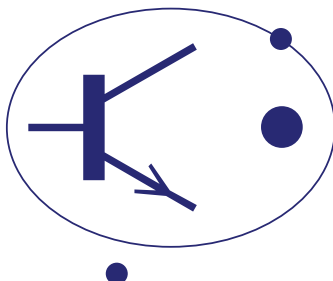


# BRITISH PHYSICS OLYMPIAD



## British Physics Olympiad 2011

12<sup>th</sup> November 2010

### Paper 2

### Section 1

#### Instructions

**Questions:** Any or all parts of *Section 1* can be attempted. However students are not expected to complete all parts of *Section 1* as only 40 marks are available.

**Time:** It is recommended that students spend 1 hour 15 minutes on this section.

**Marks:** There are 78 marks available; however only a maximum total mark of 40 will be awarded. Therefore students need to plan which questions they will attempt in the time recommended.

#### Question answers

Answers can be written on loose paper or examination booklets. Graph paper and a formula sheet should be available.

Students should ensure their name and school is clearly written on their answer sheets.

#### Sittings

*Section 1* and *Section 2* of *Paper 2* may be sat in one session of three hours. Alternatively, the paper may be sat in two sessions, 1 hour 15 minutes for *Section 1* and 1 hour 45 minutes for *Section 2*. If the paper is taken in two sessions, students should not receive *Section 2* until the start of the second session, and should not be allowed to return to their answers to *Section 1*.



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### Paper 2

### Section 1

#### Important Constants

Speed of light	$c$	$3.00 \times 10^8$	$\text{ms}^{-1}$
Planck constant	$h$	$6.63 \times 10^{-34}$	J s
Electronic charge	$e$	$1.60 \times 10^{-19}$	C
Mass of electron	$m_e$	$9.11 \times 10^{-31}$	kg
Permittivity of a vacuum	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{Fm}^{-1}$
Acceleration due to free fall	$g$	9.81	$\text{ms}^{-2}$
Gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{Nm}^2\text{kg}^{-2}$
Avogadro's number	$N$	$6.02 \times 10^{23}$	Mol
Mass of Earth	$M_E$	$5.9700 \times 10^{24}$	kg
Mass of Moon	$M_M$	$7.35 \times 10^{22}$	kg
Radius of Earth	$R_E$	$6.38 \times 10^3$	km
Radius of the Moon	$R_M$	$1.74 \times 10^6$	m
Earth – Moon distance	$R_{EM}$	$3.84 \times 10^8$	m

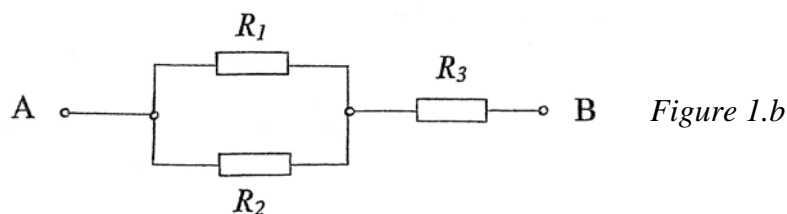
# Q1

- a) Gas is contained in a tank at a pressure of 10 atm and a temperature of  $15^{\circ}\text{C}$ . If one half of the gas is withdrawn and the temperature is raised to  $65^{\circ}\text{C}$ , what is the new pressure in the tank?

[3]

- b) In *Figure 1.b*, what is the value of the resistor  $R_3$ , in terms of the resistances  $R_1$  and  $R_2$ , expressed in its simplest form, if the total resistance across AB is equal to  $R_1$ ?

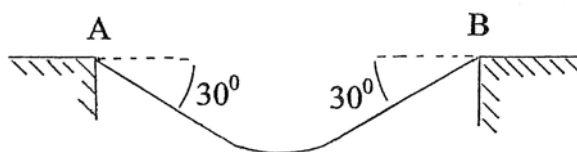
[2]



- c) What is an electric field line? Sketch the field lines due to two charges  $3Q$  and  $(-Q)$ .

[5]

- d) A uniform cable has a mass of 100 kg and is suspended between two fixed points A and B, at the same horizontal level, (*Figure 1.d*). At the support points the cable makes angles of  $30^{\circ}$ .



*Figure 1.d*

What is :

- (i) The force exerted on each support?
- (ii) The tension in the cable at its lowest point?

[5]

- e) When the Sun is directly overhead a narrow shaft of light enters an ancient temple through a small hole in the ceiling and produces a light spot, 10m below, on the floor.

- (i) At what speed does the spot move across the floor?
- (ii) If a mirror is placed on the floor to reflect the beam, at what speed will the reflected spot move across the ceiling?

