Name:	
School:	

Total Mark	

BPhO
British Physics Olympiad

2015 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 question(s) 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

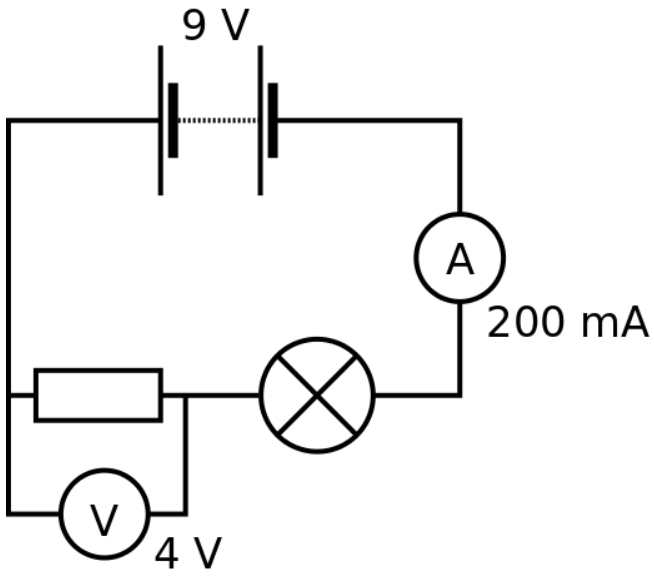
Question	0	1	2	3	4	5	6	7	8	9	10
Answer	C										

Section A: Multiple Choice Questions

1. The circuit shows a bulb and a fixed resistor in a circuit. The circuit uses a 9 V battery and a current of 200 mA flows from the battery.

   The resistance of the bulb is:

   A. 0.025 Ω
   B. 20 Ω
   C. 25 Ω
   D. 45 Ω
   E. 65 Ω



2. Telecommunication signals can be transmitted using either radio-waves or microwaves.

   When relaying information by satellite (e.g. satellite TV, internet, etc), microwaves are more suitable because:

   A. Radio-waves do not travel in space
   B. Radio-waves cannot travel through the atmosphere
   C. Microwaves are faster
   D. Radio-waves can carry more information
   E. Microwaves have a shorter wavelength

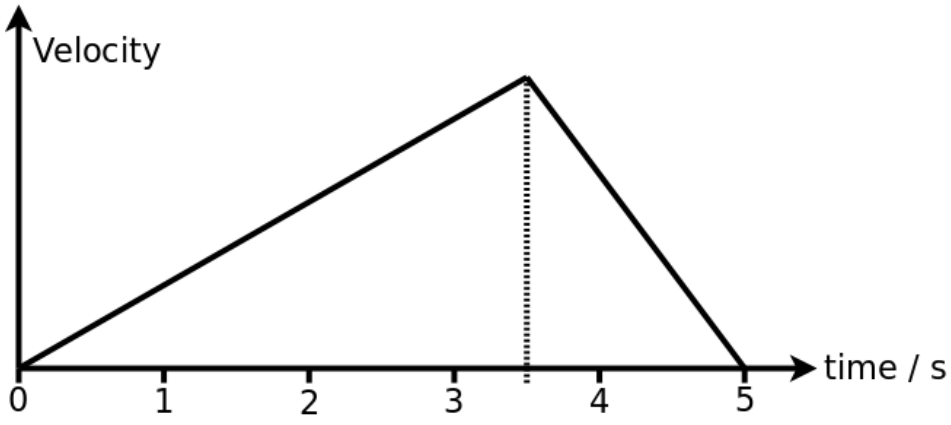
3. The rate of rotation of an object is measured by the angle that it turns through each second.

   The scientific unit for angle is the radian, where 2π radians = 360°
   and therefore 1 radian = 57.3°.

   In these units, the rate of rotation of the earth about its own axis is:

   A. 7.3×10^{-5} radians / second
   B. 4.2×10^{-3} radians / second
   C. 4.4×10^{-3} radians / second
   D. 6.28 radians / second
   E. 15 radians / second

4. The velocity-time graph shows the performance of an F1 car as it accelerates from a standing start for 3.5 seconds and then brakes, coming to a stop in 1.5 seconds. In doing so it covers a total distance of 100 m.



   The maximum velocity of the car is:

   A. 20 m/s
   B. 29 m/s
   C. 40 m/s
   D. 67 m/s
   E. 100 m/s

5. Boyle's Law states that the absolute pressure of a fixed mass of gas is inversely proportional to the volume of the gas if the temperature remains constant.

