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PHYSICAL CHEMISTRY

Surface Tension

$T = \frac{F}{l}$ T - tension F - force = dynes l - length = cms

$h = \frac{2T}{Rg\rho}$ h - height cms T - tension R - radius ρ - density g - gravity.

$h + \frac{1}{3}r = \frac{2T}{rg\rho}$

Magnetism and Electricity

$F \propto \frac{1}{d^2}$

$F = \frac{m_1 m_2}{d^2}$ F - dynes m_1, m_2 unit poles d - cms.

$F = mH$ F - dynes m - unit poles H - oersted

$H = \frac{2Md}{(d^2 - l^2)^2}$ M - magnetic moment l - half length d - distance - cms. H - oersted [Pt. on axis]

Note $H = \frac{2M}{d^3}$ (small bar magnet)

$H = \frac{M}{(d^2 + l^2)^{\frac{3}{2}}}$ [Pt. perp. to axis]

Note $H = \frac{M}{d^3}$

Couple $= MH \sin\theta$ (use to define M - magnetic moment)

$H = H_0 \tan\theta$ (derive from above - two fields at rt angles)

$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ I - moment of inertia
ω - angular velocity

$I = \frac{1}{3}m(a^2+b^2)$ where a - half length b - half breadth.

$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration.}}}$ T - periodic time.
$T = 2\pi\sqrt{\frac{I}{MH}}$

Derive $\frac{n_1^2}{n_2^2} = \frac{H_1}{H_2}$ $\frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$ $n = \frac{1}{T}$ = frequency.

$\alpha = \frac{R_t - R_0}{R_0 t}$ α - coefficient of resistance
t - temperature

$\frac{P}{Q} = \frac{R}{X}$ (Weatstone Bridge formula)

$E = at + bt^2$ a, b - constants t - temperature
E - e.m.f. produced.

$H = \frac{I\ell}{r^2}$ H - oersted ℓ - cms r - cms I - e m.u.

Derive
$H = \frac{2\pi n I}{10 r}$ n - number of turns I - amps

Derive
$I = \frac{10 r H_0}{2\pi n}\tan\theta$

Derive
$I = K\tan\theta$

$\delta H = \frac{i\,\delta l\,\sin\theta}{r^2}$ i - e.m.u. l - r - cms H - oersted

$H = \frac{2\pi n i}{r}$ - i - emu [circular coil]

$H = \frac{2\pi r^2 i}{(r^2+x^2)^{3/2}}$ x - cms - distance from centre of coil.

Note $H = \frac{2\pi r^2 i}{x^3}$ [small coil]

$H = \frac{2I}{10r}$ r - distance from wire I - current in amps.

$H = \frac{4\pi n i}{l}$ l - length of coil i - e.m.u [solenoid]

$B = \mu H$ B - Flux density μ - Permeability H - oersted

$J = \frac{M}{V}$ J - Intensity of Magnetisation V - volume.

$J = \frac{m}{a}$ - m - pole strength a - cross section area [for magnet]

$\chi = \frac{J}{H}$ χ - Susceptibility

$B = H + 4\pi J$

$\mu = 1 + 4\pi\chi$

m.m.f = Flux × Reluctance.

$R = \frac{l}{\mu a}$ R - reluctance - gilberts

$F = \frac{BIl}{10}$ I - amps F - dynes

$F = \frac{2I_1I_2}{100r}$ $I_1 I_2$ - amps r - cms [two parallel wires]

$B = \frac{HIl}{10}$ $\mu = 1$ for air.

Couple $= \frac{nHIA}{10} \cos\theta$ A - area n - number of turns

$E = \frac{Blv}{10^8}$ volts [Electro-magnetic Induction]

$e = -\frac{d\omega}{dt}$

$E = \frac{2Blv}{10^8} \sin\theta$

$E = E_{max.} \sin\theta$

$E = \frac{nBA\omega}{10^8} \sin \omega t = E_0 \sin \omega t$

$E = \frac{2\pi nBAf}{10^8} \sin 2\pi ft. = E_0 \sin 2\pi ft.$

Torque $\propto Hil \propto I_F I_a$

$\frac{V_s}{V_p} = \frac{n_s}{n_p}$ V - volts s - secondary p - primary

n - number of turns

$E = L\frac{dI}{dt}$ - L - self inductance.

1 Henry = 10^9 e.m.u.

$L = \frac{4\pi n^2 \mu A}{l}$ · e.m.u.

$E_2 = M\frac{dI_1}{dt}$ · M - mutual inductance

$M = \frac{4\pi n_1 n_2 \mu A}{l}$ e.m.u.

$M = \sqrt{L_1 L_2}$

$K = \frac{M}{\sqrt{L_1 L_2}}$ K · co-efficient of coupling

$\mathcal{E} = \frac{1}{2} L I_0^2$ I_0 - maximum current $\mathcal{E}$ - energy

Electro-statics

$F \propto \frac{1}{d^2}$ F - dynes d - cms

$F = \frac{Q_1 Q_2}{K d^2}$ Q - e.s.u. - unit of charge
K = 1 (approx) for air.

$F = QE$ dynes E - electric intensity

$E = \frac{Q}{d^2}$

$V = \frac{Q}{r}$ V - unit charge from infinity to Q, work.

$W = QV$

$Q = VC$ C - capacity

$K = \frac{C_K}{C_{AIR}}$ K - dielectric constant.

