feeling of reverence for all that these old buildings symbolize.

And secondly there is a new feeling of the greatness & importance of the PRESENT. One is surrounded by

Celebrated Cambridge Men

A.D. 1390 – 1908. C.G. Griffenhoofe, M.A.

Hugh Balsham – Bp. of Ely – 1281 Peterhouse founded.

Edmund Gonville (Rev) 1348 founded Gon. & C.

John Alcock – Bp of Ely. 1450 (c.) Jesus Col. on site of St Radegunds convent.

John Fisher. Vice-Chancellor & Lady Margaret Prof. 1480 (c). & Confessor to Lady M. mother of Henry VII who founded St Johns & ~~Corp~~ Christs. Imprisoned with More & beheaded 1535.

Thos. Cranmer. Jesus 1503. Reformer & courtier martyred 1556 at Oxford.

Hugh Latimer. Clare 1510. Reformer. martyred 1533 with Ridley – "candle".

Desiderius Erasmus. Queens 1512. b. Rotterdam Utrecht, Paris, Oxford. Camb.

Miles Coverdale – 1514. 1st trans of Bible into Eng. buried by London Bridge.

Nicholas Ridley. Pembroke. 1518. Reformer martyred 1533 with Latimer

Matthew Parker. Archbp. Canterb. Corp. Ch. 1522. opposed extremists of Reformation Collected MSS. for Corpus Library.

John Caius - 1529 Gt physician reformed Gonville.

Sir Thos. Gresham. Gon + Cai. 1535 Financier
built Royal Exchange + Gresham Coll.

Sir Walter Mildmay Chr. 1540 founded Emm. "I have set an acorn wh. when it becomes an oak God alone knows what will be the fruit thereof" A Puritan.

Thos. Cartwright Johns 1550. "founder of Puritan party in England": Intolerant extremist Calvinist.

Edmund Spenser. Pemb. 1569. Faërie Queene.

Francis Bacon Lord Verulam. Trin 1573. Lord Chancellor
Novum Organum

Christopher Marlowe. Corpus 1580

Ben Jonson. St John's 1590

Wm. Harvey. Gon + Cai 1593. Circ. of blood

Matthew Wren Bp. Ely. Pemb 1601 Uncle to Sir Christopher
opposed Puritans with Laud

Oliver Cromwell. Sid Sussex 1616 M.P. for Camb.
+ High Steward. Protector 1649-60.

John Milton. Chr. 1625 "Milton is not only the highest but the completest type of Puritanism" Green's Hist. of Eng. People.

John Harvard. Emm. 1627. Emigrated to USA.
died aged 31 + left books
+ fortune to found Harvard

Jeremy Taylor Gon + Cai 1628.
"devotion enough for a cloister learning enough for a Univ. wit enough for a college of virtuosi".

Jeremiah Horrocks - Emm. 1632. Transit of Venus between Sunday services. d. 23 yrs old.

Isaac Barrow. Trin. 1643. Prof of Gk - then Lucasian Prof of Math. then Master of Trin. Encouraged young Newton who succeed to L. chair. Wrote "Treatise on Supremacy of Pope". Got Wren to build Library.

John Dryden Trin 1650

Sam Pepys. Trin A 1650 + Magdalen '52.
Clerk of the King's Ships. + Sec. to Admiralty.

Sir Isaac Newton. Trin 1661 Lucasian Prof of Math.
Optics, gravitation F.R.S. 1672. Principia 1687.
M.P. for Univ. Pope: Nature, + nature's laws lay hid in night, God said "Let Newton be" and all was light.
"I do not know what I may appear to the world but to myself I seem to have been only like a boy playing on the sea shore + diverting myself in now + then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me".
"Newton quem genus humanum ingenio superavit" inscription on statue by Roubiliac in Trin Ch.

Sir Rbt Walpole Kings 1696. one of England's greatest Prime Ministers.

Thos. Gray. Pet. 1734 – bucket of water. Penb'd. Elegy in Country churchyard.

