Data and Formulae Booklet for Advanced and Intermediate Physics

The following equations and formulae may be useful in answering some of the questions in the examination.

Mechanics kinematics: uniformly accelerated motion

Equations of motion:

$$v = u + at$$

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

$$s = \left(\frac{u+v}{2}\right)t$$

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

Mechanics dynamics

Newton's second law: $F = \frac{dp}{dt} = \frac{d(mv)}{dt}$

Kinetic Energy: $\text{K.E.} = \frac{1}{2}mv^2$

Potential Energy: $\text{P.E.} = mgh$

Mechanical Work Done: $W = Fs$

Power: $P = Fv$

Momentum: $p = mv$

Mechanics dynamics: circular and rotational motion

Angular displacement: $s = r\theta$

Angular speed: $v = r\omega$ $\omega = \frac{d\theta}{dt}$

Angular acceleration: $a = r\alpha$ $\alpha = \frac{d\omega}{dt}$

Centripetal acceleration: $a = \frac{v^2}{r}$

Centripetal force: $F = \frac{mv^2}{r} = mr\omega^2$

Period: $T = \frac{2\pi r}{v}$

Angular momentum: $L = I\omega$

Torque: $\tau = I\alpha$

Work done in rotation: $W = \tau\theta$

Rotational Kinetic energy: $\text{K.E.} = \frac{1}{2} I\omega^2$

Simple harmonic motion

Displacement: $x = x_0 \sin(\omega t + \phi)$

Velocity:

$v = \omega x_0 \cos(\omega t + \phi)$

$v = \pm\omega\sqrt{x_0^2 - x^2}$

Acceleration: $a = -\omega^2 x$

Period: $T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$

Mass on a light spring: $T = 2\pi\sqrt{\dfrac{m}{k}}$

Ray optics

Refractive index: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

$${}_1n_2 = \frac{\sin(\theta_1)}{\sin(\theta_2)} = \frac{v_1}{v_2}$$

Thin lenses: $\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$ (real is positive)

$\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$ (Cartesian)

Magnification: $m = \dfrac{v}{u} = \dfrac{h_i}{h_o}$ (real is positive)

$m = -\dfrac{v}{u} = -\dfrac{h_i}{h_o}$ (Cartesian)

Current electricity

Ohm's Law: $V = IR$

Current: $I = nAvq$

Resistors in series: $R_{\text{Total}} = R_1 + R_2 + \dots$

Resistors in parallel: $\dfrac{1}{R_{\text{Total}}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dots$

Potential divider rule: $\dfrac{V_1}{V_{\text{Total}}} = \dfrac{R_1}{R_{\text{Total}}}$

Power: $P = IV = I^2R = \dfrac{V^2}{R}$

Resistivity: $\rho = \dfrac{RA}{l}$

Temperature coefficient: $\alpha = \dfrac{R_\theta - R_0}{R_0\theta}$

Alternating current

For sinusoidal alternating supply voltage: $V = V_0 \sin(\omega t + \phi)$

$V_0 = BAN\omega$

Root mean square for sinusoidal alternating current and voltage: $I_{\text{rms}} = \dfrac{I_0}{\sqrt{2}}$ $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}}$

Reactance: $X_L = 2\pi fL$ $X_C = \dfrac{1}{2\pi fC}$

Stationary waves on strings

Frequency of waves on strings: $f_n = \dfrac{n}{2L}\sqrt{\dfrac{T}{\mu}} = nf_1$

Speed of waves on strings: $v = \sqrt{\dfrac{T}{\mu}}$

Wave motion

Velocity of a wave: $v = f\lambda$

Two slit interference: $y = \dfrac{\lambda D}{d}$

Diffraction grating: $d\sin(\theta) = n\lambda$ $\quad d = \dfrac{1}{N}$

Single slit diffraction: $\sin(\theta) \approx \theta = \dfrac{\lambda}{a}$

Diffraction of circular aperture: $\sin(\theta) \approx \theta = 1.22\dfrac{\lambda}{a}$

