Quadratic Equation $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

Trig identity $2\sin\theta\cos\theta = \sin(2\theta)$

Vector Components of vector A

$A_x = A\ \cos\theta$ $\quad\quad \frac{A_x}{A} = \cos\theta$

$A_y = A\ \sin\theta$ $\quad\quad \frac{A_y}{A} = \sin\theta$

Magnitude of A $= \sqrt{A_x^2 + A_y^2}$

Dir of Angle $\theta = \tan^{-1}\frac{A_y}{A_x}$ *(observe sign of components)*

$\tan\theta = \frac{A_y}{A_x} = \frac{\sin\theta}{\cos\theta}$

$R_x = A_x + B_x + C_x$ … $\quad\quad R_y = A_y + B_y + C_y$ …

Negative vector same magnitude opp. direction.

Velocity – displacement changing with time

$V_{av,x} = \frac{\Delta x}{\Delta t}$ $\quad$ *Δ is Final minus Initial*

0 slope = no velocity

Acceleration – velocity changing with time

$a_{av,x} = \frac{\Delta V}{\Delta t}$ $\quad$ *Δ is Final minus Initial*

$V_{av,x} = \left(\frac{V_{0x}+V_x}{2}\right)$ *For constant acceleration only*

Equations for Constant Acceleration

$a_x = \frac{V_x - V_{ox}}{t}$ $\quad\quad V_x = V_{0x} + a_x t$

$t = \frac{V_x - V_{ox}}{a_x}$

$V_x^2 = V_{0x}^2 + 2a_x(x - x_0)$ $\;(\boldsymbol{or})\;$ $a = \frac{V_f^2 - V_i^2}{2(x_f - x_i)}$

$x = x_0 + V_{0x}t + \frac{a_x t^2}{2}$ $\quad$ *Position after time t*

$x - x_0 = \left(\frac{V_{0x}+V_x}{2}\right)t$ $\quad$ *Distance traveled in t* $x - x_0 =$

$(V_{av})\quad(t)\quad = \;= \left(\frac{V_{0x}+V_x}{2}\right)\left(\frac{V_x - V_{0x}}{A_x}\right) = \frac{V_x^2 - V_{0x}^2}{2a_x}$

Free Fall – Vertical Motion *g, 9.81 m/s² (or rd. to 10 m/s²)*

$y = y_0 + V_{iy}t + \frac{-g_y t^2}{2}$

$V_y = V_{0y} - g_y t$

$V_y^2 = V_{0y}^2 + 2g_y(y - y_0)$

At highest point before fall, V_y

Projectile Motion Horizontal (θ = 0)

$x = x_0 + V_{0x}t$ $\quad\quad V_x = V_{ox}$

$y = y_0 + V_{0y}t - \frac{gt^2}{2}$ $\quad\quad V_y = V_{0y} - gt$

Projectile Motion At An Angle (θ > 0)

$x = x_0 + (V_0\cos\theta_0)\,t$

$V_x = (V_0\cos\theta_0)$

$y = y_0 + (V_0\sin\theta_0)\,t - \frac{gt^2}{2}$

$V_y = (V_0\sin\theta_0) - gt$

Distance from origin $\quad r = \sqrt{x^2 + y^2}$

Magnitude Velocity $\quad V = \sqrt{V_x^2 + V_y^2}$

Direction Velocity $\quad \theta = \tan^{-1}\frac{V_y}{V_x}$

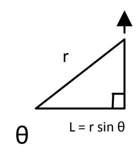
Total Travel Time $\quad t = \frac{2V_i\sin\theta}{g}$

Distance $\quad x = \frac{2V_i^2\sin\theta\cos\theta}{g} = \frac{V_i^2}{g}\sin(2\theta)$

Max. Height $V_y = 0$

Torque $\tau = r(F\sin\theta)$

Moment Arm $l = r\ \sin(\theta)$



Hooke's Law $F_{spring} = -kx, k = \frac{F}{x}$

Friction $f_k = f_k n;\ \ f_s = f_s n$ (proportional to normal force)