Wm. Paley. Chr. 1754. Evidences of Christianity.

Wm. Pitt. Pemb. 1773. Prime Min. ab 25.

Wm. Wilberforce Joh. 1776. overthrew Slave trade.

Wm Wordsworth Joh. 1787

Sam. Taylor Coleridge Jesus 1791.

Henry Martyn Joh. 1797. India, Persia, Arabia.

Thos. Young. Emm. 1797. M.D. elasticity, light, etc translator of Rosetta Stone pen near Alexandria with hieroglyphic demotic & Greek characters.

Lord Palmerston Joh. 1803.

Henry Kirke White Joh. 1805. son of Nottingham butcher – very poor. very poetical d. 21 yrs.

Lord Byron. Trin. 1805.

Sir John F.W. Herschel Joh. 1809. – nebulae

Wm. Whewell Trin 1812. Prof. of Mineralogy & then of Moral Philos. & Master of Trin. started the Nat. Sci. Tripos 1851. wrote on Tides, Astron.

Thos. Bab. Lord Macaulay. Trin 1818.

Sir Geo. B. Airey. Trin. 1819. Lucasian Prof & then Plumian Prof of Astron. "g" by pendulum method. Turned down Adams' suggestion re Neptune.

Chas. R. Darwin. Chr. 1828. – Origin of Species after Voyage of Beagle.

Alfred Lord Tennyson. Trin. 1828.

Wm. M. Thackeray. Trin 1829.

Sir Geo. Gabriel Stokes. Pemb. 1837. Lucasian Prof for 50 yrs. Gt Physicist.

Arthur Cayley Trin. 1838. Salderian Prof of Math.

Chas. Kingsley. Magdalen 1838 Prof of Mod. Hist.

James Couch Adams Joh. 1839 Discovered Neptune by math. rival of Arago Lowndean Prof of astron.

Wm Thomson Lord Kelvin. Pet. 1841. Glasgow.

Jas. Clerk Maxwell Pet & Trin. 1850 first Cavendish Prof of Expt. Physics. d. 48.

Chas. S. Parnell Magd. 1865 Irish patriot

Introduction to Alumnae

Outline of I.O.D.E. address.

It is always a pleasure to say 'Thank you' to those to whom one is indebted & it would be a great pleasure to me to come here today & say Thank you to this society to which I owe so much if only I felt it within my power to express my gratitude & to make you feel that I realize how great is my obligation to you because of the many experiences which your War Memorial Scholarship made possible to me.

As the first holder of your scholarship I am to tell you, if I can, what it has meant to me & what I consider its value to those others now enjoying a similar experience & to the many who year after year will leave these shores to return, as you have hoped, better fitted to play some useful part in the life & development of this country.

Quotations -

Huxley: The only medicine for suffering, crime and all the other woes of mankind, is wisdom.

Liberal Eduction. p. 86.

p. 83. Education is the instruction of the intellect in the laws of Nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws -

Sir Rbt Ball: The study of the heavens, of boundless interest & of exquisite beauty, leads to the contemplation of grand phenomena in Nature and great achievements of human genius.

Cambridge.

My object in going to Cambridge was that I might continue my studies in Physics - in particular that wonderfully interesting branch of it, Radioactivity at the Cavendish Laboratory under the supervision of Professor Sir E. Rutherford - that man who has done more than any other man to unravel the mysteries of the radioactive elements and to push his researches experiments to the very heart of atomic structure.

I arrived in Cambridge the last day of June 1921 when the town & country side were in all the beauty of early summer foliage & blossom - It lies 56 miles north of London on the edge of what used to be the fen land, rich in historic interest & legend - Ely with its glorious Minster & the Hereward the Wake country 15 miles to the N. St. Ives with its old arched bridge on which a chapel stands near the birthplace of Oliver Cromwell, about the same distance to the ~~west~~ N. W. Bedford bringing thoughts of Bunyan lies some 20 miles west. & Newmarket famed for generations for its horse racing lies to the S. E. But Cambridge itself is unique & to know it & its buildings & their treasures & history & something of the lives & deeds of the great men who dwelt there is to have what even Huxley might have called a "liberal education". But though I lived there for almost 2 years, I only began to take in even part of it.

