⊛ Formula Sheet (XI) Solutions

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① $|\vec{R}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$\tan\phi = \dfrac{B\sin\theta}{A + B\cos\theta}$

② Eqns of Motion

1^{st}: $v = u + at$

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

3^{rd}: $v^2 = u^2 + 2as$

③ $S_n = u + \frac{a}{2}(2n-1)$

④ $v_{instantaneous} = \dfrac{dx}{dt}$

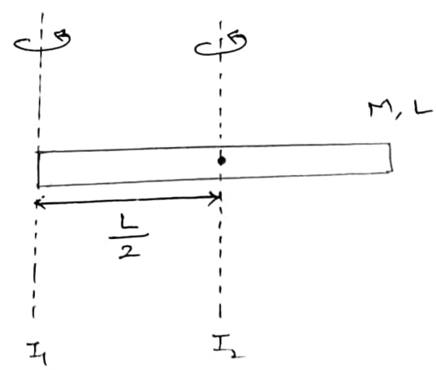
⑤ $\boxed{I_2 = \dfrac{ML^2}{12}}$

For I_1, we apply parallel axis theorem

$\therefore I_1 = I_2 + M\left(\frac{L}{2}\right)^2$

$= \dfrac{ML^2}{12} + \dfrac{ML^2 \times 3}{4 \times 3}$

$\boxed{I_1 = \dfrac{ML^2}{3}}$



⑥ $I = \frac{2}{5} MR^2$

⑦ $I = mr^2$

⑧ $$\boxed{I_3 = \frac{ML^2}{6}}$$

Now, I_1 and I_2 are symmetrically "equivalent".

$\therefore$ Let $I_1 = I_2 = I'$

Now, we apply perpendicular axis theorem,

$$I_3 = I_1 + I_2$$

$$I_3 = I' + I'$$

$$\therefore I' = \boxed{\frac{ML^2}{12} = \cancel{I_3}\ I_1 = I_2}$$

Now, for I_4 we can apply parallel axis theorem

$$I_4 = I_1 + M\left(\frac{L}{2}\right)^2$$

$$= \frac{ML^2}{12} + \frac{ML^2 \times 3}{4 \times 3}$$

$$\boxed{I_4 = \frac{ML^2}{3}}$$

⑨ $\therefore$

a) $t = \sqrt{\frac{2h}{g}}$ b) $v = \sqrt{2gh}$

(10)

$$a = v\left(\frac{dv}{dx}\right)$$

(11)

a) $y_{com} = \frac{h}{4}$ (solid) b) $y_{com} = \frac{h}{3}$ (hollow)

b) Ring, $y_{com} = \frac{2R}{\pi}$

Disc, $y_{com} = \frac{4R}{3\pi}$

c) Hemispherical shell, $y_{com} = \frac{R}{2}$

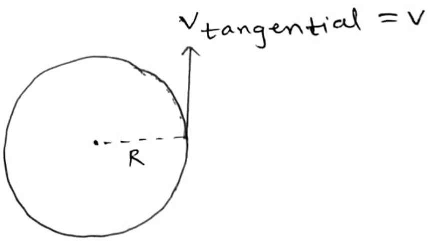
Solid Hemisphere, $y_{com} = \frac{3R}{8}$

(12)

a) $I_p = 0$ $(r < R)$ $I_p = \frac{GM}{r^2}$ $(r > R)$

(13) a) $\vec{v} = \vec{\omega} \times \vec{r}$

b) $a_c = \frac{v^2}{r}$



c) $a_t = \frac{dv}{dt} \rightarrow v_{tangential}$

d) $a = \sqrt{a_c^2 + a_t^2}$

(14) Eqn of Trajectory:

$$y = x\tan\theta - \frac{1}{2}\cdot\frac{gx^2}{u^2\cos^2\theta}$$

(15) $W = \vec{F}\cdot\vec{s}$

$$= \int \vec{F}\cdot\vec{ds} \quad \text{(Integral form)}$$

(16) b) Solid Sphere

$$I_p = \frac{GMr}{R^3} \quad (r<R) \qquad I_p = \frac{GM}{r^2} \quad (r>R)$$

(17) $J = \int F\,dt$

(18) Impulse - momentum Theorem : $J = \Delta p$

(19) $V_{esc} = \sqrt{2gR}$

(20)

$$\boxed{I_1 = \frac{MR^2}{2}}$$

Now I_2 and I_3 are equivalent due to symmetry

$$I_1 = I_2 + I_3 \qquad (\because \text{Let } I_2 = I_3 = I_d)$$

$$I_1 = I_d + I_d$$

$$\therefore I_d = \boxed{\frac{MR^2}{4} = I_2 = I_3}$$

(21)

$$e = \frac{V_{sep}}{V_{app}} = \frac{v_1 + v_2}{u_1 - u_2}$$ (for the given case)