$C = r$ C - capacity of sphere

$C = \frac{A}{4\pi d}$ C - capacity of parallel plate condenser

$C = C_1 + C_2 + C_3$ condensers in parallel

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$ condensers in series

$$\text{Energy} = W = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$E = -\frac{dV}{dr}$$

ELASTICITY

$F \propto$ Extension $\rightarrow$ Hook's Law

Stress $= \frac{F}{A}$ F - Force A - Area

Strain $= \frac{\delta V}{V}$ V - Volume

$E = \frac{\text{stress}}{\text{strain}}$ E - Youngs Modulus

$K = \frac{PV}{\delta V}$ P - Pressure K - Bulk Modulus.

$n = \frac{F}{A.\theta}$ n - Sheer Modulus.

$\sigma = \frac{\text{lateral contraction per unit width}}{\text{Longitudinal elongation per unit length}}$ σ - Poissan's Ratio

P.E. per unit volume $= \frac{1}{2}$ stress X strain.

GRAVITATION

$F \propto \frac{m_1 m_2}{r^2}$

$F = G\frac{m_1 m_2}{r^2}$ $G \sim 6.6 \times 10^{-8}$

G - Universal gravitational constant.

$\rho = \frac{3g}{4\pi R G}$ ρ - density of the earth.

$V = \sqrt{\frac{2GM}{R}}$ V - velocity to escape from earth

$V = \sqrt{\frac{GM}{R}}$ V - vel. of rocket circling at dist. R above the earth.

$T = 2\pi\sqrt{\frac{l}{g}}$ Simple pendulum

$T = 2\pi\sqrt{\frac{K^2 + l^2}{lg}}$ Rigid pendulum.

$\frac{8\pi^2}{g} = \frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}$ Bessel's Equation.

$g_h = g_0\left(1 - \frac{2h}{R} \cdots\right)$

$g_d = g_0\left(1 - \frac{d}{R}\right)$

LIGHT

$n = \dfrac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}}$ For minimum deviation.

$D = (n-1)A$ D – Dispersion

$D = A(n_B - n_R)$

$D.P. = \dfrac{n_B - n_R}{n_Y - 1}$ D. P. – Dispersive power.

$\frac{1}{F} = \frac{1}{V} + \frac{1}{u}$ For ~~cove~~ convex and concave mirrors and lenses.

$m = \frac{u}{V}$ For convex and concave mirrors and lenses.

${}_1n_3 = {}_1n_2 \times {}_2n_3$

$\frac{1}{f} = \frac{1}{V} - \frac{1}{u}$ Lens formula for Cartesian sign convention.

$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ Mirror formula for Cartesian sign convention.

$\frac{n'}{v} - \frac{n}{u} = \frac{n' - n}{r}$ Refraction at a single curved surface.

$f = \frac{n'r}{n'-n}$ focal length of single curved surface

$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$F = \frac{1}{f}$ where F is the power in Dioptres.

$F = F_1 + F_2$ Two lenses in contact.
$1/F = 1/F_1 + 1/F_2$ Two lenses in contact.

$xx' = ff'$ where f and f' are the two focal lengths of the lens and x and x' are the distances of the object and the image from the two focii.

$M.P. = \frac{\tan w_2}{\tan w_1}$ where w_1 and w_2 are the angles subtended by the object and the image

$M.P = 1 - \frac{D}{f}$ where D is distance of distinct vision

For compound microscope

$$M.P. = -\frac{D}{f_e} \cdot \frac{V_o}{u_o}$$

For astronomical telescope

$$M.P. = -\frac{F_o}{f_e}$$

$F_F - F_C = \omega F$ where ω is the dispersive power and F the lens power

$\omega F + \omega F' = 0$ For Achromatic pair.

Photometry

$I = \frac{L}{r^2}$

$I = \frac{L}{r^2} \cos\theta$

Physical optics

$y = a \sin \omega t$

$x = \frac{m D \lambda}{d}$ For maximum.

$x = \frac{(m+\frac{1}{2}) D \lambda}{d}$ For minimum.

Fringe width $= \frac{D\lambda}{d}$

$r_m = \sqrt{m R \lambda}$ where R is radius of the lens and r is the radius of the m^{th} dark ring.

$$\nu = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$ Spectral lines. R is Rydberg's constant.

ν is the frequency

Electricity

Alternating Current

$e = -\frac{dN}{dt}$

$e = E_0 \sin \omega t$ t - time

$e = B\omega AT \sin\theta$ T - number of turns
B - field A - area

$i = \frac{E_0}{R} \sin \omega t$
$e = I_0 \sin \omega t$

Power $= Ri^2$

$I = \frac{I_0}{\sqrt{2}}$

$E = \frac{E_0}{\sqrt{2}}$

For inductance $e = \omega L I_0 \sin(\omega t + \frac{\pi}{2})$

Reactance $= \omega L = \frac{E_0}{I_0}$

L and R in series Z = Impedance $= \frac{|V|}{|I|}$

$$\frac{|V|}{|I|} = \sqrt{R^2 + \omega^2 L^2}$$

Quality $= Q = \frac{\omega L}{R}$

Condenser

$$i = \omega C E_0 \sin(\omega t + \tfrac{\pi}{2})$$

$$\text{Reactance} = \frac{E_0}{I_0} = \frac{1}{\omega C}$$

C and R in series

$$Z = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$$

L and R in parallel

$$Z = \frac{1}{\sqrt{\frac{1}{\omega^2 L^2} + \frac{1}{R^2}}}$$

C and R in parallel

$$Z = \frac{1}{\sqrt{\frac{1}{R^2} + \omega^2 C^2}}$$

Resonance circuits

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$|V_L| = \frac{V}{R}\sqrt{\frac{L}{C}}$$

$$|V_C| = \frac{V}{R}\sqrt{\frac{L}{C}}$$

Anti-resonance circuits

$$\omega_0^2 = \frac{L - CR^2}{L^2C}$$

If Q is large then R is small

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Electricity M.K.S.