Colleges

Trinity →

Johns →

Peterhouse the oldest of all the Cambridge Colleges was founded in 1281 by Hugh Balsham, Bp. of Ely. Lord Kelvin was one of its most famous students. Near it, across Trumpington Street is Pembroke College where studied the martyred reformer Ridley, Edmund Spenser, Wm Pitt prime Minister of Eng. at the age of 25! and Sir Geo. Gabriel Stokes. The next College is Corpus Christi a great Masters of which was Matthew Parker afterwards Arch Bp. of Cantbr 1522. His magnificent collection of early MSS. & incunabula & illuminated script is of surpassing value & interest. Amongst the treasures is the diary of Richard Coeur de Lion during his Palestine campaign - a book of such merit that it was translated & sent to the Palestine Commander during the recent war. Kings College with its beautiful grounds & bridge over the Cam & its stately glorious Chapel owing its dignified framework to Henry Seventh while to Henry VIII is due the beauty of the fan-vaulted ceiling, the rich stained glass & the elaborate wood carving of screen & choirs. The music here is very beautiful - organ & voices blending, rising, falling & floating through the vast gothic building dimly lit on a winter evening with flickering candles.

Of Trinity College what can one say — intellectual home of Bacon & Sir Isaac Newton, Isaac Barrow, Dryden, Byron Macaulay, Sir Geo. Airey, Tennyson, Thackery - to mention but a few of the past & of the present Sir J. J. T., Prof Eddington, Sir E. R. & Aston - three of these being Nobel prizemen in Physics.

St Johns College can claim an almost equally famous list — Ben Jonson, Wilberforce, Wordsworth, Palmerston, Kirke White, Sir John Herschel, & John Couch Adams who shares with Le Verrier the honour of discovery of Neptune. Jesus College parts of whose buildings, courts & chapel were the century convent of St Radegund, suppressed in by Royal decree in order that the College might be founded.

And so one might go on & mention some point of historic or architectural interest in each & name the great men connected with each who are remembered

because in some sphere or other of human endeavour "their works do follow them" — "Where e'er we tread
'Tis haunted, holy ground, Ground where the grass has
yielded to the steps of generations of illustrious men".

So much so does this spirit of the Past permeate the atmosphere of Cambridge that I cannot refrain from dwelling upon four great men whose spirits seemed almost omnipresent to me.

First of all that greatest of all Cambridge men Isaac Newton "qui genus humanum ingenio superavit" as reads the inscription on his statue, who between the years 1660 to 1700 grappled with the mysteries of the Universe of Matter and unravelling many of its secrets laid bare the Laws of Force & explained many of the phenomena of Nature, building a foundation upon which every further advance of physical science is based so that even Einstein in erecting his more complete structure of mathematical formulae does not pull down but literally builds around the foundation which Isaac Newton laid. With wit but with real truth Pope wrote "Nature and Natures' laws lay hid in night; God said, Let Newton be, — and all was light."

It is with a feeling akin to reverence that one looks up at the stone lancet windows near the Great Gate of Trinity College - the windows of the room once occupied by Isaac Newton.

And then second only to Newton I think of Chas Darwin. It was Cuvier who asked, When shall Natural Science have its Newton? He was then born, came later as a student to Christ's College, Cambridge & went forth from there to travel far & wide, observing, thinking, correlating his facts & in due time giving to the world the old Theory of Evolution imbued with a new significance & a new force which has to such a great extent revolutionized modern thought. A great man coming of great ancestors and passing on his mental

strength to the 2nd & 3rd generations so that his sons & grandsons have been and still are amongst the intellectual ornaments of Cambridge.

