Name:	
School:	

Total Mark	

BPhO
British Physics Olympiad

2014 Physics Challenge

Time allowed: 1 hour

Attempt all questions

Write your answers on this question paper

You may use a calculator

Section A: Ten multiple choice questions worth 1 mark each (worth 10 marks in total)
Allow about 15 minutes for this section

Section B: Two short answer questions (worth 10 marks in total)
Questions require a clear explanation of the underlying physical principles
Allow about 15 minutes for this section

Section C: Longer answer questions requiring calculations (worth 30 marks in total)
Questions may be set on unfamiliar topics. Additional information necessary to answer the question will be given in the question
Allow 30 minutes for this section

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

Section A: Multiple Choice Answers

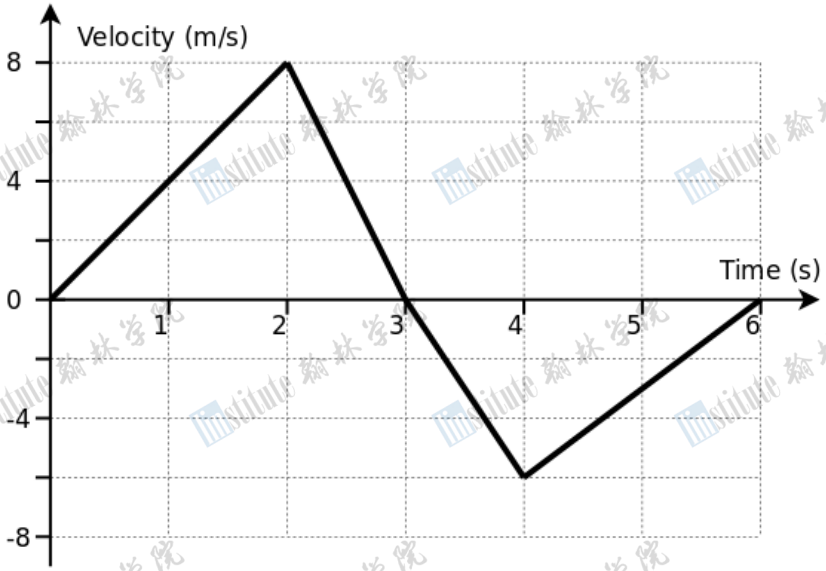
Write the correct letter in the grid. The first column has been done as an example if the answer to question zero were C

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

Section A: Multiple Choice Questions

1. A tennis player moves in a straight line with a velocity as shown in the graph below. Their final displacement from their starting position is:

A. 0 m
B. 3 m
C. 9 m
D. 12 m
E. 21 m



2. When taking measurements there are several different sources of error.

The effect of these errors can be reduced by good scientific technique and through careful analysis.

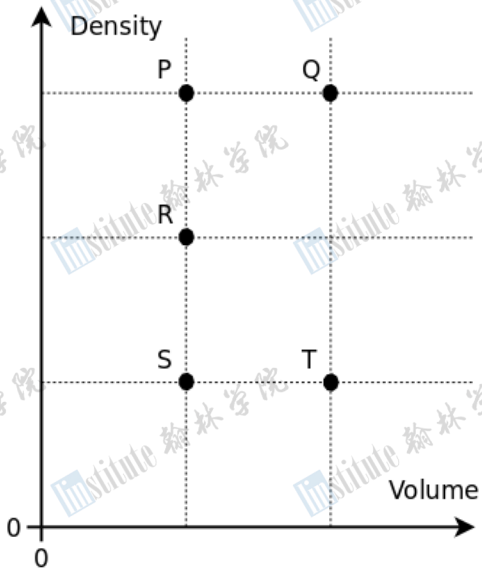
The most significant reason for plotting a graph is to:

A. Increase the precision of the readings
B. Avoid parallax error
C. Reduce the effect of random errors
D. Ensure a fair test
E. Recognise equipment failure

3. The graph shows the Volume and Density of several different objects.

The two objects that have the same mass are:

A. P & Q
B. P & S
C. R & Q
D. R & T
E. None

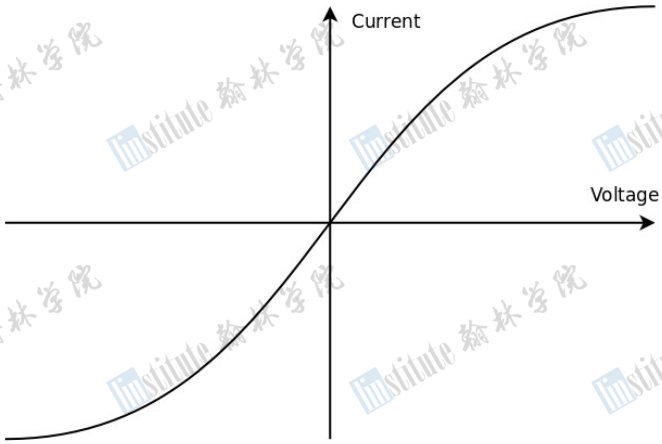


4. In a camera flash, the energy is stored by charging an electronic component called a capacitor. The charging circuit draws 400 mA of current from the 3 volt battery and takes 1.6 seconds to reach full charge.

