

Name	
School	

Total Mark	
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# BRITISH PHYSICS OLYMPIAD



## 2011 Physics Challenge

Time allowed: 1 hour

Attempt all questions

Write your answers on this question paper

You may use a calculator

Assume the gravitational field strength has a value of  $10 \text{ N / kg}$

**Section A:** Ten multiple choice questions worth 1 mark each (worth 10 marks in total)  
Allow about 10 minutes for this section

**Section B:** Two short answer questions (worth 8 marks in total)  
Questions require a clear explanation of the underlying physical principles  
Allow about 10 minutes for this section

**Section C:** Longer answer questions requiring calculations (worth 32 marks in total)  
Questions may be set on unfamiliar topics. Additional information necessary to answer the question will be given in the question  
Allow 40 minutes for this section

Total 50 marks; mark allocations for each sub-section are shown in brackets

### Section A: Multiple Choice Answers

Write the correct letter in the grid. The first column has been done as an example if the answer to question zero were C

Question	0	1	2	3	4	5	6	7	8	9	10
Answer	C										

1. In imperial units, length can be measured in inches where 1.00 inch = 2.54 cm.  
A block of metal has a volume of 2.00 cubic inches. The volume in metric units is:

- A.  $3.28 \times 10^{-5} \text{ m}^3$
- B.  $32.77 \times 10^{-4} \text{ m}^3$
- C.  $5.08 \times 10^{-2} \text{ m}^3$
- D.  $12.90 \times 10^{-2} \text{ m}^3$
- E.  $3.28 \times 10^{-1} \text{ m}^3$

2. A group of explorers near the equator leave base camp and travel 7km North and then 2km East and then finally 5km South. They then realise that they are late for dinner! In what direction should they travel to return directly to base camp?

- A. West
- B. South West
- C. South
- D. South East
- E. North East

3. A 50kg brick starts from rest and slides down a slope converting gravitational potential energy to kinetic energy. In the process it has to do work against a constant force due to friction of 65N. Air resistance may be ignored. The slope is 40m long and the top of the slope is 6.0m vertically above the bottom of the slope. What will be the speed of the block at the bottom of the slope?

- A. 16 m/s
- B. 11 m/s
- C. 4 m/s
- D. 0 m/s
- E. Cannot be determined from the information given.

4. A solar panel is used to heat water. Each minute 20 litres of water pass through the panel. The water entering the panel is at a temperature of 20°C and the water leaving the panel is at a temperature of 26°C. Water requires 4200J to raise the temperature of 1kg by 1°C and the mass of 1litre of water is 1kg. Assuming that the water does not lose any energy and that the solar panel is 100% efficient, how much radiant energy falls on the solar panel each second?

- A. 500 kJ
- B. 84 kJ
- C. 25 kJ
- D. 8.4 kJ
- E. 0.42 kJ

5. A student uses a radioactivity detector to measure the background count in the laboratory, with no radioactive sources present, to be 25 counts per minute. A radioactive isotope has an initial activity of 400 counts per minute and a half-life of 5 minutes. The student uses the same radioactivity detector to measure the radioactivity of the isotope. How long does it take for the detected count rate to reduce to 50 counts per minute?

- A. 10 minutes
- B. 15 minutes
- C. 20 minutes
- D. 25 minutes
- E. 30 minutes

6. A heater is connected to a 12V battery and has a power output of 36W. The same heater is now connected to an 8V battery. Assume that the resistance of the heater remains constant. What is the power output of the heater?

- A. 36W
- B. 24W
- C. 16W
- D. 12W
- E. 8W

7. The best estimate for the wavelength of red light is:

- A. 0.7mm ( $7 \times 10^{-4}$  m)
- B. 70 $\mu$ m ( $7 \times 10^{-5}$  m)
- C. 7 $\mu$ m ( $7 \times 10^{-6}$  m)
- D. 700nm ( $7 \times 10^{-7}$  m)
- E. 70nm ( $7 \times 10^{-8}$  m)

8. A large rock is dropped off a cliff and hits the ground below at 20 m/s. If a rock with three times the mass was dropped off a cliff of four times the height, what speed would it hit the ground at (ignore air resistance)?