Thirdly I think of that great Dutch scholar & teacher, Erasmus, who came to Queen's College Camb. in 1512 as Professor of Greek. The Present owes a great debt to that lonely spirit of the Past – Erasmus who revealed so much of the beauty & wonder of Ancient literature; Erasmus who turned the searchlight of his wit & sarcasm & denunciation upon the evils of his day – unrighteousness in the hearts of men & wickedness in high places both of Church & State; Erasmus who saw the danger of the Reformation extremists and by his wisdom & understanding influenced Melanthon & through him Luther & thus saved Protestantism from at least one pernicious dogma.

One other great figure from the Past seemed also to me to live again in the Cambridge of today – John Milton came to Christ's College in 1625. Of his works I need not write – you probably know far more of them than I do, but of the character of the man I must speak – the triumph of mind over matter, of indomitable will over darkness, Milton who wrote "Thou art become, O worst imprisonment, the dungeon to thyself" and yet his spirit triumphed & he still lives on to teach & inspire mankind – "not only", says Green, "the highest but the completest type of Puritanism".

I have tried, very briefly, to make you feel something of the atmosphere in a great old University Town like Cambridge. It is something to which we have no parallel in this country

Furthermore it is a great thing for a student from Canada or the U.S.A. to see the different interpretation given to the word Education there in Canada or in Oxford. It is a much broader thing - not mere book learning - indeed at first the visiting student is led to think that book learning is quite a secondary thing. In reality one finds that the greatest importance is attached to the training of the students mind how to acquire how to handle knowledge for himself rather than that he may become as it were a repository for so many cut & dried facts.

The Cambridge B.A. degree may mean a really immense amount of hard work and sound learning obtained by three years of a Tripos or Honour course, or it may mean very very little scholarship in our usual strict sense of that term - what it always does mean is this that the recipient has for three years been steeped in the Cambridge atmosphere mixing more or less with

cultured minds and absorbing consciously or unconsciously something of that atmosphere.

Univ. Customs

There are many University customs which are quaint & interesting & often have a show of pageantry about them.

When the Judge of the Assizes comes to Cambridge his official abode is by some ancient royal decree at the Masters Lodge of Trinity College. Here he receives the Vice Chancellor of the University in his scarlet robes preceded by the Esquire Beddells carrying silver headed staffs & followed by the Proctor black robes & white collared responsible for the discipline of the students & always attended by two men known as his dogs - in dark blue cloaks, black silk hats & carrying each a large metal bound book - the statutes of the university. With flare of trumpets from two heralds dressed as in the days of chivalry, the V.C. conducts the Judge in wig & full robes & attended by several interesting looking men in black velvet & long robes, to the University Church Great St. Marys, opposite the Senate House & University Library where a service is held invoking Divine blessing & guidance on the administration of Justice about to be conducted.

A meeting of the V.C. & members of the Senate. The ruling body of the University is called a Congregation & is held

several times a month when rules are made & appointments to Committees etc confirmed under the name of graces. and very often a few if not a great many degrees are conferred - The latter ceremony is very interesting. The Proctor stands by the seated V.C. & reads something very fast & unintelligibly. The College tutor advances from the middle of the floor where he has been standing with the students: each man he presents for a degree holds one of the fingers of his left hand until in front of the V.C. when his name is read out & he advances, kneels, places his two hands between those of the V.C. in the attitude of a supplicant & the V.C. pronounces in Latin. the "admitto te." after which he withdraws. In the case of an honorary degree the Public Orator of the Univ makes a Latin speech of Presentation after which the honoured gentleman goes forward & kneels before the V.C.

Once every year there is held a service called the Commemoration of Benefactors on a Sunday at 2.30 p.m. the V.C. Proctors & members of Senate in full robes proceed to the University Church & there in the presence of any students or others who may like to go there is read from the Pulpit a long & most interesting list of the Benefactors of the University from

King Henry III & good Queen Elenor – a list of
Kings & Queens, ~~Knights~~ & Commoners.
founders of colleges – professorships, donors
of prizes, buildings, laboratories, books
telescopes & art treasures – a list of
benefactions extending over nearly
seven centuries.