When fully charged, the energy transferred from the battery is approximately:

A. 0.6 J
B. 1 J
C. 2 J
D. 5 J
E. 1900 J

5. The voltage – current graph for a filament light bulb is shown below.

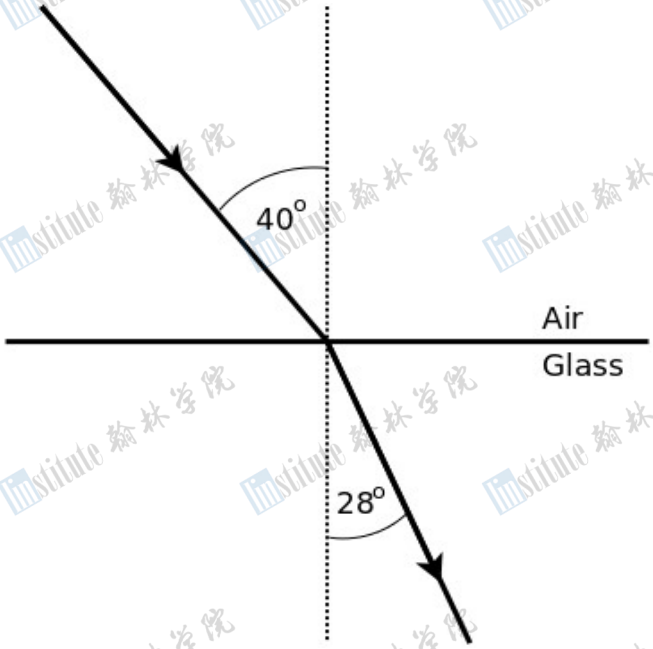


The graph has this shape because:

A. Resistance of the filament increases as the current increases
B. Resistance of the filament decreases as the current increases
C. The filament has a higher resistance than the connecting wires
D. The filament has a lower resistance than the connecting wires
E. None of the above

6. A light ray is refracted as it crosses from air into glass, as shown in the diagram. When the angle of incidence is increased to 80°, the angle of refraction will be approximately:

A. 28°
B. 46°
C. 56°
D. 68°
E. None, because TIR will occur above the critical angle



7. The initial activity of a radioactive isotope is 120 Bq and the half-life is 20 minutes. For a sample of the same isotope with twice the mass, the values would be:

	Initial Activitiy / Bq	Half Life / minutes
A	120	20
B	240	20
C	60	20
D	120	40
E	120	10

8. A fixed mass of gas is trapped in a syringe. The volume of the syringe is slowly reduced, compressing the gas without changing the temperature.

The pressure exerted on the walls of the syringe changes because:

A. The gas becomes more dense
B. The particles have more kinetic energy
C. The particles collide with each other more often
D. The particles hit the walls of the syringe with more force
E. The particles hit the walls of the syringe more often

9. Light and sound can both be thought of as a wave.

Which of the following statements is NOT true?

A. They can both transfer energy
B. They can both be reflected
C. They can both be refracted
D. They can both be diffracted
E. They can both be polarised

10. An aircraft of mass 4000 kg produces a thrust of 10 kN. The aircraft needs to travel at 35 m/s to take off.

From a standing start, the time to become airborne is approximately:

A. 2.5 s
B. 3.5 s
C. 9 s
D. 14 s
E. 88 s

Section B: Short Answer Questions

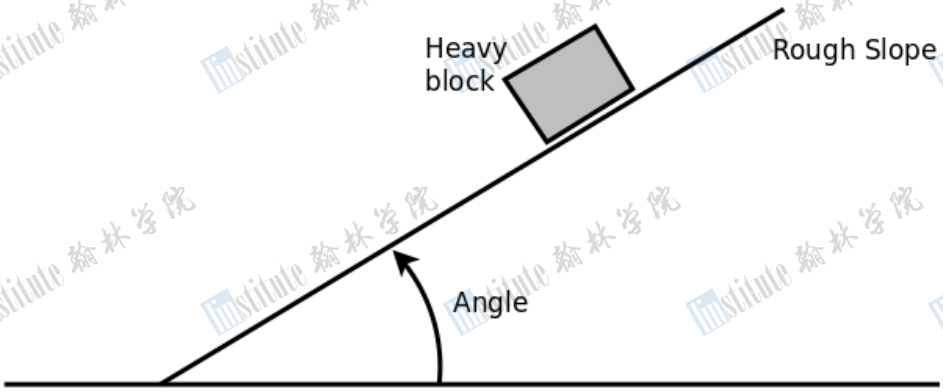
11. The diagram shows a heavy block resting on a rough slope.