(22)

$$B = \frac{-P}{\left(\frac{\Delta V}{V}\right)}$$

(23)

a) $$g' = \frac{g}{\left(1+\frac{h}{R}\right)^2} \approx \underbrace{g\left(1 - \frac{2h}{R}\right)}_{\text{Approximation}}$$

b) $$g' = g\left(1 - \frac{d}{R}\right)$$

(24) Eqn of continuity : $Av_1 = av_2$

(25) $$F_B = \underbrace{V}_{\text{volume immersed}}\ \underbrace{\rho}_{\text{density of fluid}}\ g$$

(26) Areal velocity $\Rightarrow$ $\boxed{\frac{dA}{dt} = \frac{L}{2m}}$

$L \Rightarrow$ angular momentum

$m \Rightarrow$ mass

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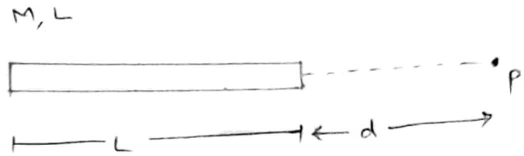
$$I_1 = \frac{2}{3} M R^2$$

28

$$I_p = \frac{GM}{(L+d)\,d} \quad \underline{\underline{(\text{rod})}}$$



$$I_p = \frac{GM}{R^2} \cdot \left(\frac{\sin\theta}{\theta}\right) \quad \left(\underline{\underline{\text{for circular arc}}}\right)$$

29

$$|\vec{\tau}| = r F \sin\theta$$

$$\vec{\tau} = \vec{r} \times \vec{F} \quad (\text{vector form})$$

30

$$\boxed{T.E = -K.E = \frac{P.E}{2}}$$

31

i) $\omega = \omega_0 + \alpha t$

ii) $\theta = \omega_0 t + \frac{1}{2} \alpha t^2$

iii) $\omega^2 = \omega_0^2 + 2\alpha\theta$

32

$$P_A = P_0 + \rho g h$$

33

$$P_1 + \rho g h_1 + \frac{1}{2} \rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2} \rho v_2^2$$

Bernoullis Theorem

(34)

i) $V_p = \ominus \dfrac{GM}{r} \quad (r > R)$

ii) $V_p = \ominus \dfrac{GM}{2R^3}\left(3R^2 - r^2\right) \quad (r < R)$

ii) on the axis of ring

$$V_p = \ominus \frac{GM}{\sqrt{R^2 + x^2}}$$

(35) $\alpha : \beta : \gamma = 1 : 2 : 3$.

(36)

$$\boxed{\text{Work done by all forces} = \Delta K.E} \quad \text{(original)}$$

$$\Delta K + \Delta U = \underbrace{W_{nc}}_{\text{non-conservative}} + \underbrace{W_{other}\ (\text{except } c)}_{\text{conservative}}$$

→ Modified form of Work - Energy Theorem (optional)

(37) $\tan\theta = \dfrac{a}{g}$

(38)

$$\underbrace{-\frac{dT}{dt}}_{\text{rate of cooling}} = k\left[T_{avg} - \underbrace{T_0}_{\text{surrounding Temperature}}\right]$$

(39) $Y = \frac{\text{stress}}{\text{strain}}$

(40) $\Delta Q = \Delta U + W$

(41) $C_p - C_v = R$

(42) $P = \frac{1}{3} \rho V_{rms}^2$

(43)

Type	f	C_p	C_v
mono	3	$\frac{5R}{2}$	$\frac{3R}{2}$
di	5	$\frac{7R}{2}$	$\frac{5R}{2}$
Tri (linear)	5	$\frac{7R}{2}$	$\frac{5R}{2}$
Tri (non-linear)	6	$4R$	$3R$

(44) $V_{rms} > V_{avg} > V_{mp}$

(45) $T = 2\pi \sqrt{\frac{I}{mgl}}$

(46) Stefan's law

$P = e\sigma A T^4$

(47) $F = -\frac{dU}{dx}$

(48) For string,

V_{min} (bottom)

$= \sqrt{5gR}$

For rod,

V_{min} (bottom)

