Data and Formulae Booklet

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

**Uniformly accelerated motion:**

Useful formulae:

\[ v = u + at \]
\[ s = ut + \frac{1}{2}at^2 \]
\[ v^2 = u^2 + 2as \]
\[ s = \left( \frac{u + v}{2} \right) t \]

**Ray optics:**

Refractive index:

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
\[ \frac{n_2}{n_1} = \frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} \]
\[ n_3 = n_2 \cdot n_3 \]

Thin lenses:

\[ \frac{1}{f} = \frac{1}{u} + \frac{1}{v} \] (real is positive)
\[ \frac{1}{f} = \frac{1}{u} - \frac{1}{v} \] (Cartesian)

Magnification:

\[ m = \frac{v}{u} = \frac{h_v}{h_u} \] (real is positive)
\[ m = -\frac{v}{u} = -\frac{h_v}{h_u} \] (Cartesian)

**Mechanics:**

Newton’s second law:

\[ F = \frac{d(mv)}{dt} \]

Power:

\[ P = Fv \]

Momentum:

\[ p = mv \]

**Current electricity:**

Current:

\[ I = nAve \]

Resistors in series:

\[ R_{\text{TOTAL}} = R_1 + R_2 + \ldots \]

Resistors in parallel:

\[ \frac{1}{R_{\text{TOTAL}}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \]

Power:

\[ P = IV \]

Resistivity:

\[ \rho = \frac{RA}{L} \]

Temperature coefficient:

\[ \alpha = \frac{R_0 - R_a}{R_0 \theta} \]

**Alternating current:**

For sinusoidal alternating current:

\[ I = I_0 \sin 2\pi ft \]

Root mean square for sinusoidal alternating current and voltage:

\[ I_{\text{rms}} = \frac{I_0}{\sqrt{2}}; \quad V_{\text{rms}} = \frac{V_0}{\sqrt{2}} \]

Reactance:

\[ X_L = 2\pi L; \quad X_C = \frac{1}{2\pi C} \]
Stationary waves:

Speed of waves on strings: \[ v = \sqrt{\frac{T}{\mu}} \]

Wave motion:

Two slit interference: \[ s = \frac{\lambda D}{d} \]

Diffraction grating: \[ d \sin \theta = n \lambda \]

Single slit diffraction: \[ \theta = \frac{\lambda}{a} \]

Diffraction of circular aperture: \[ \sin \theta \approx \theta = 1.22 \frac{\lambda}{a} \]

Fields:

Electric field strength: \[ E = \frac{F}{q} = \frac{dV}{dr} \]

Uniform field: \[ E = \frac{F}{q} = \frac{V}{d} \]

Force between point charges: \[ F = \frac{Q_1 Q_2}{4 \pi \varepsilon_0 r^2} \]

Electric field strength of a point charge: \[ E = \frac{Q}{4 \pi \varepsilon_0 r^2} \]

Force between point masses: \[ F = \frac{GM_1 M_2}{r^2} \]

Electric potential: \[ V = \frac{Q}{4 \pi \varepsilon_0 r} \]

Gravitational potential: \[ V_G = -\frac{GM}{r} \]

Work: \[ W = QV \]

Capacitance:

Capacitance of parallel plates: \[ C = \frac{\varepsilon_0 \varepsilon_r A}{d} \]

Capacitors in parallel: \[ C = C_1 + C_2 + \ldots \]

Capacitors in series: \[ \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots \]

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

Charging: \[ Q = Q_0 \left(1 - e^{-\frac{t}{RC}}\right) \]

Discharging: \[ Q = Q_0 e^{-\frac{t}{RC}} \]

Inductance:

Mutual inductance: \[ M = -\frac{E}{dt} \]

Self inductance: \[ L = -\frac{E}{dt} \]

Energy stored: \[ W = \frac{1}{2} Li^2 \]

Electromagnetism:

Force on wire: \[ F = BlI \]