$f = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$ $\epsilon_0 = 8\cdot85 \times 10^{-12}$

$E = \frac{\sigma}{\epsilon_0}$ ~~charge~~ field at small distance from conductor

$E = \frac{q}{4\pi\epsilon_0 r^2}$ field due to ~~f~~ sphere

$V = \frac{q}{4\pi\epsilon_0 r}$

$C = 4\pi\epsilon_0 a$ capacity of sphere

$C_0 = 4\pi\epsilon_0 \frac{ab}{b-a}$ spherical condenser.

$C_k = 4\pi\epsilon \frac{ab}{b-a}$ $\epsilon = K\epsilon_0$

$C = \frac{\epsilon_0 A}{d}$ parallel plate condenser.

$V = d\sqrt{\frac{2f}{\epsilon_0 A}}$ electrometer

$f = \frac{\sigma^2}{2\epsilon_0}$ force between plates of condenser

$B = \frac{\mu_0 i}{2\pi a}$ field due to wire

$H = \frac{B}{\mu_0}$

$H = \frac{i}{2\pi a}$ field due to wire.

$f = 2 \times 10^{-7}$ newtons per metre force due to current of one amp flowing in two wires one metre apart.

$\mu_0 = 4\pi \times 10^{-7}$

$B = \frac{\mu_0 i}{2a}$
$H = \frac{i}{2a}$ } field at centre of coil.

$H = \frac{i a^2}{2(a^2+x^2)^{\frac{3}{2}}}$ field on axis of coil

$V = R\,i$ Ohm's Law

$R_T = R_1 + R_2 + R_3 + \cdots + R_n$ series

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots + \frac{1}{R_n}$ parallel

$T_s - T = K \frac{wM}{Wm}$ K molecular elevation

$$\frac{P \times V}{T} = K \rightarrow \text{Osmotic pressure.}$$

1 gm. mol. wt. of solute in 22,400 ml. at 273°Abs gives an O.P. of 76 cms of Hg.

$$\frac{p - p'}{p} = \frac{n}{n+N} \quad \text{Raoults Law}$$

$$\frac{p - p'}{p} = \frac{wM}{Wm} \quad \text{or} \quad \frac{\frac{w}{m}}{\frac{w}{m} + \frac{W}{M}}$$

$$p_o = \frac{p - p'}{MP} \cdot RT d_s$$

$$\frac{p - p'}{p_o} = \frac{d_v}{d_s}$$

$$\frac{1 + \alpha}{1} = \frac{\text{Observed O.P.}}{\text{calculated O.P.}} = i \qquad \alpha \rightarrow \text{activity.}$$

$$A_x B_y \rightarrow xA + yB$$

$$\alpha = \frac{i - 1}{x + y - 1} \qquad \alpha \rightarrow \text{activity}$$

PHYSICAL CHEMISTRY

Steam distillation → V.P. of X + V.P. of Y = A.P

$$\frac{\text{Weight of X}}{\text{Weight of Y}} = \frac{\text{V.P. of X}}{\text{V.P. of Y}} \times \frac{\text{M.W. of X}}{\text{M.W. of Y}}$$

Partition Law $\frac{\text{conc. of X in A}}{\text{conc of X in B}} = K$ Partition constant

If assosiation of mols. of X in A then

$$\frac{\text{conc of X in A}}{(\text{conc of X in B})^2} = K$$

Henry's Law $\frac{\text{Pressure of gas}}{\text{wt of gas per given vol}} = K \quad \frac{P}{C} = K$

$$M.W. = 2\,V.P.$$

$PV = RT \qquad R = 2$ gm cals per deg. (approx)

$PV = \frac{1}{3} m n u^2$ Kinetic theory of gases.

$\left(p + \frac{a}{v^2}\right)(v - b) = RT$ Van der Waal's equation

$u = \frac{K}{\sqrt{\text{Density}}}$ Graham's Law of Diffusion

DYNAMICS AND STATICS

$s = vt$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$t = \frac{2u}{g}$ time of flight of projectile

$s = \frac{u^2}{2g}$ greatest height of projectile.

$F = m\alpha$

$T = \frac{2m_1 m_2}{m_1 + m_2} g$ tension on pulley string

Ft measures impulse

$\frac{1}{2}mv^2$ measures kinetic energy

Fv measures power

$R^2 = v_1^2 + v_2^2 + 2v_1 v_2 \cos\theta$

$R = \sqrt{F_1^2 + F_2^2 + 2F_1 F_2 \cos\theta}$

$P : Q : R = \sin\lambda : \sin\beta : \sin\alpha$

$$\left.\begin{aligned}\Sigma(F_1 y_1) &= \Sigma(F_1)\times(\bar{y})\\ \Sigma(F_1 x_1) &= \Sigma(F_1)\times(\bar{x})\end{aligned}\right\}$$ moments about a lines

Resultant of n couples is a couple with arm p_1 and force $F_1 + \frac{F_2 p_2}{p_1} + \frac{F_3 p_3}{p_1} \dots + \frac{F_n p_n}{p_1}$ (algebraic sum)

Resultant of a couple and a force is a force P distant $\frac{Fp}{P}$ from original ~~pol~~ position.

