AS CHALLENGE PAPER 2012

Name	
School	
Town & County	

Total Mark/50

BPhO
British Physics Olympiad

Time Allowed: ***One hour***

Attempt as many questions as you can.

Write your answers on this question paper.

Marks allocated for each question are shown in brackets on the right.

You may use any calculator.

You may use any public examination formula booklet.

Allow no more than ***10 minutes*** *for* ***section A.***

The gravitational field strength on the earth is 9.8 N kg^{-1}

Section A: Multiple Choice

Circle the correct answer to each question. There is only one correct answer.

Each question is worth 1 mark.

Write your answers in the table at the end of the multiple choice questions on page 3.

1. A stone is dropped to the ground from a height h and takes time t to reach the ground. When this experiment is carried out in a lift rising at a constant speed, the time taken for the stone to fall the same height h in the lift is

A. Dependent upon the speed of the lift B. Greater than t C. Equal to t D. Less than t

2. A 600 W microwave oven can cook a 300 g potato in 9 minutes. How long would it take to cook six 200 g potatoes placed in the microwave at the same time?

A. 9 minutes B. 18 minutes C. 27 minutes D. 36 minutes

3. A mass m is lifted at a constant slow speed. The force of gravity when it is held in your hand is mg. When it is being lifted, the force required is

A. Slightly less than mg B. Equal to mg C. Slightly more than mg D. Dependent upon the how fast it is raised

4. Two plane mirrors are at an angle of 15^{o} as shown in figure 1 below. A small object O is placed between them at an equal distance from mirror A and from mirror B. How many images can be seen (including the original)? (You can fit your eyeball between the mirrors if you want to)

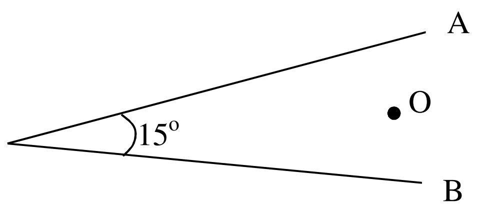


Figure 1.

A. None B. 24 C. 36 D. 48

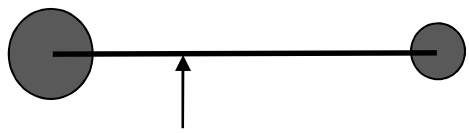
5. An estimate of the energy stored in a 1½ V torch battery is

A. 10^4 J B. 3×10^5 J C. 10^7 J D. 3×10^8 J

6. Jack and Jill decide to throw pennies out of a window. They lean out and Jill throws hers straight down to the ground with an initial speed of 4 m/s whilst Jack throws his straight upwards with an initial speed of 4 m/s. How do the speeds and kinetic energies of the pennies compare when they each hit the ground?
You should ignore air resistance.

A. Jack's penny has a greater speed and greater KE
B. Jack's penny has the same speed but greater KE
C. Jill's penny has the same speed but greater KE
D. Jill's penny has the same speed and the same KE

7. Two spheres of the same density but different masses are supported with their centres at the ends of a uniform bar of length ℓ = 10 units. The larger sphere has three times the mass of the smaller sphere, and the bar itself has a mass equal to the mass of the smaller sphere.
How many units from the left hand end should the pivot be placed to balance the bar?



A. 1 unit B. 2 units C. 3 units D. 4 units

8. A heavy piece of apparatus used to measure sea salinity is attached by a short rope to a flexible rubber balloon filled with air. The balloon should sit on the surface of the sea. On one occasion too little air is put in and the balloon sits just below the surface of the sea. The sea becomes rough and the balloon sinks down just a little further. What is likely to happen to the apparatus?

A. It sinks to the ocean floor
B. It sinks to some reasonable depth and stays there
C. It rises again and sits just below the surface of the sea
D. It remains at the level it has just sunk to

9. A tea urn has two elements used to heat the water; a slow one used for heating the full urn over a long period of time (taking t_1 minutes) and a fast one used for heating the full urn quickly (taking t_2 minutes). If both elements are used at the same time, how long will it now take to heat the full urn?

A. $t_1 + t_2$ mins. B. $\frac{t_1}{t_2}$ mins. C. $\sqrt{(t_1^2 + t_2^2)}$ mins. D. $\frac{t_1 t_2}{t_1 + t_2}$ mins.

10. An alpha particle emitted from a radioactive source has an energy of 4.0 MeV (an electron-volt or 1 eV is equal to 1.6 x 10^{-19} J). It loses its energy largely by ionising air molecules as it passes close by, until it loses most of its energy. If the ionisation energy of an air molecule is on average 34 eV and the alpha travels a distance of 7 cm in air, what is the average distance between ionised molecules that it leaves in its wake?