- A. 20 m/s
- B. 40 m/s
- C. 60 m/s
- D. 80 m/s
- E. 240 m/s

9. When a gas in a sealed container (which cannot expand) is heated the pressure increases.

This is because:

- i. The particles of the gas hit the container walls more often
- ii. The particles of the gas hit the container walls harder
- iii. The particles of the gas have more potential energy

- A. (i) only
- B. (ii) only
- C. (iii) only
- D. (i) and (ii) only
- E. (ii) and (iii) only

10. In a simple d.c. electric motor:

- i. The split ring commutator changes the direction of the current in the armature coils every half turn
- ii. The force acting on the coils of the armature only depends on the strength of the magnetic field
- iii. The armature is made of plastic. This is because it must not be magnetic and should not conduct electricity

Which of the above statements are TRUE?

- A. (i) only
- B. (ii) only
- C. (iii) only
- D. (i) and (ii) only
- E. (i) and (iii) only

**Section B: Short Answer Questions**

11. Even on a warm day, when the air is warm, you still feel cold when coming out of the sea or out of a swimming pool. A similar effect can be observed in the laboratory by pouring a small amount of ethanol on to the back of the hand. Even though the ethanol is warm, your hand still feels cold. Explain why, in either of these examples, you feel cold even though the air around you is warm.

[4 marks]

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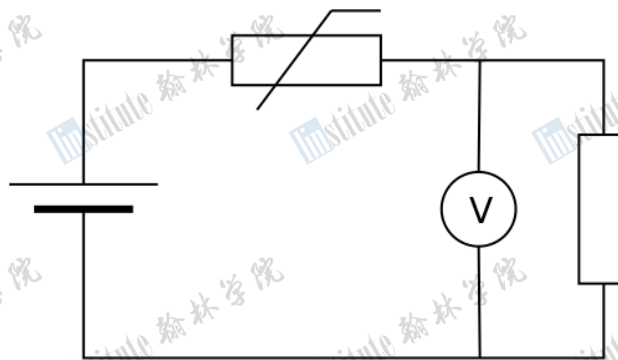
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12. Consider the circuit below. **Explain** what happens to the reading on the voltmeter as the temperature increases (i.e. state what happens and explain why).

[4 marks]



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**Section C: Longer Questions**

13. Archimedes principle and Buoyancy

Archimedes principle is used to explain buoyancy and why things float. Archimedes principle states that any objects (such as a brick) immersed in a fluid (such as water) experiences an upthrust (U) equal to the weight of fluid displaced.

$$\text{Upthrust} = \text{Weight of fluid displaced}$$

a) Consider a float, in the form of a cube, secured to the bottom of a deep pool of fresh water by a rope.

Length of each side = 20 cm

Density of float material =  $400 \text{ kg/m}^3$

Density of fresh water =  $1000 \text{ kg/m}^3$

i. Calculate the weight of the float

[2 marks]

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ii. Calculate the weight of the water displaced

[1 mark]

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iii. Hence calculate the tension in the rope

[2 marks]

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b) The rope now breaks. Calculate the initial acceleration of the float

[2 marks]

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- c) Sketch the velocity time graph for the float on the axes below. No scale is required on the velocity or time axes. Assume the pool is very deep and the float reaches terminal velocity before reaching the surface.

[2 marks]



- d) Consider the following acceleration-time graphs.

In each case **add a scale** to the acceleration axis and continue the graph until such time as the float has reached its terminal velocity. No scale is required on the time axis.