Projectiles

Horizontal component $\rightarrow v\cos\alpha$

Vertical component $\rightarrow v\sin\alpha$

Time to reach greatest height $t = \frac{v\sin\alpha}{g}$

Time of flight $t = \frac{2v\sin\alpha}{g}$

Greatest height $s = \frac{v^2\sin^2\alpha}{2g}$

Horizontal range $s = \frac{v^2\sin 2\alpha}{g}$

Range on an inclined plane

$$= \frac{2v^2}{g\cos^2\alpha}\sin(\beta-\alpha)\cos\beta$$

$\frac{ds}{dt} = v$ $\frac{dv}{dt} = \alpha$ $\int a\,dt = v$

$\frac{d^2s}{dt^2} = \alpha$ $\int v\,dt = s$

<u>Circular Motion</u>

$$\text{acc} = \omega v$$
$$= r\omega^2$$
$$= \frac{v^2}{r}$$
$$T = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$$

S.H.M.

$$V = \omega \times \frac{\sqrt{r^2 - x^2}}{r}$$

$$T = 2\pi \frac{r}{v} = \frac{2\pi}{\omega}$$

$$\frac{\text{acc.}}{\text{Disp.}} = \frac{4\pi^2}{T^2} = \omega^2$$

$T = 2\pi\sqrt{\frac{m}{k}}$ <u>Vibrating Spring</u>

$T = 2\pi\sqrt{\frac{l}{g}}$ <u>Simple pendulum.</u>

$Te \cos\theta = mg$ <u>Conical</u>
$Te \sin\theta = \frac{mv^2}{r}$ <u>pendulum</u>

$$\frac{v^2}{rg} = \frac{r}{h} = \tan\theta$$

$$T = 2\pi\sqrt{\frac{h}{g}}$$

Elasticity $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$v_1 - v_2 = -e(u_1 - u_2)$$

$e \to$ co-efficient of restitution

$\tan\alpha = e\tan\beta$ oblique impact.

Applied Mathematics

$$\underline{a} + \underline{b} = \underline{b} + \underline{a}$$
$$(\underline{a} + \underline{b}) + \underline{c} = \underline{a} + (\underline{b} + \underline{c})$$
$$\underline{a} \cdot \underline{b} = |a||b| \cos\theta$$
$$\underline{a} \cdot \underline{b} = a_x b_x + a_y b_y + a_z b_z$$
$$\underline{a} \times \underline{b} = |a||b| \sin\theta \; i_p$$
$$\underline{a} \times \underline{b} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

$$\underline{i} \times \underline{i} = \underline{j} \times \underline{j} = \underline{k} \times \underline{k} = 0$$

$\underline{i} \times \underline{j} = \underline{k}$; $\underline{j} \times \underline{k} = \underline{i}$; $\underline{k} \times \underline{i} = \underline{j}$; $\underline{k} \times \underline{j} = -\underline{i}$ etc.

$$\underline{a} \cdot \underline{b} \times \underline{c} = [\underline{a}, \underline{b}, \underline{c}] = \begin{vmatrix} a_x & a_y & a_z \\ b_x & b_y & b_z \\ c_x & c_y & c_z \end{vmatrix}$$

$\underline{r} = \underline{a} + \lambda \underline{p}$ equation of a line $\underline{a}$ is constant

$$\underline{a} \times (\underline{b} \times \underline{c}) = (\underline{a}.\underline{c})\underline{b} - (\underline{a}.\underline{b})\underline{c}$$

Angular velocity $\omega = \dfrac{v \sin\alpha - u \sin\beta}{r}$

angular velo of A about B $A \to v$; $B \to u$.

$v_r = \dot{r}$ $\quad f_r = \ddot{r} - r\dot{\theta}^2$

$v_\theta = r\dot{\theta}$ $\quad f_\theta = \frac{1}{r}\frac{d}{dt}(r^2\dot{\theta}) = 2\dot{r}\dot{\theta} + r\ddot{\theta}$

Work done by force $= \int \underline{F} \cdot \underline{dl} = \int X dx + \int Y dy$

Simple harmonic motion $\quad \ddot{x} + n^2 x = 0$

$\dot{x} = \sqrt{V^2 - n^2x^2}$ V is max. vel. i.e. $\dot{x} = V$ at $x = 0$

$x = \frac{V}{n} \sin nt$ When $x = 0$, $t = 0$

$$T = \frac{2\pi}{n}$$

$$x = A \cos nt + B \sin nt$$

$x = a \cos(nt + \epsilon)$ $a = \sqrt{A^2 + B^2}$

$\dot{x} = n\sqrt{a^2 - x^2}$ where motion is about $x = 0$.

$(nt + \epsilon)$ is the phase angle

Projectiles $x = V \cos\alpha\, t$

$y = V \sin\alpha\, t - \frac{1}{2}gt^2$

Equation of path $y = x \tan\alpha - \frac{1}{2}g\frac{x^2}{V^2}\sec^2\alpha$

Time of flight $= \frac{2V\sin\alpha}{g}$

Range $= \frac{V^2 \sin 2\alpha}{g}$

Parabola of safety $x^2 = \frac{2V^2}{g}\left(\frac{V^2}{2g} - y\right)$

Directrix $= \frac{2V^2 \cos^2\alpha}{g}$

$d^2 = \frac{u^4}{g^2} - \frac{2u^2h}{g}$ where d is the distance of an obstacle height h just cleared c

Organic Chemistry

$-OH$	alcohol
$-C{=}O\,(-H)$	aldehyde
$-C(=O)-$	ketone
$-C{=}O\,(-OH)$	acid
$-O-$	ether
$-NH_2$	amine
$-NO_2$	nitro
$-C{=}O\,(-NH_2)$	amide
$-SO_3OH$	sulphonate
$-C(OH)-C(OH)-$	glycol

Solubility Soluble in water → simple alcohols; aldehydes; acetone; carboxylic acids.

Insoluble in water → ethers, esters, amines, nitro-compounds, aromatic aldehydes, halogen derivatives of paraffins.

Sodium Hydroxide gives NH_3 from ammonium salts in the cold. When heated it gives ammonia from amides. Esters are hydrolysed giving the sodium salt of the acid. Chloroform is given by chloral or chloral hydrate.