A. 6 x 10^{-8} m B. 6 x 10^{-7} m C. 6 x 10^{-5} m D. 6 x 10^{-4} m

Answers

Please write you answers to Section A below:

Qu 1	Qu 2	Qu 3	Qu 4	Qu 5	Qu 6	Qu 7	Qu 8	Qu 9	Qu 10

Section B: Written Answers

Question 11.

The weights shown in figure 2 below are balanced on strings and pulleys of negligible mass and friction. The masses m_A and m_B are not the same.

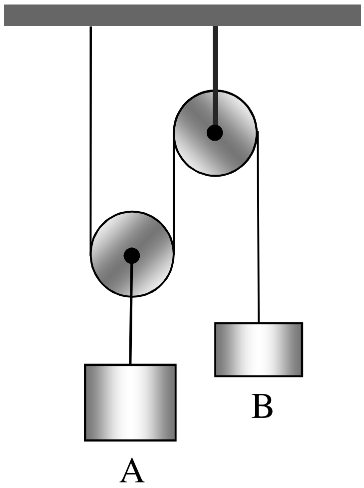


Figure 2.

a) If mass **A** is pulled down by a distance h, how far does mass **B** move?

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____ [1]

b) In terms of masses m_A and m_B, what would be the changes of gravitational potential energy (gpe) of each mass, and what would be the change in gpe of the whole system?

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____ [2]

c) When **A** is pulled down and then released, the masses remain stationary in their new positions. How has the gravitational potential energy of the system changed from the start?

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____ [1]

d) What is the ratio of the masses $\frac{m_A}{m_B}$? Give a reason for your answer.

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____ [2]

/6

Question 12.

A student decides to calibrate a thermistor in order to measure variations in the temperature of the room. He connects a small bead sized thermistor across the terminals of a 5 V power supply and in series with a 1 A ammeter. The resistance of the thermistor is 120 Ω at room temperature.

a) Instead of showing small variations in room temperature, the thermistor is likely to go up in smoke. Explain why.

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____ [4]

In the light of his experience, he decides to redesign his simple circuit as is shown in figure 3 below. He has a few values of resistor R to choose from; 5 kΩ, 500 Ω, 50 Ω.

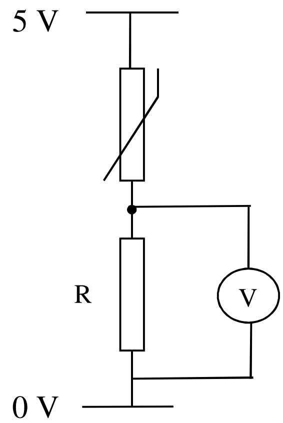

Figure 3.

b) State which value of *R* would give the biggest variation of V with temperature. Explain your choice.

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____ [2]

c) State which value of *R* would be most likely to cause the same problem as in (a). Again, explain your choice.

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____ [1]

/7

Question 13.

Two pendulums shown in figure 4 below have equal masses at the end of light straight rods, but one pendulum (of length 2ℓ) is twice the length of the other (of length ℓ).

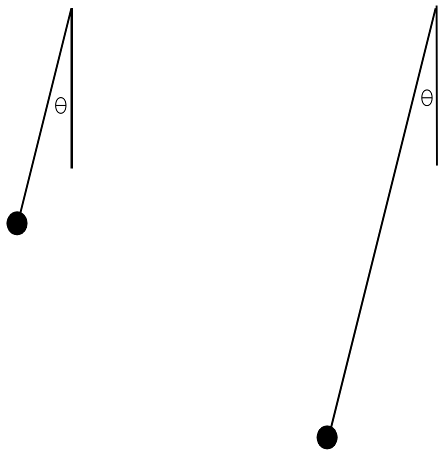

Figure 4.

a) When they are swung through the same initial angle θ and released, which of them has the greater energy in its swing? Give a reason for your answer.

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____ [2]

b) Each pendulum is released from a horizontal position where the mass at the end is level with the support. The speed at the bottom of the swing for the long pendulum is v_L and the speed at the bottom of the swing for the short pendulum is v_S. By considering the potential and kinetic energy of each pendulum, what is the ratio $\frac{v_L}{v_S}$?

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____ [2]

c) If the short pendulum is released from a horizontal position again, and achieves speed v_S at the bottom of the swing, from what angle θ should the longer pendulum be released so that it reaches the same speed of v_S at the bottom of its swing?