Titular Degree

1882 Tripos

Library.

Roy Comm.

Tribute to Miss Clough.

etc.

The Education of women at Cambridge began in the year 1871 when Newnham College was founded with Miss Clough as its Principal and Professor Henry Sidgwick (Moral Philos.) as its chief advisor & champion. It is an interesting fact, I think, that 1871 was also the year when McGill Univ. first opened any of its classes to women. Womens Education at Cambridge & at McGill is thus exactly contemporaneous, but the struggle for full academic status has met with greater degree of fulfilment here than in Cambridge. Until this year in Cambridge no woman could receive a degree although since 1882 they were admitted on equal terms with men to Tripos classes & Exams and to the Laboratories. Even now the degree given them is only what is called Titular — carrying with it none of the voting rights & privileges which the degree gives to a man. Furthermore the women are still denied membership in the University, and cannot take a book from the University Library in their own names.

The women of Newnham & Girton Colleges resent very much the position in which the University keeps them — they are there on sufferance as it were — not in virtue of any right to be there. It is interesting to note that

though there certainly exists in the University a very strong, bitter party of young & old men who oppose the women at every turn – they are in the minority and it is the outside vote of the hundreds of M.A.'s who are conservative & shall we say somewhat bigotted, who come to Cambridge only about once a year for the purpose of voting against any such innovation & grave menace as the inclusion into full membership of the Women's Colleges this is the somewhat antiquated vote that turns the scale against the women.

The recent Royal Commission appointed by Parliament to consider matters pertaining to Oxford & Cambridge reported in favour of the full admission of women – & some of the more ardent women of Cambridge are hoping to use Parliamentary force to gain their desires, but it seemed to me that it would be the wiser course to govern quietly with the increased liberty they now have been granted & wait for full membership to be granted from within the Senate & not as a result of Parliamentary pressure from without.

I must here pay a tribute to the fine women whom I had the privilege of meeting & seeing considerable of at Newnham – for though I did not reside in the college as I had at first considered doing, I was attached as a non-resident research student. I dined in Clough Hall once a week & had many nice talks with the Principal Miss Clough, niece of the Foundress, & with the Tutors & lecturers – especially dear old Miss Sharpley, Miss Collier Miss Steele Smith. These women, like the respected Warden of

the Royal Victoria College, represent the very highest & best type of educated Englishwoman, cultured in mind, dignified in manner, warm & tender of heart, & with a task set before them to which they have been & are devoting the best energies of their lives. We who follow afar off & who have benefited greatly by their efforts & their example, are indeed glad to pay this small tribute of honour & respect. It is a privilege & a pleasure to have known them.

Final Outline of Address to Alumnae Society

Feb. 1921.

Preliminary remarks - (1) Send off Jun 1921 (2) Sold...

Cambridge Situation & Surroundings. Ely, St Ives, Bedford, Newmarket.

Town - Round Ch - etc.

Colleges :- Peterhouse 1281 Kelvin & Sir Thos Gray.

Pembroke 1346 (Countess of P.) Ridley Ed Spenser, Wm Pitt, Son of G Stokes. P.M.

Corpus Christi 1352 St Benets pre norman - 1660 Chapel by Sir Ch. Wren

Kings - Clare Library

Trinity; intellectual home of Bacon. Newton 1660 Bu.. Dryden, Byron, Macaulay, Airy, Tennyson, Thack.. & now of Sir J.J. Thomson, Eddington, Sir E.R., Aston

Caius 1348 & 1557.

Christs - Chas Darwin 1828 John Milton 1625

Sidney Sussex. Cromwell.

Emmanuel - Young, Cromwells son, John Harvard.

Queens, Erasmus 1512.

St Johns 1511 / Lady Margaret mother of Henry VII.