[4]

- f) The potassium isotope  $^{42}\text{K}_{19}$  disintegrates into  $^{42}\text{Ca}_{20}$ .

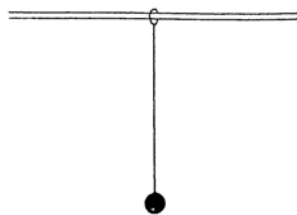
- (i) What are the likely source/s of radiation produced?
- (ii) How many protons, neutrons and electrons are present in an atom of the daughter nucleus  $^{42}\text{Ca}_{20}$ ?

[3]

- g) A thin film of glass, refractive index 1.52, and thickness  $0.42\text{ }\mu\text{m}$  is viewed by reflection with white light at normal incidence. What *visible* wavelength is most strongly reflected?

[6]

- h) A 50 kg ball is attached to one end of a 1.2 m chord that has a mass of 0.13 kg and initially hangs vertically in equilibrium. The other end of the chord is attached to a ring that can slide on a smooth horizontal rod, (*Figure 1.h*). A horizontal blow is delivered to the chord which excites its fundamental mode. Assume the ball remains stationary as the chord vibrates.



*Figure 1.h*

- (i) What is the frequency,  $f$ , and period,  $T$ , of the fundamental mode?
- (ii) What is the amplitude,  $A$ , of the ring if its maximum velocity is  $15\text{ ms}^{-1}$ ?
- (iii) If, initially, the ball is not stationary, determine its natural period,  $T_0$ .
- (iv) Determine the ratio ( $T / T_0$ ). Is the original assumption justified?

[11]

- i) A sphere, mass  $M$  and speed  $u$ , collides elastically head-on with an identical sphere of mass  $m$  which is initially at rest. After the collision the masses  $M$  and  $m$  have respectively speeds, in the direction of  $u$ , of  $v$  and  $w$ .

(i) Prove or verify that  $u + v = w$ .

(ii) If  $R = (u-v)/u$ , prove  $R = mw/(Mu)$ .

(iii) Express  $R$  in terms of  $M$  and  $m$  only.

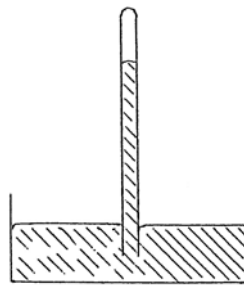
[8]

- j) Two identical plastic balls of mass  $5.00 \text{ g}$  are charged to  $+1.00 \text{ } \mu\text{C}$  and suspended from a fixed point by massless non-conducting threads, each of length  $1.00 \text{ m}$ . Verify that the angle between the threads is  $41.0^\circ$ .

[7]

- k) The height of mercury, density  $1.35 \times 10^4 \text{ kg m}^{-3}$ , in a barometer, (*Figure 1.k*), is  $75.9 \text{ cm}$ , at  $15^\circ\text{C}$ . The height of the evacuated space in the barometer is  $8.0 \text{ cm}$ . The internal diameter of the barometer is  $6.5 \text{ mm}$ . A small amount of nitrogen is introduced into the this space and the mercury level drops to  $62.2 \text{ cm}$ . Determine the mass,  $m$ , of nitrogen present.

[7]



*Figure 1.k*

l) A battery consisting of two cells, in series, each of emf  $E$ , is used to charge a capacitor, capacitance  $C$ .

- (i) What is the energy of the charged capacitor?
- (ii) How much energy has been lost?
- (iii) If the capacitor is charged in two stages, first with one cell and then with two cells, determine the energy lost. Comment on the result.

[8]

m) Two masses of 0.90 kg and 1.10 kg are hung vertically from identical springs on a common support each with force constant  $39.48 \text{ Nm}^{-1}$ . Both are released simultaneously from a position of maximum extension to describe simple harmonic motion. Calculate:

- (i) The frequencies of the two masses.
- (ii) The beat period and frequency.

[4]

n) The tangential frictional force produced by a band brake on a rotating metal drum of circumference 0.25 m is 20 N. The mass of the drum is 0.40 kg and its specific heat capacity is  $0.35 \text{ kJ kg}^{-1}\text{K}^{-1}$ . Calculate the number of complete revolutions required to increase its temperature by 5.0 K.

[3]

o) If the atmosphere is assumed to be composed of a layer of air of uniform density,  $1.23 \text{ kg m}^{-3}$ , calculate its height if it produces a pressure of  $1.01 \times 10^5 \text{ Pa}$  at the Earth's surface.

[2]

**End of Section 1**