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____ [2]

/6

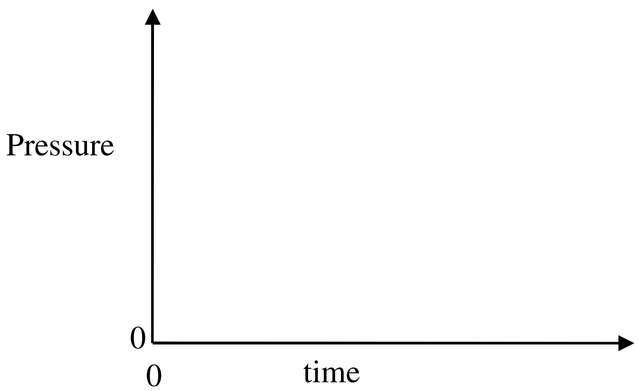
Question 14.

The volume of a car tyre is 20 litres when correctly inflated. The tyre is found to be flat so that the rim of the wheel is sitting on the ground. It still has 16 litres of air in the tyre at atmospheric pressure. An electrically operated air pump is available. This works using a tiny piston in a cylinder which oscillates very fast and can pump air from the atmosphere through the pump at the rate of 4 litres/minute. We will assume that the temperature remains constant.

a) The extra volume of 4 litres would be filled in 1 minute at 4 litres/min. Explain why it takes very much longer than 1 minute to correctly inflate the car tyre.

[2]

b) Sketch a graph showing how the air pressure in the tyre might increase with time after the first few minutes.



[2]

c) When the tyre is filled with air at one atmosphere of pressure, it will not lift the rim off the ground. An excess pressure is required for that purpose. When inflated, each car tyre has about 130 cm^2 of area in contact with the ground. If the car has a mass of 1,200 kg, what is this excess pressure in a car tyre needed to lift the weight of the car? Express this in terms of atmospheric pressure.

Atmospheric pressure is 1.0×10^5 Pa.

[3]

d) Boyle's Law for a gas states that P x V = constant, and this can be used to relate the volume and pressure of the air inside and outside the tyre when it is correctly inflated. What is the volume of air taken from the atmosphere which provides the excess pressure in the tyre?

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____ [3]

e) How long would it take the pump to correctly inflate the tyre when it is flat and sitting on the rim with only 16 litres of air in it?

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____ [2]

/12

Question 15.

In a particle physics experiment, light from a particle detector is to be collected and concentrated by reflecting it between a pair of plane mirrors with angle 2α between them, as shown in figure 5 below. A faint parallel beam of light consisting of rays parallel to the central axis is to be narrowed down by reflection off the mirrors, as shown by the single ray illustrated, for which angle $a = \alpha$.

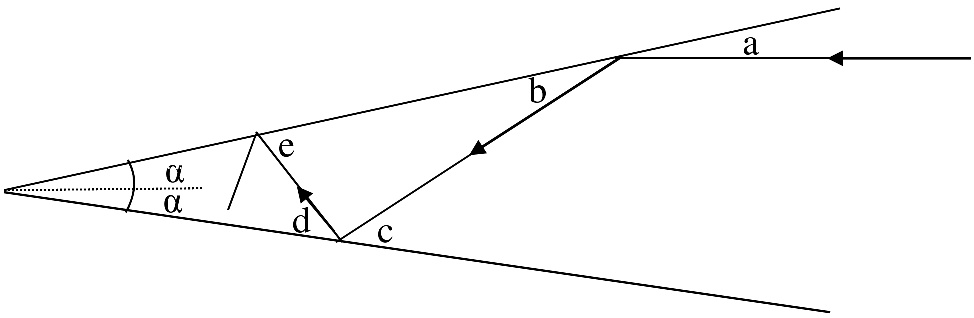

Figure 5.

a) Determine angles b, c, d, and e in terms of angle α.

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____ [3]

b) Explain what happens after several reflections of the light down the mirror funnel.

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____ [2]

c) If angle α is 10^o what is the total number of reflections between the mirrors that will be made by a beam, of light entering parallel to the axis of symmetry as shown?

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____ [1]

d) If the mirrors are replaced by an internally silvered circular cone whose cross-section is the same as that shown above, why will this not make any difference to the calculations given above for the plane angled mirrors with a beam of light parallel to the axis?

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____ [1]

e) An ear trumpet is not very common now, but it was used to collect sound and focus it into the ear. It was a cone about 0.5 metres long with an angle 2α of about 30^o. Sound might have a frequency of 400 Hz and the speed of sound is 330 m/s. Why is the model above that we have used for light not valid for an ear trumpet used to collect sound?

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____ [2]

/9

END OF PAPER