Ben Jonson, Wilberforce, Wordsworth, Palmerston, Kirke White, Sir J. Herschel, J C Adams.

Girton - Newnham

Cavendish Lab. 1874 Maxwell, Rayleigh, J.J., R.

Trend of Modern Research Towards the Light.

Prof. Sampson Astr. Roy. for Scotland.

(1) Metaphorical or figurative

(2) Literal

History of the Cavendish Lab. Camb.

The systematic teaching of practical physics is a modern development - Newton, Boyle, Young & all gt experimenters of past generations acquired their skill in the use of apparatus by solitary practice or by helping some older master in his work. Until the second half of 19th century was well begun no teaching laboratory & no regular courses of instruction were known

In Brit the pioneer work was that of Kelvin at Glasgow with his group of private assistants; in London & Oxford about 1867 when one room was set apart for pract. physics - becoming in Oxford the Clarendon Lab. 1870. in London. 1876 Carey Foster & W G Adams Latter visited France & Germany & found only lab for systematic instruction was that of Jamin at the Sorbonne. - ~~Carey Foster~~ " I was convinced that there could be no sound teaching of physics apart from pract. work; students must have personal acquaintance with phenom. before they can profitably reason about them."

In Camb. 1860 Senate expressed need for a Prof of Expt. Physics & a Lab. the Nat. Sci. Tripos having been established in 1851 In Oct. 1870 the Chancellor 7th Duke of Devonshire. Wm Cavendish, offered to provide the necess. funds & on June 16 1874 The Cav. Lab was formally opened with John Clerk Maxwell as the 1st Prof until 1879 (1871-) - Lord Rayleigh R 79 - 84

J.J. Thomson 1884 — 1918 w 19 Sir E. R —

Clerk Maxwell period - Chrystal (now Math Edin.) Schuster

J A Fleming. R T Glazebrook

Cl. Maxwell repeated expts of Henry Cavendish on measurement of curr. by physiological shock

however,

...rld

...ly

...ts &

Trial Outline of Address to Alumnae Society

women first admitted only in Long Vac.

Lord Rayleigh from death of C-M 1879

In 1882 he admitted women on equal terms with men & they were given permission to write Tripos Exam

His own manifold researches - determination of elect. units - &c. Resigned & stuck for private work & Terling 1884.

J.J.T. 27 yrs old - old Relfe there, Heaviside Heyles & Lincoln. Excitement in Lab over repetition of Hertz experiments - i.e. verification of Clerke Maxwells Elb. mag. eqns -

Both my work and my greatest interest, however, were centred in the Cavendish Laboratory.

There are few - if any - laboratories in the world which have such a record as that possessed by the Cavendish both for producing great scientists & for achieving great scientific results.

Opened in 1874

Outline of Address to I.O.D.E. April 1924. Mt Royal Hotel

Introduction: Thanks to IODE. (1) as a Canadian for IODE's work in Canada esp. Armistice Day remembrance - (2) as Scholarship holder.

Aim of Scholarships - Value of study overseas
see attached pages -
my own experiences - Canterbury, Newnham,
Importance of 2nd year
Opportunities for travel -

Conclusion - Banner in R.V.C. Gift of Queen Alexandra in 1907 - work of Miss G. F. Watts -
Central idea is the unfolding of Canada into the full stature of nationhood - reaching up towards the attainment of high ideals - Our Lady of the Snows growing up towards her triple crown of
Love, Faith, Hope.
The Gaelic blessing - Peace & Growth to her
Strength & Worth to her.
Doves bringing the 7 gifts of the Spirit
The gifts of (1) Wisdom (2) Pittie (3) Strength
(4) Comfort (5) Understanding (6) Congings
(7) Reverence.

"Knowledge inspired by Reverence is
Praise and Worship"

Quotation from Huxley. Wisdom ... p. 1.
Education.

That education may bring wisdom which
coupled with Reverence may result in
better & greater Service is the ideal of the IODE
& shewed in the ideal of their War Memorial Scholars