2nd Law: $\Sigma\vec{F} = m\vec{a}\ (or)\ \Sigma\vec{F_x} = m\vec{a_x}\ ;\ \Sigma\vec{F_y} = m\vec{a_y}$

$Equil\ \Sigma\vec{F} = 0\ ;\ \Sigma\vec{\tau} = 0$

3rd Law: $\overrightarrow{F_{a\ on\ b}} = \overrightarrow{F_{b\ on\ a}}$

Circular Motion

$a_{rad} = \frac{v^2}{R}$ $\quad v = \frac{2\pi R}{T} = 2\pi Rf$ $\quad a_{rad} = \frac{4\pi^2 R}{T^2}$

$F_{net} = m\frac{v^2}{R}$

$F_g = G\frac{m_1 m_2}{r^2}$ $\quad w = mg = G\frac{m_1 m_2}{r^2}$ $\quad g = G\frac{m_e}{R_e^2}$ **Satellite**

$v = \sqrt{\frac{Gm_e}{r}}\ ;\ \ v = \frac{2\pi R}{T}\ ;\ F_g = G\frac{m_1 m_2}{r^2}$

$T = \frac{2\pi R}{v} = 2\pi r\sqrt{\frac{r}{Gm_e}} = \frac{2\pi r^{3/2}}{\sqrt{Gm_e}}$

$G = 6.67\times10^{-11}\ NM^2/kg^2$

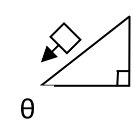
Incline Plane

Normal Force $\vec{N}$ = mg cosθ

(perpindicular to surface)

a = g sin θ

Accel=0, μ_k on slope = tan θ = sin/cos



20mm = 2cm = 0.02m $\quad$ 1mm = 0.001m $\quad$ 20g=0.02kg 1g=0.001kg

1 L= 0.001 m³ $\quad$ 1 m³ = 1000 L $\quad$ m²=10000cm²

Work

$W = F_{parallel} s = (F cos\varphi) s$

unit 1 J. = 1 N m

Incline Plane

$W_{friction} = \left(-\mu \cdot mgCos(\theta)\right) d$

$W_{gravity} = \left(mgSin(\theta)\right)$

$W_{Normal} = 0$

$W_{NET} = W_{gravity} + |W_{friction}|$

Kinetic Energy

$F_{total} s = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$

$K = \frac{1}{2} m v^2$

$W_{total} = K_f - K_i = \Delta K$

1 J. = 1 N·m = 1(kg ·m/s^2) · m = 1 kg·m^2/s^2

From Rest (e.g. explosions)

$0 = m_1 v_1 + m_2 v_2$; $v_1 = \frac{m_2 v_2}{m_1}$; $v_2 = \frac{m_1 v_1}{m_2}$

Work by Varying Force (F=kx)

$W = \frac{1}{2} k x^2$

Potential Energy

(for y = height)

$W_{grav} = Fs = mg(y_i - y_f) = mgy_i - mgy_f$

$U_{grav} = mgy = gravitational\ potential\ energy$

$\frac{1}{2} m v_i^2 + mgy_i = \frac{1}{2} m v_f^2 + mgy_f$

K + U = total mechanical energy

Wk Energy Theorem:$K_i + U_i = K_f + U_f$

Elastic Potential Energy

(x = displ. from un-stretched length)

$U_{el} = \frac{1}{2} k x^2$

Power

$P_{av} = \frac{\Delta W}{\Delta T}$; $P_{inst} = F_{parallel} v$

Momentum $\vec{p}$

$\vec{p} = m\vec{v}$; $\vec{p} = \vec{p}_a + \vec{p}_b + \vec{p}_c \dots$

(kg·m/s) it is vector so add components

Newton 2nd: $\sum \vec{F} = \lim_{\Delta t \to 0} \frac{\overrightarrow{\Delta p}}{\Delta t}$

momentum of isolated system is constant

$m_{1i} v_{1i} + m_{2i} v_{2i} + \cdots = m_{1f} v_{1f} + m_{2f} v_{2f} + \cdots$

