L-Università ta' Malta

MATSEC Examinations Board

Data and Formulae Booklet for Advanced and Intermediate Physics

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

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

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

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

Magnification: $m = \frac{v}{u} = \frac{h_\mathrm{i}}{h_\mathrm{o}}$ (real is positive)

$m = -\frac{v}{u} = -\frac{h_\mathrm{i}}{h_\mathrm{o}}$ (Cartesian)

Current electricity

Ohm's Law: $V = IR$

Current: $I = nAvq$

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

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

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

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

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:

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} \qquad V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

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

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

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

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

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

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

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

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

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

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

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

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

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:	$C_{\text{Total}} = C_1 + C_2 + \ldots$
Capacitors in series:	$\frac{1}{C_{\text{Total}}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
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:	$B = \frac{\mu_0 I}{2\pi r}$
Induced e.m.f.:	$E = -\frac{d(N\phi)}{dt}$
E.m.f. induced in a moving straight conductor in a uniform magnetic field:	$E = Blv$
Hall voltage:	$V_H = \frac{BI}{nqt}$

Temperature

Temperature two point scale:	$\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100\ °\text{C}$
Temperature absolute scale:	$T = 273.16 \frac{P}{P_{tr}}\ \text{K}$
Celsius scale:	$\theta(°\text{C}) = T(\text{K}) - 273.15\ \text{K}$

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:	$k = \frac{R}{N_\text{A}}$

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: $\sigma = \frac{F}{A}$

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: $hf = \phi + \left(\frac{1}{2}mv^2\right)_{\max}$

Energy levels: $\Delta E = E_2 - E_1 = hf = \frac{hc}{\lambda}$

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

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:	$\tan(\theta) = \frac{\sin(\theta)}{\cos(\theta)}$
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:	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Physical Constants

Acceleration of free fall on	$g = 9.81 \text{m s}^{-2}$

and near the Earth's surface:

Boltzmann constant:	$k = 1.38 \times 10^{-23}$ J K^{-1}
Molar gas constant:	$R = 8.31$ J K^{-1} mol^{-1}
Avogadro's constant:	$N_A = 6.02 \times 10^{23}$ mol^{-1}
Coulomb's law constant:	$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}$ N m^{2} 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:	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
Permittivity of free space:	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
Permeability of free space:	$\mu_0 = 4\pi \times 10^{-7}$ 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:	$\lambda = 400\ \text{nm to } 700\ \text{nm}$
One year:	$1\ \text{year} = 365.25\ \text{days}$
One light year:	$1\ \text{ly} = 9.46 \times 10^{15}\ \text{m}$