$= \sqrt{4gR}$

(49) $F_t = -u\left(\frac{dm}{dt}\right)$

(50) $W_{adiabatic} = ?$ (w)

$W = \frac{1}{1-\gamma}(P_2V_2 - P_1V_1)$

(51) $V_p = \ominus \frac{GM}{R}$ $(r < R)$

$V_p = \ominus \frac{GM}{r}$ $(r > R)$

(52)

$$\frac{dQ}{dt} = kA\left(\frac{dT}{dx}\right)$$

(53)

$$v = \pm\omega\sqrt{A^2 - x^2}$$

(54)

$$W_{isothermal} = nRT \ln\left(\frac{V_2}{V_1}\right)$$

(55)

$$V_T = \frac{2}{9} \cdot \frac{r^2 g (\rho - \rho_L)}{\eta}$$

(56)

$$\mu = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \ominus \frac{(\Delta r/r)}{(\Delta l/l)}$$

(57)

$$\tau = I\alpha$$

(58)

$$\vec{L} = m(\vec{r} \times \vec{v})$$ [for point mass]

$$\vec{L} = I\vec{\omega}$$ (bodies)

(59)

(i) $\longrightarrow$ isobaric

(ii) $\longrightarrow$ isothermal

(iii) $\longrightarrow$ adiabatic

(iv) $\longrightarrow$ isochoric

(60) $$T = 2\pi\sqrt{\frac{m}{k_1 + k_2}}$$

(61) $$U = \frac{1}{2} K A^2$$

(62) $$T = 2\pi\sqrt{\frac{I}{c}}$$ $c \rightarrow$ Torsional constant

(63) Weins Displacement Law

$$\lambda \propto \frac{1}{T} \Rightarrow \lambda T = b = \text{constant}$$

(64) Ideal gas equation

$$PV = nRT$$

(65) $$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$V_{mp} = \sqrt{\frac{2RT}{M}}$$

$$V_{avg} = \sqrt{\frac{8}{\pi} \cdot \frac{RT}{M}}$$

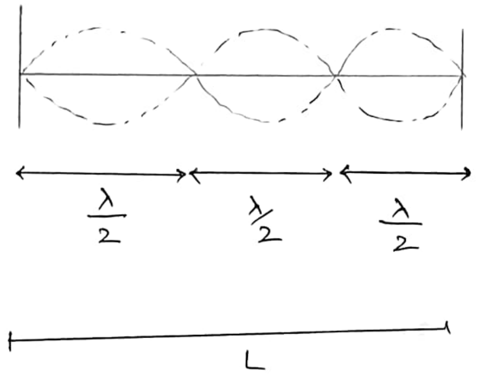
(66) $$\eta = 1 - \frac{T_2}{T_1}$$

(67) $W = 0$

(68) $V_{wave} = \dfrac{\omega}{k}$

(69) $C = \dfrac{\Delta Q}{n \Delta T}$

(70) string is fixed at both ends



$\therefore \quad L = 3\dfrac{\lambda}{2} \Rightarrow \therefore \underbrace{\lambda = \dfrac{2L}{3}}$

We know,

$$v = f\lambda$$

$$\therefore f = \frac{v}{\left(\frac{2L}{3}\right)} = \frac{3v}{2L}$$

$$\therefore \boxed{f = \frac{3v}{2L}} \quad \text{(freq)}$$

71

$$\Delta\phi = \left(\frac{2\pi}{\lambda}\right) \cdot \Delta x \qquad \text{(with } x\text{)}$$

$$\Delta\phi = \left(\frac{2\pi}{T}\right) \cdot \Delta t \qquad \text{(with } t\text{)}$$

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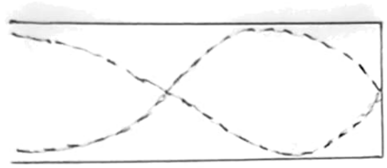

73 $a = -\omega^2 x$

74 $U = nC_v\Delta T = \frac{f}{2} nR\Delta T$

75 $k = \frac{R}{N_A}$

76 $E = \frac{1}{2} kT$

77 $T = 2\pi\sqrt{\frac{l}{g}}$

78 $k = \frac{2\pi}{\lambda}$

79 $\nu_{apparent} = \left(\frac{V \pm V_o}{V \pm V_s}\right) \nu_{actual}$

(80) $I = 2\pi^2 f^2 A^2 \rho v$

(81)

a) units of G : $N m^2 kg^{-2}$

b) Unit of R : $J K^{-1} mol^{-1}$

c) unit of b : m - k

d) Intensity unit : W/m^2