For small angles, there is a friction force preventing the block from sliding down the slope.

The angle of the slope is increased and, at one particular angle, the block begins to slide down the slope.

Explain why the block begins to slide when the angle is increased.

[5 marks]



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12. In the circuit shown, the power supply is a fixed voltage V and the resistor is a fixed value R.

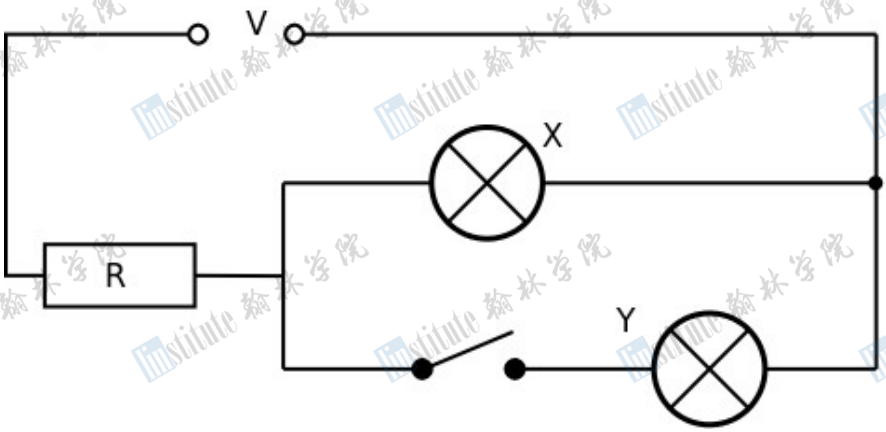
The two bulbs are identical.

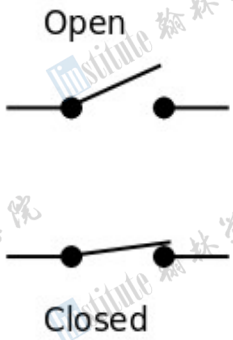
When the switch is open just bulb X is lit.

When the switch is closed both bulb X and bulb Y are lit.

State **and** explain whether the brightness of bulb X will increase, decrease or stay the same when the switch is changed from open to closed.

[5 marks]





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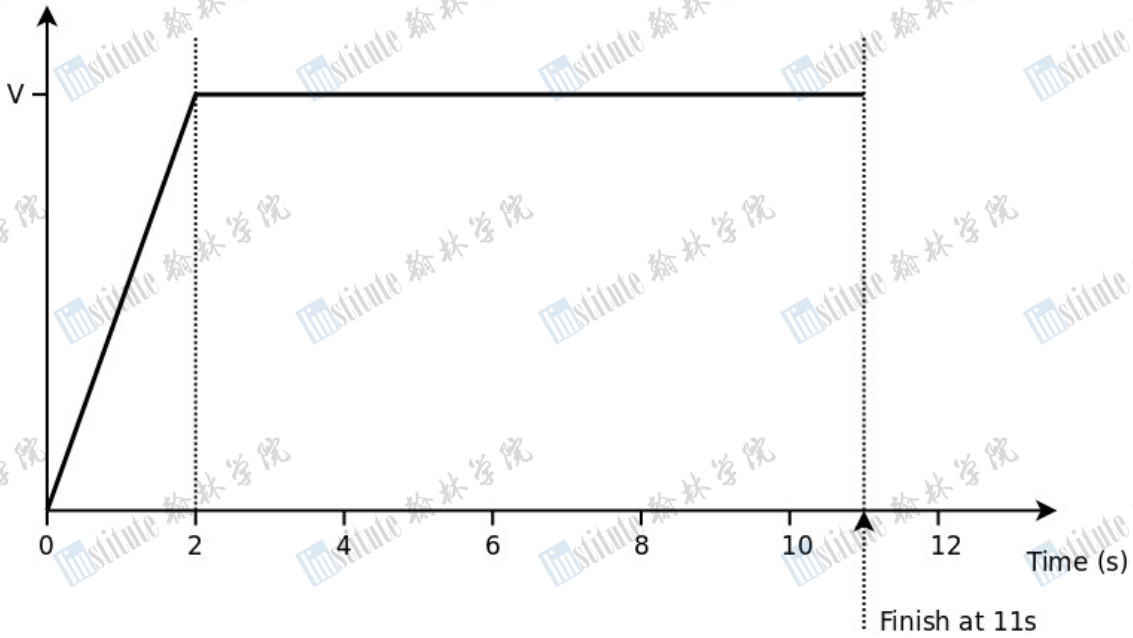
13. In this question you are asked to consider the effect of wind speed on the timing of a sprinter in a 100 m race.