- i. Sketch an acceleration-time graph for the float. Label this **graph A**

[2 marks]

- ii. Add a second line to show the acceleration-time graph for the same float immersed in salt water having a density of  $1024 \text{ kg/m}^3$ . Label this **graph B**

[3 marks]

- iii. Add a third line to show the acceleration-time graph, in fresh water, for a float made of the same material but having twice the dimensions i.e. a cube with sides of length 40cm. Label this **graph C**

[2 marks]



14. Using Graphs – change of resistance with temperature

A group of students are investigating how the resistance of a particular material changes with temperature. Their teacher suggests that the relationship is given by

$$R = R_0 + \alpha T$$

R = Resistance ( $\Omega$ )

$R_0$  = Resistance at  $0^\circ\text{C}$  ( $\Omega$ ) - a constant

T = temperature ( $^\circ\text{C}$ )

$\alpha$  = a constant

- a) Given an ammeter, voltmeter, variable power supply and wires etc. as necessary, draw a suitable circuit that would enable the students to measure the resistance of the wire.

[2 marks]

- b) The students take readings of resistance and temperature. Suggest how they could make their results as reliable as possible

[1 mark]

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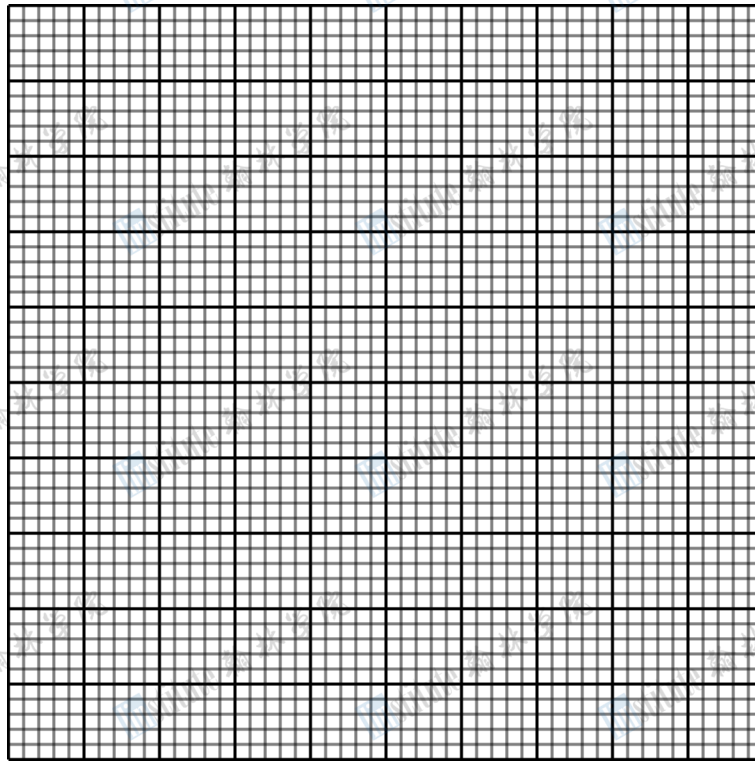
- c) Use the results given in the table to plot a suitable graph of resistance and temperature.

Add a line of best fit.

[3 marks]

Temperature ( $^\circ\text{C}$ )	Resistance ( $\Omega$ )
20	20.0
30	21.1
40	22.0
50	23.0
60	24.1
70	25.2
80	26.5
90	27.8





d) To what extent do the results of the experiment support the relationship suggested by the teacher? [2 marks]

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e) Use the graph, or the data in the table, to determine the best estimate for values for  $R_0$  and  $\alpha$  [2 marks]

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f) State suitable units for  $\alpha$  [1 mark]

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15. Melting Snow

A motorist decides to melt the snow off a car windscreen using hot water

They find the following information:

- 1 litre of snow can be compressed to  $\frac{1}{5}$ <sup>th</sup> litre of ice
- 1 litre = 1000 cm<sup>3</sup>
- water has a density of 1000 kg/m<sup>3</sup>
- ice has a density of 920 kg/m<sup>3</sup>
- the energy required to turn 1kg ice at 0°C into 1kg of water at 0°C is 334 kJ
- the energy required to change the temperature of 1kg of water by 1°C is 4200 J

They use hot water with a temperature of 72°C

- a) Calculate the minimum volume of hot water required to melt 1 litre of snow [4 marks]

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- b) Suggest why, in reality, the motorist is likely to need a greater volume of hot water than the amount calculated in (a) [1 mark]

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