Elastic Collision

Same kinetic energy after collision

$KE_i = KE_f$; $\rightarrow$ $\frac{1}{2} m v_i^2 = \frac{1}{2} m v_f^2$

clue: items bounce: billiard, car on ice)

In-elastic Collision

Less kinetic energy after collision

Heat

cal = 4.186 J ; Joule = 0.239 cal

BTU = 778 ft·lb=252 cal = 1055 J

c = Specific Heat to Raise Temp c units = J/KgK

Q = mcΔT (amount of heat in Joules)

L_f=Heat of Fusion to melt a mass L_f units =J/kg

Q = m L_f (amount of heat in Joules)

L_v = Heat of Vaporization (to gas) L_v units = J/kg

Q = m L_v (amount of heat in Joules)

Boyle's Law: $\boldsymbol{pV = constant}$, $when\ \boldsymbol{n}\ and\ \boldsymbol{T}\ constant$

Charles's Law:

$\boldsymbol{p} = \boldsymbol{T}\ when\ \boldsymbol{n}\ and\ \boldsymbol{V}\ constant$

Ideal Gas Equation

$$pV = nRT$$

R= 8.31 J/mol·K

STP : 0^oC=273K and 1 atm=1.013x10^5 Pa

$(for\ constant\ m): \frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} = constant$

$n = \frac{m_{mass\ total}}{M_{molar\ mass}}$

$\frac{m_{mass\ of\ sample}}{\rho_{density}} = V_{vol}$ $\rho = \frac{m}{V}$ $m = \rho V$

Caution:

M usually in g/mol make sure m and M are in same units

e.g. O_2 M=32 g/mol or 32 x 10^{-3} kg/mol

Buoyant Force

$\boldsymbol{F_b = \rho_{fluid}\, g\, V_{volume}}$

Archimedes principle, fluid exerts an upward force on the object equal to the weight of the fluid displaced.

Pascal's Law

$p = p_0 - \rho g h$ Variation of pressure with height

$p = \frac{F_1}{A_1} = \frac{F_2}{A_2}$ $and F_2 = \frac{A_2}{A_1} F_1$

$\frac{mv^2}{2} = W_{fr} = \mu mgd$ $d = \frac{v_i + v_f}{2}\ t\ (if\ stop)$

Constants

$\epsilon_0 \cong 8.85 \times 10^{-12}\ C^2/(Nm^2)$

$k = \frac{1}{4\pi\epsilon_0}$

$k \cong 8.99 \times 10^{9}\ Nm^2/C^2$

$1eV = 1.6 \times 10^{-19} J$

$\mu_0 = 4\pi \times 10^{-7} = 1.26 \times 10^{-6}\ N \cdot A^{-2} or \frac{H}{m} or \frac{T\cdot m}{A}$