If a following wind is present, it will provide a small extra force, helping the sprinter to accelerate.

With no following wind, a very simplified graph of a 100 m sprint is shown below.



(a) Use the graph to show v = 10 m/s

[3 marks]

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(b) Calculate the resultant force acting on the sprinter when they are accelerating given that they have a mass of 70 kg.

[2 mark]

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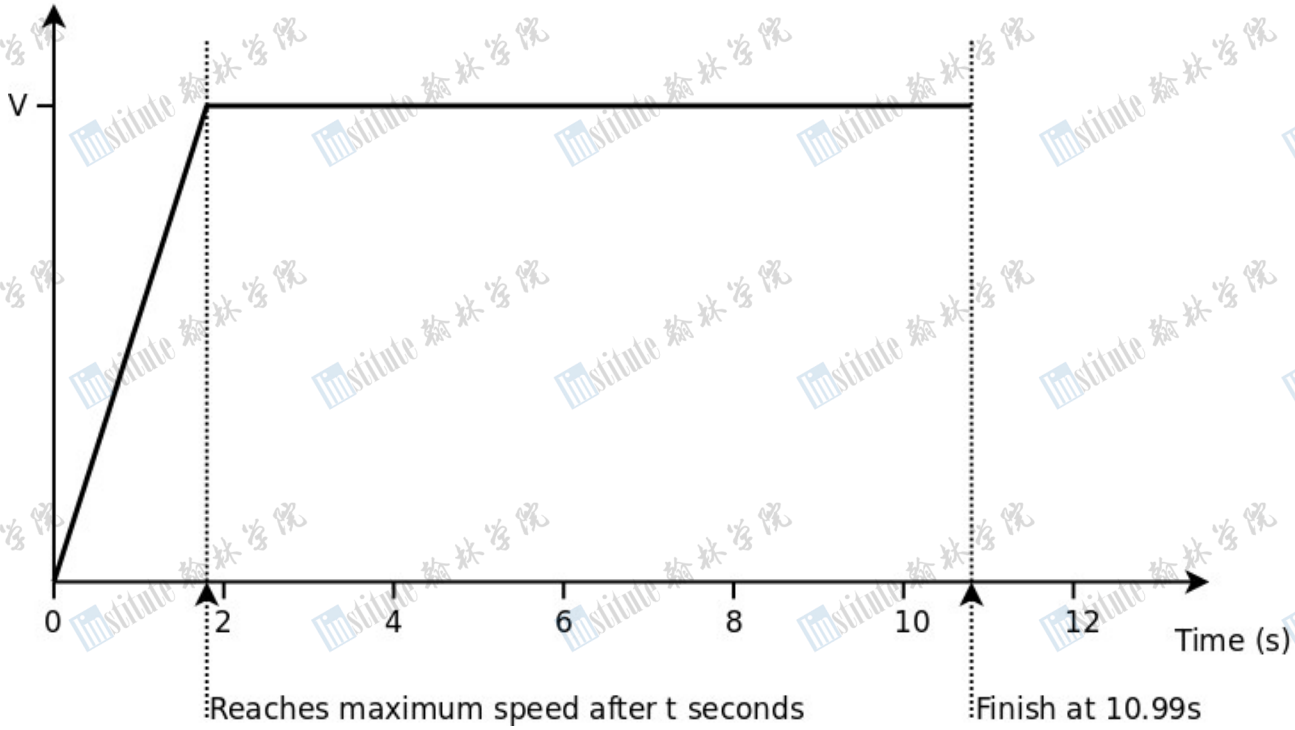
With a following wind the sprinter achieves the **same** maximum speed of 10 m/s but has a slightly greater acceleration and reaches maximum speed after only t seconds (where t is slightly less than 2 seconds).

The following wind reduces the time to complete the race by 10 milliseconds (ms) as shown on the graph below.



(c) Using the graph or otherwise, calculate the time (t) taken to reach maximum speed.