Dilute Acid catalyses hydrolysis of ester into alcohol and acid.

Ammonia converts esters to amides

Soda-lime with sodium salt of acid gives hydrocarbon.

Concentrated H_2SO_4 gives:-

CO with formic acid or formates

CO and CO_2 with oxalic acid or oxalates

CO and CO_2 and blackening with tartaric acid, tartrates

CO and CO_2 and slow blackening with citric acid and citrates.

PCl_5 gives HCl with hydroxyl groups.

Aromatic compounds with OH in nucleus give colour with ferric chloride.
Nitrous acid gives nitrogen with $-NH_2$ group.
Silver nitrate reduced to silver → aldehyde.
Strong reducing agent nitro-group → amino group.
Hydroxylamine gives oximes with aldehyde
Phenylhydrazine gives phenylhydrazones with ketone
Iodine and NaOH give iodoform with ethyl alcohol, acetaldehyde, acetone, isopropyl alcohol.
Bromine and potash give amines with aliphatic and aromatic carboxylic acid.

The polar of an external point is the chord of contact of tangents from that point.

If two circles cut orthogonally any diameter of one is cut harmonically by the other

In a self conjugate triangle each vertex is the pole of the opposite side.

In a complete quadrilateral the diagonal point triangle is self conjugate.

In a Harmonic pencil all transversals are cut in an harmonic range.

If a pencil is equiangular with a Harmonic pencil then it is also harmonic.

An angle and its bisectors form a Harmonic pencil.

In a Harmonic pencil, if the angle between two alternate rays is a right angle these rays are the bisectors of the angles between the other two.

In a complete quadrilateral all the ranges and pencils are harmonic.

If a point lies on a line, the polar of the point passes through the pole of the line.

If a line passes through a point the pole of the line lies on the polar of the point.

A tangent and its point of contact are pole and polar.

The power of a point is, w.r.t. a circle, its distance from the centre squared minus the radius of the circle squred.

The radical axis of two circles is the locus of points of equal powers w.r.t. the two circles.

The radical axis is a straight line perpendicular to the line of centres.

For three circles the radical axes are concurrent.

Co-axal circles are such that each pair has the same radical axis.

In a co-axal system all circles through the limiting points are orthogonal to each circle in the system.

If a transversal is cut in a Harmonic Range by a pencil of four rays the intercepts on a line parallel to one ray are equal.

then $\frac{BP}{PC} \times \frac{CQ}{QA} \times \frac{AR}{RB} = 1$

In a triangle ABC with transversal PQR cutting BC, CA, AB at P, Q, R respectively, then $\frac{BP}{PC} \times \frac{CQ}{QA} \times \frac{AR}{RB} = 1$

If two triangles are in perspective the intersection of pairs of corresponding sides are collinear.

If from a point on the circumcircle of a triangle perpendiculars are drawn to the sides, the feet of the perpendiculars are collinear.

If two circles are orthogonal, the tangent of one is the radius of the other.

If two circles are orthogonal, the distance between their centres squared equals the sum of the squares on the radii.

If two circles are orthogonal the angles, cut off by the common chord, in the segments are complementary or add up to 270°.

to the squares on corresponding sides.

The square on the bisector of the vertical angle of a triangle is equal to the difference of the rectangles contained by the other two sides and by the segments of the base.

In a cyclic quadrilateral the rectangle contained by the diagonals is equal to the sum of the rect angles contained by the opposite side. (and conversely)

In a quadrilateral (not cyclic) the sum of rectangles contained by the opposite sides is greater than the rectangle contained by the diagonals

In a triangle the mid-pts of the sides, the feet of the altitudes and the mid-pts of the joins of the ortho-centre to the vertices are concyclic.

In a triangle the circum-centre, ortho-centre and the median centre are collinear.

In a triangle ABC with P, Q, R points on BC, CA, AB respectively so that AP, BQ, CR concur,

GEOMETRY

The medians of a triangle are concurrent and cut at a point of trisection.

The altitudes of a triangle are concurrent.

Equiangular triangles are similar.

If the sides of two triangles are proportional the triangles are similar.

If two triangles have an angle of one equal to an angle of the other and the sides about the equal angles are proportional the triangles are similar.

If two chords of a circle intersect the rectangles contained by the segments are equal.

If from a point outside a circle two secants are drawn, the rectangles contained by the secants and their external segments are equal.

The areas of similar triangles are proportional

$$\int \frac{dx}{\sqrt{a^2-x^2}} = \sin^{-1}\frac{x}{a}$$

$$\int a^x\,dx = \frac{a^x}{\log a}$$

$$\int \frac{dx}{\sqrt{x^2+a^2}} = \log\left(x+\sqrt{x^2+a^2}\right)$$

$$\int \frac{dx}{\sqrt{x^2-a^2}} = \log\left(x+\sqrt{x^2-a^2}\right)$$

$$\int \tan x\,dx = -\log\cos x$$

$$\int \cot x\,dx = \log\sin x$$

$$\int u\frac{dv}{dx}dx = uv - \int v\frac{du}{dx}\,dx$$

$$\int \frac{d\theta}{\sin\theta} = \log\tan\frac{\theta}{2}$$

$$\int \frac{d\theta}{\cos\theta} = \log\frac{1+\tan\frac{\theta}{2}}{1-\tan\frac{\theta}{2}}$$