$B_{earth} = 5 \times 10^{-5} T$

Subscript of Force F_{32} = Force on 3 from 2

Unit Charge *e (proton⁺, electron⁻)*

$e \cong 1.60 \times 10^{-19}\ C$

Masses

$electron \cong 9.1 \times 10^{-31}\ kg$

$proton\ or\ neutron \cong 1.7 \times 10^{-27}\ kg$

$electrons\ per\ charge = n = \frac{q}{e}$

Units

$N = \frac{m\cdot kg}{s^2}$ $F = \frac{C}{V}$

$V = \frac{Nm}{C} = \frac{J}{C}$ $E = \frac{V}{m} = \frac{N}{C}$

$R(\Omega) = \frac{V}{I}, A = \frac{C}{s}$

$T = \frac{Wb}{m^2} = kg \cdot s^2 \cdot A^{-1}$ $Wb = Tm^2 = \frac{Nm}{A}$

Coulomb's Law

$F = k\frac{|q_1 q_2|}{r^2}$

Magnetic Field

$F = |q|vBsin\theta$

$F_{onConductor} = BI\Delta Lsin\theta$

$F_{2wires} = \frac{\mu_0 I_1 I_2}{2\pi r}\Delta l$

$B_{ctrLoop} = \frac{\mu_0 IN}{2R}$

Particles (circ. Motion): $R = \frac{mv}{|q|B}$ $F = |q|vB = \frac{mv^2}{r}$

$B_{longwire} = \frac{\mu_0 I}{2\pi r}$

Magnetic Flux

$\Phi_B = BA\ cos\phi\ \ (Wb)$

Faraday's Law $\mathcal{E} = \frac{\Delta\Phi_B}{\Delta t} = \mathcal{E} = -N\frac{\Phi_2 - \Phi_1}{\Delta t}$

Gauss's Law

$\Phi_E = \sum E_\perp \Delta A = 4\pi kq$

Electric Flux Φ_E over area A

$\Phi_E = EA\ \cos\phi$

Work & Energy

$W = Fd\ \cos\varphi = qEd\ \cos\varphi$

$W = \frac{Q^2}{2C} = \frac{QV}{2} = \frac{CV^2}{2} = qV$

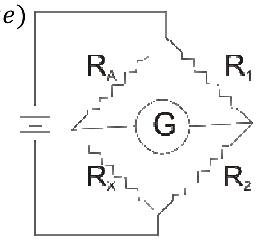
$W_{21} = q_2(V_a - V_b) = q_2(k\frac{q_1}{r_a} - k\frac{q_1}{r_b})$

$PE_{21} = q_2 V_b = q_2(k\frac{q_1}{r_b})$

Electric Field

$\vec{E} = \frac{\vec{F'}}{q'} = \frac{ma}{q} = \frac{V}{d} = \frac{V}{\Delta x}$

$E = k\frac{|q|}{r^2}$ $(due\ to\ point\ charge)$



Volt and Ohms Law

$V = k\frac{q}{r}$ $(at\ dist\ r\ from\ q)$

$V = IR; P = VI$ $\mathcal{E} = Ir + Ir$

$AC:\ I_{rms} = \frac{I_{max}}{\sqrt{2}}\ ;\ V_{rms} = \frac{V_{max}}{\sqrt{2}}$

Transformer $\frac{V_2}{V_1} = \frac{N_2}{N_1}$ Wheatstone $\frac{R_a}{R_x} = \frac{R_1}{R_2}$

Resistance

$R = \frac{V}{I}$ $Ohms\ Law\ V = RI$ $P = VI$ $I = \frac{Q}{t}$

$R = \rho\frac{L}{A}$ Resistivity (length cross sectional area)

Series: $R_{eq} = R_1 + R_2 + R_3$ ... (I same, V differs)

Parallel: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ ... (V same, I differs)

Capacitance

$C = \frac{Q}{V_{ab}} = \epsilon_0\frac{A}{d}$ ('d' distance between plates)

$\sigma = \frac{Q}{A}\ or - \frac{Q}{A}$ (surface charge density each plate)

$E = \frac{V}{d}$

$\omega = {}^1/_2\ \varepsilon_0 E^2\ \ J/M$ (energy density)

Parallel: $C_{eq} = C_1 + C_2 + C_3$ ... (V same, Q differs)

Series: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ ...(Q same, V differs)

Diffraction $a = \frac{2m\lambda L}{d_m}$

Optics (spherical lens) 1 goes into 2

$f_{ocal} = \frac{R}{2}$ $m = -\frac{h}{H} = -\frac{d_i}{d_o}$

Conv. $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} = \frac{2}{R}$ Diverg $\frac{1}{d_o} - \frac{1}{d_i} = \frac{1}{f}$

$n = \frac{c}{v}$ Snell's: $n\ sin\theta_1 = n\ sin\theta_2$

Critical angle: $sin\theta_c = \frac{n_2}{n_1}$

Thin Lens Equation: $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

20mm = 2cm = 0.02m 1mm = 0.001m 20g=0.02kg 1g=0.001kg

1 L= 0.001 m^3 1 m^3 = 1000 L m^2=10000cm^2