Formula Sheet

Nov 2021

Mechanics

Equations of motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
	$s = 1/2(u+v)t$
Impulse	$F\Delta t = \Delta(mv)$
Work	$W = Fs\cos\theta$
Centripetal acceleration	$a = \dfrac{v^2}{r} = \omega^2 r$
Hydrostatic pressure	$p = \rho g h$

Electricity

Current	$I = \dfrac{\Delta Q}{\Delta t}$
Power	$P = VI$
Resistance	$V = IR$
Electric current	$I = nAvq$
Resistivity	$R = \dfrac{\rho\ell}{A}$
Resistors in series	$R = R_1 + R_2 + \ldots$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$
AC voltage	$V = V_0 \sin\omega t$

SHM

Acceleration	$a = -\omega^2 x$
Displacement	$x = A\sin(\omega t + \phi)$
Period of a spring	$T = 2\pi\sqrt{\dfrac{m}{k}}$

Radioactivity

Radioactive decay	$N = N_0 \exp(-\lambda t)$
Decay constant	$\lambda t_{\frac{1}{2}} = \ln 2 = 0.693$

Thermal

Heat transfer	$Q = mc\Delta T$ and $Q = mL$
Thermodynamics	$\Delta Q = \Delta U + \Delta W$

Waves

Refraction	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
Double slit fringes	$w = \dfrac{\lambda d}{s}$
Doppler effect	$f_o = \dfrac{f_s c}{c \pm v_s}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$
Photon energy	$E = hf$

Gases

Gas law	$pV = nRT$
Work done by a gas	$\Delta W = p\Delta V$
Pressure of an ideal gas	$pV = \frac{1}{3}Nm\langle c^2\rangle$
Energy of a molecule	$\frac{1}{2}mc^2_{\mathrm{RMS}} = \frac{3}{2}kT$

Fields

Field and potential	$E = -\dfrac{\Delta V}{\Delta x}$
Gravitational potential	$V_g = -\dfrac{GM}{r}$
Gravitational field	$E_g = \dfrac{GM}{r^2}$
Electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
Electric field	$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$
Capacitance	$C = \dfrac{Q}{V}$
Capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
Capacitors in parallel	$C = C_1 + C_2 + \ldots$
Energy of a capacitor	$E = \frac{1}{2}QV$
Magnetic force	$F = I\ell B$ and $F = qvB$
EM induction	$\varepsilon = -N\dfrac{\mathrm{d}\phi}{\mathrm{d}t}$

Important Constants

Constant	**Symbol**	**Value**
Speed of light in free space	c	$3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Elementary charge	e	$1.602 \times 10^{-19}\,\mathrm{C}$
Planck constant	h	$6.63 \times 10^{-34}\,\mathrm{J\,s}$
Mass of electron	m_e	$9.110 \times 10^{-31}\,\mathrm{kg}$
Mass of proton	m_p	$1.673 \times 10^{-27}\,\mathrm{kg}$
Mass of neutron	m_p	$1.675 \times 10^{-27}\,\mathrm{kg}$
atomic mass unit	u	$1.661 \times 10^{-27}\,\mathrm{kg} = 931.5\,\mathrm{MeV\,c^{-2}}$
Gravitational constant	G	$6.67 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$
Earth's gravitational field strength	g	$9.81\,\mathrm{N\,kg^{-1}}$
Permittivity of free space	ε_0	$8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
Avogadro constant	N_A	$6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Gas constant	R	$8.3145\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Mass of Sun	M_S	$1.99 \times 10^{30}\,\mathrm{kg}$
Radius of Earth	R_E	$6.37 \times 10^{6}\,\mathrm{m}$
Specific heat capacity of water	c_w	$4180\,\mathrm{J\,kg^{-1}\,^\circ C^{-1}}$

$$T_{(\mathrm{K})} = T_{(^\circ\mathrm{C})} + 273$$

$$\text{Volume of a sphere} = \tfrac{4}{3}\pi r^3$$

$$\begin{aligned}
e^x &\approx 1 + x + \ldots && x \ll 1 \\
(1+x)^n &\approx 1 + nx && x \ll 1 \\
\frac{1}{(1+x)^n} &\approx 1 - nx && x \ll 1 \\
\tan\theta &\approx \sin\theta \approx \theta && \text{for } \theta \ll 1 \\
\cos\theta &\approx 1 - \frac{\theta^2}{2} && \text{for } \theta \ll 1
\end{aligned}$$

British Physics Olympiad Competition

BPhO Answer Booklet

13th November 2021

Name	
School	
Exam Code	

The question paper must not be taken out of the exam room.

Instructions

Time: **5 minutes reading time (NO writing) for Section 2**
Then **2 hours 40 minutes** for writing the exam.

Questions: There are two sections in the paper and you should spend about 1 hour 20 minutes on each section.

Section 1 - Students may attempt any parts but are not expected to complete all parts.

Section 2 - Only **two questions** out of the four questions should be attempted.
Each question contains independent parts so that later parts should be attempted even if earlier parts are incomplete.

Marks: A **maximum of 50 marks** can be awarded for *Section 1*. There is a total of ≈ **88** marks allocated to the problems of Question 1 which makes up the whole of *Section 1*.

Each question in *Section 2* is out of 25, with a **maximum of 50 marks from two questions** only. Students are recommended to spend about 40 minutes on each question.

Working: Working, calculations, explanations and diagrams, properly laid out, must be shown for full credit. The final answer alone is not sufficient. Writing must be clear.

Instructions: You are allowed any standard exam board data/formula sheet.

Calculators: Any standard calculator may be used, but calculators cannot be programmable and must not have symbolic algebra capability.

Solutions: Answers and calculations are to be written in the Answer booklet. A formula sheet should also be made available. Students should ensure that their **Name**, **School** and **Exam code** written clearly on the Answer booklet. **Number each question answered.**

BPhO Answer Booklet

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