Torque on a rectangular coil: \[ \tau = BANI \]

Force on moving charge: \[ F = Bqv \]

Magnetic flux: \[ \Phi = BA \]

Field inside a solenoid: \[ B = \mu_0 H, nI \]

Field near a long straight wire: \[ B = \mu_0 \frac{l}{2\pi r} \]

Induced emf: \[ E = -N \frac{d\Phi}{dt} \]

Emf induced in a moving conductor: \[ E = Blv \]

Simple alternator emf: \[ V = V_0 \sin(\omega t + \phi) \]

Hall voltage: \[ V_H = \frac{Bl}{nQ_0} \]
Temperature:
Temperature (K): \( T = 273.16 \frac{P}{P_0} - 273.15 \) K
Celsius scale: \( \theta (^\circ C) = T (K) - 273.15 \) K

First and second laws of thermodynamics:
First law of thermodynamics: \( \Delta U = \Delta Q + \Delta W \)
Ideal heat engine: \( \eta = 1 - \frac{T_c}{T_h} \)

Gases:
Ideal gas equation: \( PV = nRT \)
Kinetic theory of an ideal gas:
\[ PV = \frac{1}{3} N m \langle v^2 \rangle \]
Boltzmann's constant: \( k = \frac{R}{N_A} \)
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: \( F = k\Delta x \)
Stress: \( \sigma = \frac{F}{A} \)
Strain: \( \varepsilon = \frac{\Delta l}{l} \)
Young's modulus: \( Y = \frac{\sigma}{\varepsilon} \)
Energy stored in a stretched wire: \( E = \frac{1}{2} k (\Delta l)^2 \)

Heat transfer:
Thermal conduction: \( \frac{dQ}{dt} = -kA \frac{d\theta}{dx} \)

Quantum phenomena:
Quantum energy: \( E = hf \)
Mass-energy \( E = mc^2 \)
Photoelectric effect: \( hf = \Phi + \left( \frac{1}{2} mv^2 \right)_{\text{max}} \)
Energy levels: \( hf = E_2 - E_1 \)
De Broglie wavelength: \( \lambda = \frac{h}{mv} \)

Radioactivity:
Decay rate: \( \frac{dN}{dt} = -\lambda N ; A = \lambda N \)
\( N = N_0 e^{-\lambda t} \)
Half-life: \( T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \)
Absorption law for gamma radiation: \( I = I_0 e^{-\mu d} \)
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:
\[
\ln(x^n) = n\ln x \\
\ln(e^x) = kx
\]

Equation of a straight line: \( y = mx + c \)

Relationship between cosine and sine:
\( \sin(90° - \theta) = \cos \theta \)

Small angles: \( \sin \theta \approx \tan \theta \approx \theta \) (in radians)
\( \cos \theta \approx 1 \)

The following constants may be useful in answering some of the questions in the examination.

Acceleration of free fall on and near the Earth’s surface \( g = 9.81 \text{ m s}^{-2} \)
Gravitational field strength on and near the Earth’s surface \( g = 9.81 \text{ N kg}^{-1} \)
Boltzmann constant \( k = 1.38 \times 10^{-23} \text{ J K}^{-1} \)
Molar gas constant \( R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1} \)
Avogadro’s constant \( N_a = 6.02 \times 10^{23} \text{ mol}^{-1} \)
Coulomb’s law constant \( k = 1/(4\pi\varepsilon_0) = 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \)
Charge of an electron \( e = -1.60 \times 10^{-19} \text{ C} \)
Mass of an electron \( m_e = 9.11 \times 10^{-31} \text{ kg} \)
Electronvolt \( 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \)
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 \( h = 6.63 \times 10^{-34} \text{ J s} \)
Speed of light in a vacuum \( c = 3.00 \times 10^8 \text{ m s}^{-1} \)
Unified atomic mass unit \( u = 1.66 \times 10^{-27} \text{ kg} \)