Fields

Electric field strength: $E = \dfrac{F}{q} = -\dfrac{dV}{dr}$

Uniform electric field: $E = \dfrac{V}{d}$

Force between point charges: $F = \dfrac{Qq}{4\pi\varepsilon r^2}$

Electric field strength due to a point charge: $E = \dfrac{Q}{4\pi\varepsilon r^2}$

Relative permittivity: $\varepsilon_r = \dfrac{\varepsilon}{\varepsilon_0}$

Electric potential due to a point charge: $V = \dfrac{Q}{4\pi\varepsilon_0 r}$

Work done when a point charge moves: $W = qV = \Delta\left(\dfrac{1}{2}mv^2\right)$

Gravitational field strength: $g = \dfrac{F}{m} = -\dfrac{dV}{dr}$

Force between two point masses: $F = \dfrac{GMm}{r^2}$

Gravitational field strength due to a point mass: $g = \dfrac{GM}{r^2}$

Gravitational potential due to a point mass: $V = -\dfrac{GM}{r}$

Work done when a point mass moves: $W = mV = \Delta\left(\dfrac{1}{2}mv^2\right)$

Capacitance

Charge on a capacitor: $Q = CV$

Capacitance of parallel plates: $C = \frac{\varepsilon_0 \varepsilon_r A}{d} = \frac{\varepsilon A}{d}$

Capacitors in parallel: $C_{\text{Total}} = C_1 + C_2 + \dots$

Capacitors in series: $\frac{1}{C_{\text{Total}}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$

Energy stored: $W = \frac{1}{2} CV^2$

Charging: $Q = Q_0 \left(1 - e^{-t/RC}\right)$

Discharging: $Q = Q_0 e^{-t/RC}$

Inductance

Self-inductance: $E_1 = -L \frac{dI_1}{dt}$

Mutual inductance: $E_2 = -M \frac{dI_1}{dt}$

Energy stored: $W = \frac{1}{2} LI^2$

Electromagnetism

Force on wire:	$F = BIl\sin(\theta)$
Torque on a rectangular coil:	$\tau = BANI\cos(\theta)$
Force on moving charge:	$F = BQv\sin(\theta)$
Magnetic flux:	$\phi = BA$
Field inside a solenoid:	$B = \mu_0\mu_r nI$
Field near a long straight wire:	$B = \dfrac{\mu_0 I}{2\pi r}$
Induced e.m.f.:	$E = -\dfrac{d(N\phi)}{dt}$
E.m.f. induced in a moving straight conductor in a uniform magnetic field:	$E = Blv$
Hall voltage:	$V_H = \dfrac{BI}{nqt}$

Temperature

Temperature two point scale:	$\theta = \dfrac{X_\theta - X_0}{X_{100} - X_0} \times 100$ °C
Temperature absolute scale:	$T = 273.16\dfrac{P}{P_{tr}}$ K

Celsius scale:	$\theta(°\mathrm{C}) = T(\mathrm{K}) - 273.15\ \mathrm{K}$	

First and second laws of thermodynamics

First law of thermodynamics:	$\Delta U = \Delta Q + \Delta W$	(Work done by system is negative)
	$\Delta U = \Delta Q - \Delta W$	(Work done by system is positive)
Efficiency of an ideal heat engine:	$\eta = 1 - \frac{T_c}{T_h}$	

Gases

Ideal gas equation:	$PV = nRT = NkT$	
Kinetic theory of an ideal gas:	$PV = \frac{1}{3} Nm\langle c^2 \rangle$	
Boltzmann's constant:	$k = \frac{R}{N_\mathrm{A}}$	
Principal molar heat capacities of an ideal gas:	$\gamma = \frac{C_P}{C_V}$	$C_P - C_V = R$
Adiabatic process:	$PV^\gamma = \text{constant}$	

