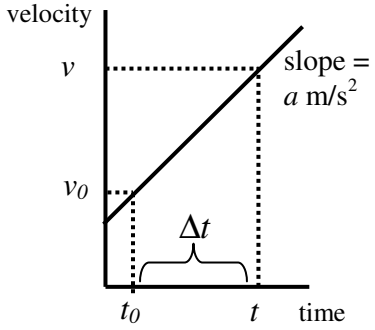
# Formula Sheet

## 1. Mechanics and Gravitation




$v^2 = v_0^{\,2} + 2a(x - x_0)$

$\vec{p} = m\vec{v}$

$\vec{F}_{net} = d\vec{p}/dt = m\vec{a}$

$s = r\theta$

$v = r\omega$

$a_t = r\alpha$

$a_r = v^2 / r$

$T = 2\pi / \omega$

$f = \mu N$

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

$dW = \vec{F}.d\vec{s}$

$P = dW / dt$

$W_{ext} = \Delta K + \Delta U + \Delta E_{thermal}$

$\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$

$\vec{\tau}_{net} = d\vec{L}/dt = I\alpha$

$I = \sum_i m_i r_i^2$

$I = I_c + MD^2$

$MX_{cm} = \sum_i m_i x_i$

$\tau = I\omega\Omega_{precession}$

$F = Gm_1 m_2 / r^2$

$U = mgh$

$U = -Gm_1 m_2 / r$

$F = kx$

$U = \frac{1}{2} kx^2$

$x = A\cos(\omega_s t + \theta)$

$\omega_s^{\,2} = k / m$

$\omega_s^{\,2} = mg\ell_{cm} / I$

## 2. Fluids/Elasticity/Materials

$p = F / A$

$p = p_0 + \rho g d$

$v_1 A_1 = v_2 A_2$

$Q = vA$

$p + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$

$\frac{F}{A} = Y\frac{\Delta L}{L}$

$p = \frac{F}{A} = -B\frac{\Delta V}{V}$

$\nu = -\varepsilon_{transverse} / \varepsilon_{longitudinal}$

$\text{Heat input} = m c_p \Delta T$

$PV = nRT = N k_B T$

## 3. Electricity and Magnetism

$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$

$\vec{F} = q\vec{E}$

$\phi_e = \vec{E} \cdot \vec{A} = E_n A$

$\sum E_n \Delta A = q_{inside} / \varepsilon_0$

$V = \frac{Q}{4\pi\varepsilon_0 r}$

$\Delta U = q\Delta V$

$P = IV$

$R = \rho\ell / A$

$V = IR$

$R_s = R_1 + R_2 + R_3 + \ldots$

$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$

$I = nqv_d A$

$\vec{F} = q\vec{v} \times \vec{B}$

$\vec{F} = I\vec{\ell} \times \vec{B}$

$\vec{\tau} = I\vec{A} \times \vec{B}$

$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{s} \times \hat{r}}{r^2}$

$B = \frac{\mu_0 I}{4\pi a}(\cos\theta_1 - \cos\theta_2)$

$B = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$

$B = \frac{\mu_0 IN}{2L}(\cos\theta_1 - \cos\theta_2)$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{inside}$

$\phi_m = \vec{B} \cdot \vec{A}$

$V = d\phi_m / dt$

## 4. Optics

$n = \frac{c}{v}$

$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{(n_1 - n_2)}{R}$

$M = -\frac{n_1 s'}{n_2 s}$

$m = \frac{\theta_{aided}}{\theta_{unaided}}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$M = -s'/s$

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{1}{f} = \frac{2}{R}$

Optical sign convention for refracting surfaces:
a) $s$ is +ve if the object is in front of surface
b) $s$ is $-$ve if the object is behind the surface
c) $R$ is +ve if the centre of curvature is behind the surface

