BRITISH PHYSICS OLYMPIAD 2016-17

BPhO Round 1

Section 1

18th November 2016

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

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. Writing must be clear.

Marks: a maximum of 40 marks can be awarded for *Section 1*. There is a total of 70 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 in examination booklets. Graph paper and formula sheets should also be made available. Students should ensure that their **name** and their **school** are clearly written on each and every answer sheet.

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}

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Question 1.

(a) Sketch the electric field lines due to two point charges, of magnitudes $+Q$ and $+2Q$, at A and B, separated by a distance d.

(i) Determine the location of the neutral point, P, where the electric field is zero.

(ii) Why does the magnitude of the electric field vary along a field line?

[5]

(b) A charge of 0.5 x 10^6 C passes through a 12 V battery when the battery discharges. Assuming that the p.d. across the terminals remains constant, calculate the time for which it can supply 0.45 kW.

[2]

(c) Draw a general resistive network diagram with:

(i) two resistors in series which are, in turn, in series with three resistors in parallel.

(ii) five resistors that are not in series or parallel, or in a combination of series and parallel arrangements.

Calculate the resistance in (i) and (ii) if all the resistors have resistance R.

[5]

(d) Two spheres, of uniform density, one of mass m_1 and radius r_1 and the other of mass m_2 and radius r_2, attract each other gravitationally. What is their *relative* speed at the instant of collision if they are released from rest when a great distance apart?

[7]

(e) A bicycle tyre has a volume of 1.2×10^{-3} m^3 when fully inflated. A bicycle pump has a working volume of 9.0×10^{-5} m^3. How many strokes, n, of the pump are needed to inflate the completely flat tyre, containing no air, to a pressure of 3.0×10^5 Pa? The atmospheric pressure is 1.0×10^5 Pa. Assume the air is pumped in slowly so that there is no change in temperature.

[5]

(f) A van, travelling at constant speed of 80 km hr^{-1} (km/hour), passes a car. The car immediately begins to accelerate at a constant rate of 1.2 m s^{-2} and passes the van 0.50 km further down the road. What is the speed, v, of the car when it passes the van?

[4]

(g) A calorimeter contains 0.800 kg of water at a temperature of 15.0 ^{o}C. The heat capacity of the calorimeter is 42.8 J $^{o}C^{-1}$. 0.400 kg of molten lead is poured into the calorimeter. The final equilibrium temperature is 25.0 ^{o}C. What was the initial temperature of the lead?

The specific heat of molten lead is 158 J kg^{-1} $^{o}C^{-1}$, the specific heat of solid lead is 137 J kg^{-1} $^{o}C^{-1}$ and the specific latent heat is 2.323×10^4 J kg^{-1}. Lead freezes at 327 ^{o}C. The specific heat of water is 4200 J kg^{-1} $^{o}C^{-1}$.

[5]

(h) A small object of mass m rests on a scale-pan which is supported by a spring. The period of vertical oscillations is 0.50 s. When the amplitude of the oscillations exceeds the value, A, the mass leaves the scale-pan. Determine A.

[3]

(i) Uncharged metallic spheres of radii $6R$, $3R$ and $2R$ are mounted on insulated stands. The spheres of radii $2R$ and $6R$ are charged to a potential V above earth potential. All three spheres are then briefly joined by a copper wire. What, in terms of V, is the subsequent potential of the sphere of radius $3R$?

What fraction of the original total charge is held by the sphere of radius $3R$?

[5]

(j) The maximum kinetic energy of photoelectrons ejected from a tungsten surface by monochromatic light of wavelength 248 nm is 8.60 x 10^{-20} J.

What is the value of the work function, W, of tungsten?

[3]

(k) A ladder of length L and mass m, with a uniform density, rests against a frictionless vertical wall at an angle of 60^{o} to the wall. The lower end rests on a flat surface with a coefficient of static friction of $\mu_s = 0.40$. A student with a mass $M = 2m$ attempts to climb the ladder. What fraction of the distance up the ladder will the student have reached when the ladder begins to slip?

[5]

(l) A smooth ball of radius 10.0 cm, mass 0.600 kg, hangs by a weightless string from a support. What is the speed of a horizontal wind necessary to keep the string inclined at 39^{o} to the vertical? Make the assumption that the wind speed drops to zero on collision with the ball. The density of the air is 1.293 kg m^{-3}.

[4]

(m) The activity of polonium, Po, fell to one eighth of its initial value in 420 days. Calculate the half-life, t_h, of polonium.

Give the numerical values of a, b, c, d, e, and f in the nuclear equation

$$ {}^{a}_{b}\mathrm{Po} \rightarrow {}^{c}_{d}\alpha + {}^{206}_{82}\mathrm{Pb} + {}^{e}_{f}\gamma $$

[4]

(n) Four masses of 1 kg, 4 kg, 3 kg, and 4 kg are arranged cyclically at the corners of a square of side $2b$ and centre O. A thin circular metal ring has radius a, mass 8 kg, and with the same centre O lies in the same plane as the square. Determine the position of the centre of mass of the system from O.

[3]

(o) A trumpeter travelling in an open car sounds a note at 440 Hz. A stationary pedestrian directly in the path of the car hears a note at frequency 466 Hz. What is the speed of the car? The velocity of sound is 331 ms^{-1}.

[3]

(p) A beam of protons is accelerated from rest through a potential difference of 2000 V and enters a uniform magnetic field which is perpendicular to the direction of the proton beam. If the flux density is 0.2000 T, calculate the radius of the path of the beam.

How is the result modified for deuterons?

[4]

(q) A particle, mass *m*, slides down the smooth track, **Figure 1(q)**, from a height H under gravity. It is to complete a circular trajectory of radius R when reaching its lowest point. Determine the smallest value of H.

[3]

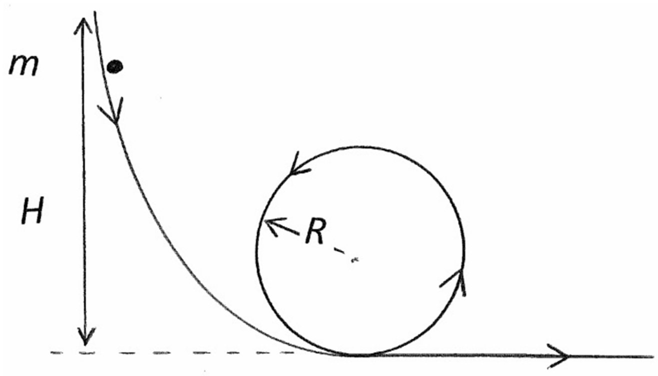

Figure 1(q).

End of Section 1