Materials

Hooke's law:	$F = k\delta l$

Stress:	$\sigma = \dfrac{F}{A}$
Strain:	$\varepsilon = \dfrac{\delta l}{l}$
Young's modulus:	$Y = \dfrac{\sigma}{\varepsilon}$
Energy stored in a stretched wire:	$E = \dfrac{1}{2}k(\delta l)^2$

Heat transfer

Thermal conduction:	$\dfrac{dQ}{dt} = -kA\dfrac{d\theta}{dx}$

Quantum phenomena

Quantum energy:	$E = hf$
Mass-energy:	$E = mc^2$
Photoelectric effect:	$hf = \phi + \left(\dfrac{1}{2}mv^2\right)_{\max}$
Energy levels:	$\Delta E = E_2 - E_1 = hf = \dfrac{hc}{\lambda}$
De Broglie wavelength:	$\lambda = \dfrac{h}{mv}$

Radioactivity

Decay rate:

$$\frac{dN}{dt} = -\lambda N$$

$$A = \lambda N$$

$$N = N_0 e^{-\lambda t}$$

Half-life:

$$T_{\frac{1}{2}} = \frac{\ln(2)}{\lambda} = \frac{0.693}{\lambda}$$

Absorption law for gamma radiation:

$$I = I_0 e^{-\mu d}$$

Doppler shift

Doppler shift:

$$f = f_0\left(1 - \frac{v}{c}\right)$$

Mathematical Formulae

Surface area of a sphere: $S = 4\pi r^2$

Volume of a sphere: $V = \frac{4}{3}\pi r^3$

Surface area of a cylinder: $S = 2\pi rh + 2\pi r^2$

Volume of a cylinder: $V = \pi r^2 h$

Logarithms: $\log_a(bc) = \log_a(b) + \log_a(c)$

$$\log_a\left(\frac{b}{c}\right)=\log_a(b)-\log_a(c)$$

$$\log_a(b^c)=c\log_a(b)$$

$$\log_a(a)=1$$

Equation of a straight line:	$y=mx+c$
Relationship between cosine and sine:	$\sin(90°\pm\theta)=\cos(\theta)$
Relationship between tangent, cosine and sine:	$\tan(\theta)=\dfrac{\sin(\theta)}{\cos(\theta)}$
Small angles:	$\sin(\theta)\approx\tan(\theta)\approx\theta\quad(\text{in radians})$
Difference of two squares:	$x^2-y^2=(x+y)(x-y)$
Formula for the roots of a quadratic equation:	$x=\dfrac{-b\pm\sqrt{b^2-4ac}}{2a}$

Physical Constants

Acceleration of free fall on and near the Earth's surface:	$g=9.81\,\text{m s}^{-2}$
Boltzmann constant:	$k=1.38\times10^{-23}\,\text{J K}^{-1}$
Molar gas constant:	$R=8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Avogadro's constant:	$N_\text{A}=6.02\times10^{23}\,\text{mol}^{-1}$
Coulomb's law constant:	$k=\dfrac{1}{4\pi\varepsilon_0}=8.99\times10^{9}\,\text{N m}^2\,\text{C}^{-2}$

Charge of an electron:	$e = -1.60 \times 10^{-19}$ C
Rest mass of an electron:	$m_e = 9.11 \times 10^{-31}$ kg
Rest mass of a proton:	$m_p = 1.673 \times 10^{-27}$ kg
Rest mass of a neutron:	$m_n = 1.675 \times 10^{-27}$ kg
Unified atomic mass unit:	$1 \text{ u} = 1.66 \times 10^{-27}$ kg $1 \text{ u} = 931.5 \text{ MeV}/c^2$
Electronvolt:	$1 \text{ eV} = 1.60 \times 10^{-19}$ J
Gravitational constant:	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Permittivity of free space:	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
Permeability of free space:	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
Planck constant:	$h = 6.63 \times 10^{-34}$ J s
Speed of light in a vacuum:	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
Range of wavelengths for visible light:	$\lambda = 400$ nm to 700 nm
One year:	1 year = 365.25 days
One light year:	$1 \text{ ly} = 9.46 \times 10^{15}$ m