British Physics Olympiad Competition

BPhO Answer Booklet

February 2024

Name	
School	
Account Number	

Instructions

Time: 3 hours (approximately 45 minutes per question).

Questions: All four questions should be attempted.

Marks: The four questions carry similar marks.

Solutions: Answers and calculations are to be written on loose paper or in examination booklets. Students should ensure their name and school is clearly written on all answer sheets.
A new question should be started on a new page.
Pages must be numbered.

Instructions: A standard formula booklet with standard physical constants should be supplied. To accommodate students sitting the paper at different times, please do not discuss any aspect of the paper on the internet until 8am Monday 26th February.

Calculators: Any standard calculator may be used, but calculators must not have symbolic algebra capability. If they are programmable, then they must be cleared or used in "exam mode".

Clarity: Solutions must be written legibly, in black pen (the papers are photocopied), and working down the page. Scribble will defnitely not be marked and overall clarity is an important aspect of this competition paper.

Formula Sheet

February 2024

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	$1.60 \times 10^{-19}\,\mathrm{C}$
Acceleration of free fall at Earth's surface	g	$9.81\,\mathrm{m\,s^{-2}}$
Permittivity of free space	ε_0	$8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
Permeability of free space	μ_0	$4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
Mass of an electron	m_e	$9.11 \times 10^{-31}\,\mathrm{kg}$
Mass of a neutron	m_n	$1.67 \times 10^{-27}\,\mathrm{kg}$
Mass of a proton	m_p	$1.67 \times 10^{-27}\,\mathrm{kg}$
Radius of a nucleon	r_0	$1.2 \times 10^{-15}\,\mathrm{m}$
Planck constant	h	$6.63 \times 10^{-34}\,\mathrm{J\,s}$
Gravitational constant	G	$6.67 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$
Boltzmann constant	k	$1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Molar gas constant	R	$8.31\,\mathrm{J\,mol^{-1}\,K^{-1}}$
Specific heat capacity of water	c_w	$4.19 \times 10^{3}\,\mathrm{J\,kg^{-1}\,K^{-1}}$
Mass of the Sun	M_S	$1.99 \times 10^{30}\,\mathrm{kg}$
Mass of the Earth	M_E	$5.97 \times 10^{24}\,\mathrm{kg}$
Radius of the Earth	R_E	$6.38 \times 10^{6}\,\mathrm{m}$

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