## 5. Quantum Physics

$E = hf$

$K_{\max} = hf - E_b$

$\lambda = h / p$

$E_n = -13.6 / n^2 \ \text{eV}$

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## 6. Mathematical Formulae

$$\frac{dx^n}{dx} = nx^{n-1}$$

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

$$\frac{d}{dt}\sin \omega t = \omega \cos \omega t$$

$$\frac{d}{dt}\cos \omega t = -\omega \sin \omega t$$

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

$$\vec{A} \cdot \vec{B} = AB\cos\theta$$
$$= A_x B_x + A_y B_y + A_z B_z$$

$$\left|\vec{A} \times \vec{B}\right| = AB\sin\theta$$

$$a^2 = b^2 + c^2 - 2bc\cos\theta$$

## 7. Fundamental constants and physical properties

$c = 299\,792\,458$ m/s

$e = 1.602 \times 10^{-19}$ C

$m_e = 9.109 \times 10^{-31}$ kg

$m_p \approx m_n \approx 1.67 \times 10^{-27}$ kg

$1\,\text{amu} = 1.661 \times 10^{-27}$ kg

$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm$^{-1}$;

$$\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2}$$

$\mu_0 = 4\pi \times 10^{-7}$ NA$^{-2}$

$h = 6.626 \times 10^{-34}$ Js; $\quad \hbar = 1.055 \times 10^{-34}$ Js

$k_B = 1.381 \times 10^{-23}$ JK$^{-1}$

$N_A = 6.02 \times 10^{23}$ mol$^{-1}$

$R = 8.31$ Jmol$^{-1}$K$^{-1}$

$c_p$ (water) $= 4190$ Jkg$^{-1}$K$^{-1}$

$c_p$ (ice) $= 2090$ Jkg$^{-1}$K$^{-1}$

$\rho$ (water) $= 1000$ kgm$^{-3}$

$\rho$ (ice) $= 920$ kgm$^{-3}$

heat of fusion (water $\leftrightarrow$ ice) $= 3.33 \times 10^5$ Jkg$^{-1}$

heat of vaporization (water $\leftrightarrow$ steam) $= 22.6 \times 10^5$ Jkg$^{-1}$

1 atm $= 1.013 \times 10^5$ Nm$^{-2}$ $= 760$ mmHg

$g = 9.80$ ms$^{-2}$

G $= 6.673 \times 10^{-11}$ Nm$^2$kg$^{-2}$

mass of Earth $= 5.974 \times 10^{24}$ kg

mass of moon $= 7.36 \times 10^{22}$ kg

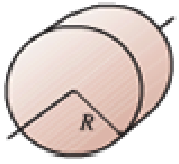
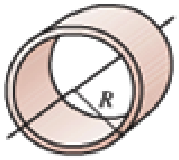
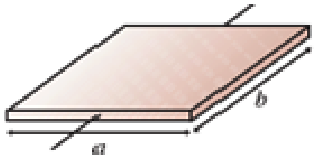
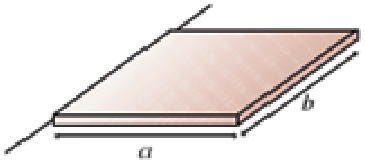
mass of sun $= 1.99 \times 10^{30}$ kg

radius of Earth $= 6.378 \times 10^6$ m

radius of moon $= 1.74 \times 10^6$ m

radius of Earth's orbit (1 AU) $= 1.496 \times 10^{11}$ m

## 8. Moments of inertia

| Object and axis | Picture | $I$ |
|---|---|---|
| Cylinder or disk, about center |  | $\frac{1}{2}MR^2$ |
| Cylindrical hoop, about center |  | $MR^2$ |
| Solid sphere, about diameter |  | $\frac{2}{5}MR^2$ |
| Spherical shell, about diameter |  | $\frac{2}{3}MR^2$ |
| Plane or slab, about center |  | $\frac{1}{12}Ma^2$ |
| Plane or slab, about edge |  | $\frac{1}{3}Ma^2$ |

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