$y = \sin^{-1}x \qquad \frac{dy}{dx} = \frac{1}{\sqrt{1-x^2}}$

$y = \cos^{-1}x \qquad \frac{dy}{dx} = -\frac{1}{\sqrt{1-x^2}}$

$y = \tan^{-1}x \qquad \frac{dy}{dx} = \frac{1}{1+x^2}$

$y = \cot^{-1}x \qquad \frac{dy}{dx} = -\frac{1}{1+x^2}$

$\int x^n dx = \frac{x^{n+1}}{n+1}$

$\int \frac{1}{x} dx = \log x$

$\int e^x dx = e^x$

$\int \cos x \, dx = \sin x$

$\int \sin x \, dx = -\cos x$

$\int \sec^2 x \, dx = \tan x$

$\int \operatorname{cosec}^2 x \, dx = -\cot x$

$\int \sec x \tan x \, dx = \sec x$

$\int \operatorname{cosec} x \cot x \, dx = -\operatorname{cosec} x$

$\int \frac{dx}{1+x^2} = \tan^{-1}x$

$\int \frac{dx}{a^2+x^2} = \frac{1}{a}\tan^{-1}\frac{x}{a}$

$\int \frac{dx}{\sqrt{1-x^2}} = \sin^{-1}x$

Calculus

$y = uv \qquad \frac{dy}{dx} = u\,dv + v\,du$

$y = \frac{u}{v} \qquad \frac{dy}{dx} = \frac{v\,du - u\,dv}{v^2}$

$\frac{dy^2}{dx} = \frac{dy^2}{dy} \times \frac{dy}{dx}$

$\tan\theta > \theta > \sin\theta$

$\lim_{\theta \to 0} \frac{\sin\theta}{\theta} = 1$

$y = \sin x \qquad \frac{dy}{dx} = \cos x$

$y = \cos x \qquad \frac{dy}{dx} = -\sin x$

$y = \tan x \qquad \frac{dy}{dx} = \sec^2 x$

$y = \cot x \qquad \frac{dy}{dx} = -\operatorname{cosec} x^2$

$y = \sec x \qquad \frac{dy}{dx} = \tan x \sec x$

$y = \operatorname{cosec} x \qquad \frac{dy}{dx} = -\cot x \operatorname{cosec} x$

$$\sin 2A = 2\sin A\cos A$$
$$\cos 2A = \cos^2 A - \sin^2 A = 2\cos^2 A - 1 = 1 - 2\sin^2 A.$$

$$\tan 2A = \frac{2\tan A}{1-\tan^2 A}$$

$$\sin 3A = 3\sin A - 4\sin^3 A$$
$$\cos 3A = 4\cos^3 A - 3\cos A$$

$$\tan 3A = \frac{3\tan A - \tan^3 A}{1 - 3\tan^2 A.}$$

$$\sin C + \sin D = 2\sin\frac{C+D}{2}\cos\frac{C-D}{2}$$
$$\sin C - \sin D = 2\cos\frac{C+D}{2}\sin\frac{C-D}{2}$$

$$\cos C + \cos D = 2\cos\frac{C+D}{2}\cos\frac{C-D}{2}$$
$$\cos C - \cos D = 2\sin\frac{D+C}{2}\sin\frac{D-C}{2}$$

$$2\sin A\cos B = \sin(A+B) + \sin(A-B)$$
$$2\cos A\sin B = \sin(A+B) - \sin(A-B)$$
$$2\cos A\cos B = \cos(A+B) + \cos(A-B)$$
$$2\sin A\sin B = \cos(A-B) - \cos(A+B)$$

$$\tan\frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$$

$$\cos\frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}}$$

$$\sin\frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}}$$

$$\tan\frac{B-C}{2} = \frac{b-c}{b+c}\cot\frac{A}{2}$$

$$\sin A = \frac{2t}{1+t^2}$$

$$\cos A = \frac{1-t^2}{1+t^2}$$

$$\sin(A+B) = \sin A\cos B + \cos A\sin B$$
$$\sin(A-B) = \sin A\cos B - \cos A\sin B$$

$$\cos(A+B) = \cos A\cos B - \sin A\sin B$$
$$\cos(A-B) = \cos A\cos B + \sin A\sin B$$

$$\tan(A+B) = \frac{\tan A + \tan B}{1 - \tan A\tan B}$$
$$\tan(A-B) = \frac{\tan A - \tan B}{1 + \tan A\tan B}$$

$$\sin(A+B)\sin(A-B) = \sin^2 A - \sin^2 B$$

Trigonometry

$$\Delta = r s$$
$$\Delta = r_1 (s-a)$$
$$\Delta = r_2 (s-b)$$
$$\Delta = r_3 (s-c)$$

$$\Delta = \frac{abc}{4R}$$
$$r = 4R \sin\frac{A}{2} \sin\frac{B}{2} \sin\frac{C}{2}$$
$$r_1 = 4R \sin\frac{A}{2} \cos\frac{B}{2} \cos\frac{C}{2}$$
$$r_2 = 4R \cos\frac{A}{2} \sin\frac{B}{2} \cos\frac{C}{2}$$
$$r_3 = 4R \cos\frac{A}{2} \cos\frac{B}{2} \sin\frac{C}{2}$$
$$s = 4R \cos\frac{A}{2} \cos\frac{B}{2} \cos\frac{C}{2}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R$$

$$a = b\cos C + c\cos B$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

$$\sin A = \frac{2}{bc}\sqrt{s(s-a)(s-b)(s-c)}$$

$$\Delta = \frac{1}{2}ab\sin C$$

$$\Delta = \sqrt{s(s-a)(s-b)(s-c)}$$

$$\frac{xx_1}{a^2} - \frac{yy_1}{b^2} = 1$$ Tangent at (x_1, y_1) on curve
Polar of (x_1, y_1)
Chord of contact of tangents from (x_1, y_1)

$$y - y_1 = -\frac{a^2 y_1}{b^2 x_1}(x - x_1)$$ normal at (x_1, y_1)

$$y = \frac{b^2}{a^2 m} x$$ Diameter; mid-pts of chords with grad. m

$$\frac{xx_1}{a^2} - \frac{yy_1}{b^2} = \frac{x_1^2}{a^2} - \frac{y_1^2}{b^2}$$ Chord with given mid-pt. (x_1, y_1)

$$m_1 m_2 = \frac{b^2}{a^2}$$ product of gradients of conjugate diameters.