[3 marks]

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(d) Hence calculate the **extra** resultant force required to decrease the time of the race by 10 ms

[3 marks]

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The extra force on the runner can be roughly approximated as $F = 0.7\ u^2$
where u is the wind speed in m/s

(e) Hence calculate the wind speed that would give the 10 ms advantage.

[2 mark]

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(f) In reality a following wind has much less effect on the recorded time.
State and explain one reason why the approximation is not valid.

[2 mark]

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14. This question is about the maximum frequency at which digital data can be transmitted along a fibre optic cable.

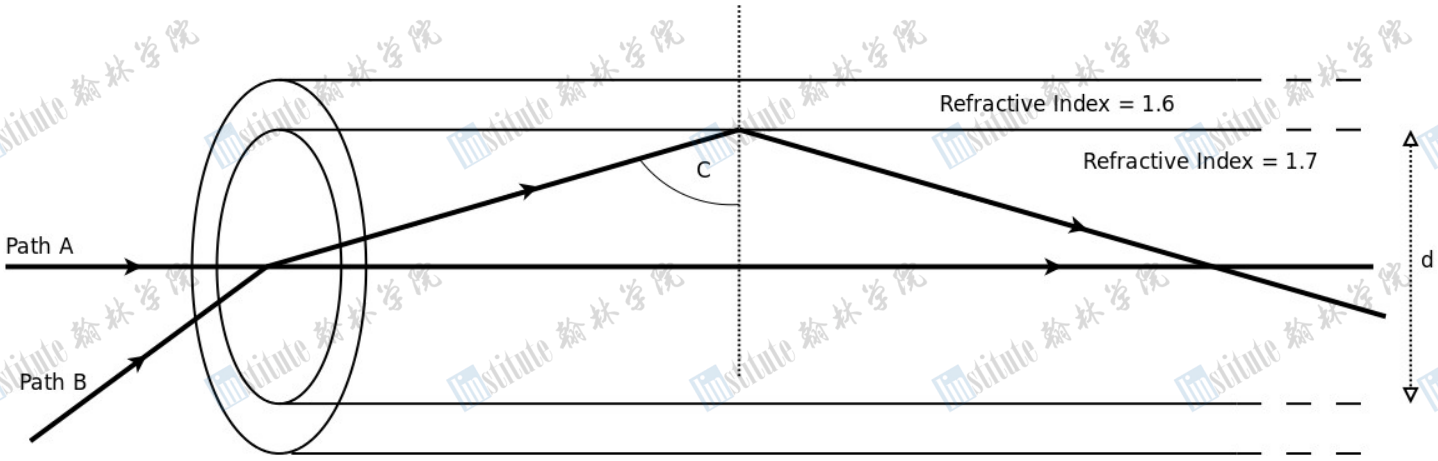
A fibre optic cable is made from two layers of glass as shown in the diagram below.

The inner 'core' of the fibre has a higher refractive index than the outer layer.

An optical signal can travel directly along the fibre taking path A in the diagram.

Alternatively, the signal can bounce along the inside of the fibre therefore taking a longer path.

The maximum distance travelled occurs when the angle is just greater than the critical angle, taking path B in the diagram.



Theory: Refractive index (n) = speed of light in a vacuum / speed of light in medium

For a light ray crossing a boundary with an angle of incidence θ_1 and an angle of refraction θ_2 and travelling from medium 1 (having a refractive index of n_1) to medium 2 (with refractive index n_2),

Snell's Law of refraction gives:

$$\sin(\theta_1) / \sin(\theta_2) = n_2 / n_1$$

The critical angle is when the angle of incidence ($\theta_1 = C$) is such that the angle of refraction is $\theta_2 = 90°$

(a) Show that the critical angle (C) as shown in the diagram is about 70°

[2 marks]

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(b) For a fibre optic cable 1 km long, show that the **time difference** between a signal taking path A and a signal taking path B is approximately 0.4 μs

Core diameter, d = 0.6 mm

Speed of light in a vacuum = 3×10^8 m/s

Hint: Sketch the two paths with B crossing the fibre and use geometry to calculate how much longer path B is than path A. Knowing the difference in the lengths of the paths, calculate the time difference.

[6 marks]

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The digital signal emerging from the end of the fibre is a combination of the signals that have travelled along the two different paths.

When the 'ON' from path A arrives at the same time as an 'OFF' from path B, the signal is lost.

(c) Hence calculate the maximum frequency that can be transmitted along the cable

[3 marks]

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(d) State **and** explain how each of the following changes affects the maximum frequency that can be transmitted:

(i) Decreasing the diameter (d) of the core

[2 marks]

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(ii) Decreasing the refractive index of the outer layer

[2 marks]

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END OF PAPER