BRITISH PHYSICS OLYMPIAD 2015-16

BPhO Round 1

Section 1

13th November 2015

Instructions

Time: 1 hour 20 minutes on this section.

Questions: Students may attempt any parts of *Section 1*. Students are not expected to complete all parts.

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

Marks: A maximum of 40 marks can be awarded for *Section 1*. There are a total of 71 marks allocated to the problems of Question 1 which makes up the whole of *Section 1.*

Solutions: answers and calculations are to be written on loose paper or examination booklets. Graph paper and formula sheets should also be made available. Students should ensure their **name** and their **school** is clearly written on all answer sheets.

Setting the paper: There are two options for setting BPhO Round 1:

- *Section 1* and *Section 2* may be sat in one session of 2 hours 40 minutes.
- *Section 1* and *Section 2* may be sat in two sessions on separate occasions, with 1 hour 20 minutes allocated for each section. If the paper is taken in two sessions on separate occasions, *Section 1* must be collected in after the first session and *Section 2* handed out at the beginning of the second session.

Important Constants

Speed of light	c	3.00×10^{8}	$m\ s^{-1}$
Planck constant	h	6.63×10^{-34}	$J\ s$
Electronic charge	e	1.60×10^{-19}	C
Mass of electron	m_e	9.11×10^{-31}	kg
Gravitational constant	G	6.67×10^{-11}	$N\ m^2\ kg^{-2}$
Acceleration of free fall	g	9.81	$m\ s^{-2}$
Permittivity of a vacuum	ε_0	8.85×10^{-12}	$F\ m^{-1}$
Avogadro constant	N_A	6.02×10^{23}	mol^{-1}

Q1.

(a) A measurement is carried out to check the speed of a camera shutter of 1/15 s. The camera is focused symmetrically on a rotating turntable which revolves at 33.3 ± 0.1 revolutions per minute and has a spot at its centre and at its circumference. A photograph shows the arc produced by the spot on the circumference subtends an angle of 12.4 ± 0.1° at the centre of rotation. What is the correct exposure time?

[3]

(b) The temperature coefficients of resistance, α, of certain alloys are positive and others are negative. They have resistance per unit length of *r*. This makes it possible to produce a resistor, using the two wires in series, which does not vary with temperature. The values of *r*, at 0 °C, and α are given in Table 1.b for constantan and manganin. These wire have lengths L_c and L_m respectively at 0 °C. What values of L_c and L_m are required to produce a 5.0 Ω resistor?

Wire	r /Ωm^{-1}	α/ °C^{-1}
Constantan	6.3	-3.0 x 10^{-5}
Manganin	5.3	+1.4 x 10^{-5}

Table 1.b

[5]

(c) A monochromatic sodium lamp, wavelength λ = 6.0 x 10^{-7} m, radiates 100 W of radiation uniformly in all directions. At what distance from the lamp will the photons have an average density of 10^6 m^{-3} ?

[5]

(d) Protons are accelerated from rest through a p.d. of 2.0 x 10^6 V and fired at a gold ($^{197}_{79}$Au) foil. What is the distance of closest approach of a proton to the gold nucleus?

[4]

(e) Figure 1.e is a section through a smooth parabolic metal bowl, which can be rotated about its vertical axis of symmetry, the y - axis. Its equation, in Cartesian coordinates, is $y = ax^2$. The gradient at the point (x, y) is $2ax$.

There is one angular speed of rotation, ω, of the bowl about the y - axis for which a small metal sphere remains at rest relative to the rotating bowl, wherever it is placed on the inner surface. Determine ω in terms of a and g.

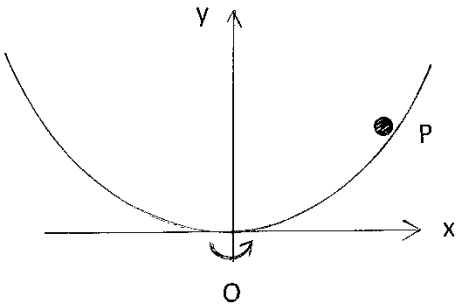

Figure 1.e

[4]

(f) A ray of light is incident on a 60°glass prism of refractive index 1.500 at an angle of incidence of 48.59°. Determine:

(i) the angle of emergence, θ, from the prism; i.e. the angle between the emergent ray and the normal to the prism face.

(ii) the angle of deviation of the ray, δ.

[5]

(g) A man blowing a whistle of frequency f moves away from a stationary observer at speed u. Derive the formula for the frequency f_1 heard by the observer. The velocity of sound is c.

If a man blowing a whistle of frequency 500 Hz moves away from a stationary observer towards a fixed wall, in a direction perpendicular to the wall at 2.00 m s^{-1}, determine the beat frequency heard by the observer if c = 330 m s^{-1}.

[6]

(h) Determine, in Figure 1.h, the total resistances, R_{TBC}, across BC, R_{TBD} across BD and R_{TBA} across AB.

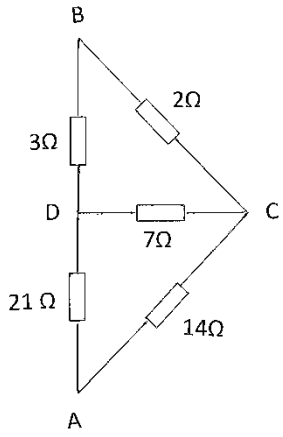

Figure 1.h

[6]

(i) What mass of radium, mass number 226, half-life of 1620 years, and an α emitter, is required to produce an average of 10 α particles per second?

[4]

(j) An a.c. voltmeter displays the rms value of the voltage, V, for a.c. signals and also for periodic signals that are not sinusoidal. What reading will it display if connected to a periodic voltage, period $4T$, that changes instantaneously from +10 V to -2 V to +4V repeatedly, the voltages lasting, respectively, for T, T and $2T$?

Determine the following;

(i) the mean voltage i.e. V_{m}.

(ii) the rms voltage i.e. V_{rms}.

(iii) the rms value of deviation from the mean, $(V - V_{\mathrm{m}})$ which is V_{rmsm}.

[4]

(k) Assuming the Earth is a homogeneous sphere, calculate the fractional difference between the acceleration due to free fall at the Earth's equator and at the poles, indicating which is the greater. You may not use a value of *g* given in the constants table as that is an average value, neither correct at the poles nor at the equator.

Mass of the $M_E = 5.98 \times 10^{24}$ kg Radius of the Earth $R_E = 6.38 \times 10^{6}$ m

[8]

(l) A horizontal square wire loop of side 4.00 cm has a resistance, R, of $2.00 \times 10^{-3}\ \Omega$. The loop is situated in a vertical downward magnetic field of 0.700 T. When the field is switched off, it decreases to zero, at a uniform rate, in 0.800 s.

Determine:

(i) the induced current, I, and its direction in the loop.

(ii) the energy dissipated in the loop.

[7]

(m) Two well separated identical conducting spheres of radius 10.0 cm are charged to +200 V and +400 V. If they are joined by a long wire, how much heat is generated?

[10]

End of Questions