$(a \sec\theta, b \tan\theta)$ point θ on curve.

$\left(a\frac{1+t^2}{1-t^2}, b\frac{2t}{1-t^2}\right)$ point t on curve.

$\frac{xx_1}{a^2} + \frac{yy_1}{b^2} = 1$ Tangent at (x, y_1) on curve.

$\frac{xx_1}{a^2} + \frac{yy_1}{b^2} = 1$ Chord of contact of tangents from (x, y_1)

$\frac{xx_1}{a^2} + \frac{yy_1}{b^2} = 1$ Polar of (x, y_1)

$y - y_1 = \frac{a^2 y_1}{b^2 x_1}(x - x_1)$ Normal at (x, y_1)

$y = -\frac{b^2}{a^2 m} x$ Diameter with grad. m.

$m_1 m_2 = -\frac{b^2}{a^2}$ Conjugate diameters.

$\frac{xx_1}{a^2} + \frac{yy_1}{b^2} = \frac{x_1^2}{a^2} + \frac{y_1^2}{b^2}$ Chord with mid-pt. (x_1, y_1)

$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ Hyperbola.

vertices $(a, 0)$ $(-a, 0)$

Directrices $x = \frac{a}{e}$; $x = -\frac{a}{e}$

Foci $(ae, 0)$ $(-ae, 0)$

$y = mx + \sqrt{a^2m^2 - b^2}$ tangent with gradient m.

$yy_1 = 2a(x+x_1)$ Tangent at (x_1, y_1)

$yy_1 = 2a(x+x_1)$ Chord of contact of tangents from (x_1, y_1)

$yy_1 = 2a(x+x_1)$ Polar of (x_1, y_1)

$\left(\frac{a}{m^2}, \frac{2a}{m}\right) \rightarrow$ Point of contact of tangent.

$y = \frac{2a}{m} \rightarrow$ Diameter.

$yy_1 - 2a(x+x_1) = y_1^2 - 4ax_1$
Chord with mid-pt (x_1, y_1)

$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ ellipse

Foci $(ae, 0)$; $(-ae, 0)$
Directricies $x = \frac{a}{e}$; $x = -\frac{a}{e}$
Vertices $(a, 0)$; $(-a, 0)$

$b^2 = a^2(1-e^2)$

$(a\cos\theta ; b\sin\theta) \rightarrow$ Pt on ellipse.

$y = mx \pm \sqrt{a^2m^2+b^2}$ Tan. with grad. m.

$\tan\theta = \frac{\pm 2\sqrt{h^2-ab}}{a+b}$ angle between the lines
$a+b=0$ for perpendicular lines.

$\frac{x^2-y^2}{a-b} = \frac{xy}{h}$ equation of bisectors of angle.

$ax^2+by^2+2hxy+2gx+2fy+c=0$
represents two straight lines if
$abc+2fhg = af^2+bg^2+ch^2$.

$\left.\begin{array}{l} x_2 = x_1+h \\ y_2 = y_1+K \end{array}\right\}$ New co-ords ⇒ original co-ords
Change of origin. $-h$ of K.

$\left.\begin{array}{l} x_2 = x_1\cos\theta - y_1\sin\theta \\ y_2 = x_1\sin\theta + y_1\cos\theta \end{array}\right\}$ Rotation of axes
$(x_2\, y_2)$ original co-ords.

$y^2 = 4ax$ Focus $(a,0)$ Vertex $(0,0)$

Directrix $x+a=0$
axis $y=0$ Latus Rectum $=4a$

$(at^2, 2at) \rightarrow$ Point on $y^2=4ax$

$y = mx + \frac{a}{m}$ - Tangent with grad. m.

$xx_1 + yy_1 = a^2 \Rightarrow$ Tangent at (x_1, y_1)

$xx_1 + yy_1 + g(x+x_1) + f(y+y_1) + c = 0$ Tangent at $(x_1 y_1)$

$xx_1 + yy_1 = a^2 \Rightarrow$ Polar of $(x_1 y_1)$

$xx_1 + yy_1 + g(x+x_1) + f(y+y_1) + c = 0$ Polar of $(x_1 y_1)$

$xx_1 + yy_1 = a^2 \Rightarrow$ Chord of contact

$x^2 + y^2 + 2g_1 x + 2f_1 y + c_1 - (x^2 + y^2 + 2g_2 x + 2f_2 y + c_2) = 0$
$\Rightarrow$ Common chord of two circles

$S_1 - S_2 = 0 \Rightarrow$ Radical axis

$S_1 + \lambda S_2 = 0 \Rightarrow$ Co-axal circles

$\sqrt{(g_1 - g_2)^2 + (f_1 - f_2)^2} = \sqrt{g_1^2 + f_1^2 - c_1} \pm \sqrt{g_2^2 + f_2^2 - c_2}$
$\Rightarrow$ Touching circles

$2g_1 g_2 + 2f_1 f_2 = c_1 + c_2 \Rightarrow$ Orthogonal circles

$\sqrt{h^2 + K^2 + 2gh + 2fK + c_1} \Rightarrow$ Length of tangent from (h, K)

$x^2 + y^2 + 2gx + c = 0$ where g varies is a system of co-axal circles

$ax^2 + 2hxy + by^2 = 0 \Rightarrow$ Two straight lines through the origin.

Co-ordinate Geometry

Length of perpendicular from (h, k) to
$x\cos\alpha + y\sin\alpha - p = 0$ is $h\cos\alpha + k\sin\alpha - p$

Equation of lines bisecting angles between the lines

$$x\cos\alpha_1 + y\sin\alpha_1 - p_1 = 0$$
$$x\cos\alpha_2 + y\sin\alpha_2 - p_2 = 0$$

is $x\cos\alpha_1 + y\sin\alpha_2 - p_1 = \pm(x\cos\alpha_2 + y\sin\alpha_2 - p_2)$

$$\left.\begin{array}{l} a_1x + b_1y + c_1 = 0 \\ a_2x + b_2y + c_2 = 0 \\ a_3x + b_3y + c_3 = 0 \end{array}\right\} \text{are concurrent if } \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} = 0$$

$\frac{x}{a} + \frac{y}{b} = 1$ a and b are intercepts on x and y axis

$$\frac{x-h}{\cos\theta} = \frac{y-k}{\sin\theta} = r$$

$x^2 + y^2 = a^2$

$(a\cos\theta, a\sin\theta) \rightarrow$ point on $x^2 + y^2 = a^2$

$x^2 + y^2 + 2gx + 2fy + c = 0$ centre $(-g, -f)$
radius $\sqrt{g^2 + f^2 - c}$

$y = mx \pm a\sqrt{1+m^2} \rightarrow$ Tangent of $x^2 + y^2 = a^2$

$$\log_e \frac{n+1}{n} = 2\left(\frac{1}{2n+1} + \frac{1}{3}\left(\frac{1}{2n+1}\right)^3 + \frac{1}{5}\left(\frac{1}{2n+1}\right)^5 \cdots\cdots\right.$$

$$x + iy = r(\cos\theta + i\sin\theta)$$

$$(\cos\theta + i\sin\theta)^n = (\cos n\theta + i\sin n\theta)$$

Sum of A.P. $\frac{n}{2}\left(2a + \overline{n-1}\,d\right)$ to n terms

Sum of G.P. $a\left(\frac{r^n-1}{r-1}\right)$ to n terms

Sum of G.P. $\frac{a}{1-r}$ to infinity.

$${}^nP_r = \frac{\underline{|n}}{\underline{|n-r}} \qquad {}^nC_0 + {}^nC_1 + {}^nC_2 \cdots {}^nC_n = 2^n$$

$${}^nC_r = \frac{\underline{|n}}{\underline{|n-r}\,\underline{|r}} \qquad {}^nC_r = {}^{n-1}C_r + {}^{n-1}C_{r-1}$$

$${}^nC_r = {}^{n-2}C_r + 2\,{}^{n-2}C_{r-1} + {}^{n-2}C_{r-2}$$

$$a^3 + b^3 + c^3 - 3abc = (a+b+c)(a^2+b^2+c^2-ab-bc-ac)$$

$$a + b > 2\sqrt{ab}$$

$$\sin\theta = \theta - \frac{\theta^3}{\underline{|3}} + \frac{\theta^5}{\underline{|5}} - \frac{\theta^7}{\underline{|7}} + \frac{\theta^9}{\underline{|9}} \cdots\cdots \quad \theta \text{ in radians}$$

$$\cos\theta = 1 - \frac{\theta^2}{\underline{|2}} + \frac{\theta^4}{\underline{|4}} - \frac{\theta^6}{\underline{|6}} + \frac{\theta^8}{\underline{|8}} \cdots\cdots \quad \theta \text{ in radians.}$$

algebra

$$(a+x)^n = a^n + {}^nC_1 a^{n-1}x + {}^nC_2 a^{n-2}x^2 + {}^nC_r a^{n-r}x^r + {}^nC_n x^n$$

$$(1+x)^n = 1 + {}^nC_1 x + {}^nC_2 x^2 + {}^nC_r x^r + {}^nC_n x^n$$

$$(1-x)^{-1} = 1 + x + x^2 + x^3 \ldots\ldots$$
$$(1-x)^{-2} = 1 + 2x + 3x^2 + 4x^3 \ldots\ldots$$
$$(1-x)^{-3} = 1 + 3x + \frac{3.4}{1.2}x^2 + \frac{4.5}{1.2}x^3 + \frac{5.6}{1.2}x^4$$

$$1^2 + 2^2 + 3^2 + 4^2 \ldots + n^2 = \frac{n(n+1)(2n+1)}{6}$$
$$1 + 2 + 3 + 4 \cdots + n = \frac{n(n+1)}{2}$$

$$1^3 + 2^3 + 3^3 + 4^3 \ldots + n^3 = \left\{\frac{n(n+1)}{2}\right\}^2$$

$$1.2 + 2.3 + 3.4 + 4.5 \ldots + n(n+1) = \frac{n(n+1)(n+2)}{3}$$

$$1.2.3 + 2.3.4 + 3.4.5 + 4.5.6 \ldots + n(n+1)(n+2) = \frac{n(n+1)(n+2)(n+3)}{4}$$

$$e = \lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n = 1 + \frac{1}{\underline{1}} + \frac{1}{\underline{2}} + \frac{1}{\underline{3}} + \frac{1}{\underline{4}} \ldots\ldots\ldots$$

$$\log_e(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \ldots\ldots (-1)^{n-1}\frac{x^n}{n}$$

$$\log_e(1-x) = -x - \frac{x^2}{2} - \frac{x^3}{3} - \frac{x^4}{4} - \ldots\ldots - \frac{x^n}{n}$$

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