   Put another way, if you have some gas in a sealed container so that it cannot escape, reducing the volume increases the pressure.

   In terms of kinetic theory, this is because:

   A. The particles of the gas hit the walls of the container harder as the volume decreases
   B. The particles of the gas hit the walls of the container more often as the volume decreases
   C. There are fewer gas particles hitting the container walls when the volume is smaller
   D. The surface area of the container is less when the volume decreases so there are fewer collisions with the gas particles
   E. The gas particles are less energetic when the volume is reduced

6. A 2.4 kW kettle is filled with 1.2 kg of water at 15 °C.
   The specific heat capacity of water is 4200 J/(kg·°C).

   The best **realistic** estimate of the time taken to boil the water in the kettle is:

   A. 30 seconds
   B. 143 seconds
   C. 170 seconds
   D. 200 seconds
   E. 1400 seconds

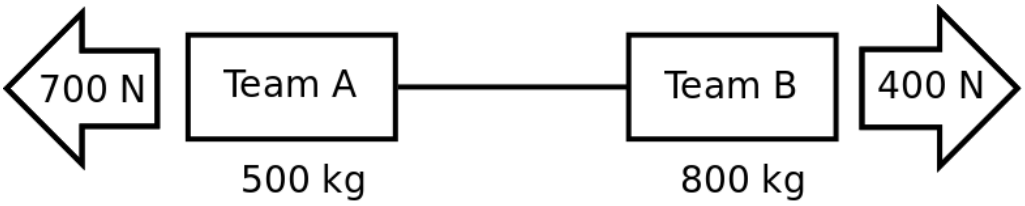
7. A mobile phone battery has a capacity of 1400 mAh (milliamp hours).

   If the phone is to last 24 hours between charges, the average current consumption of the phone must be about:

   A. 0.38 mA
   B. 34 mA
   C. 60 mA
   D. 140 mA
   E. 1.4 A

8. Two tug of war teams are shown in the simplified diagram below.

Team A has a total mass of 500 kg and exerts a pulling force of 700 N to the left.
Team B has a total mass of 800 kg and exerts a pulling force of 400 N to the right.
They are joined by a strong rope.



The acceleration of team A is:

A. 0.23 m/s^2 to the left
B. 0.50 m/s^2 to the right
C. 0.60 m/s^2 to the left
D. 1.40 m/s^2 to the left
E. 2.20 m/s^2 to the left

9. A radiation detector is used to investigate the activity of a radioactive source. The detector will record the activity of the source and will also record any background radiation. In one particular experiment the activity was measured as 185 Bq. Two half-lives later the activity was measured as 50 Bq.

The background activity was:

A. 0 Bq
B. 5 Bq
C. 25 Bq
D. 68 Bq
E. 135 Bq

10. In practical work, repeat readings are taken to make:

A. the experiment a fair test
B. the results more precise
C. the results more accurate
D. the results more reliable
E. All of the above

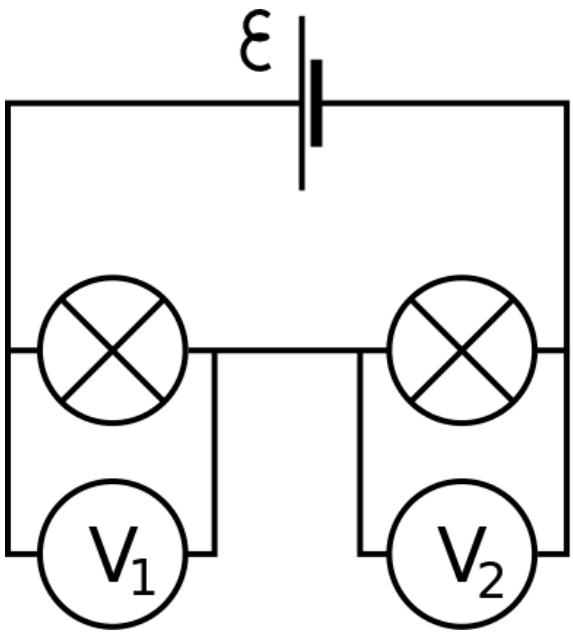
Section B: Short Answer Questions

11. A series circuit contains a cell and two bulbs.

The emf (voltage) of the cell is ε volts.

The potential differences across the two bulbs are V_1 and V_2 respectively.

(V_1 and V_2 are not necessarily the same).



Explain why the emf of the cell is equal to the sum of the potential differences across the bulbs.

I.e. **explain** why $\varepsilon = V_1 + V_2$

[5 marks]

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12. An elevator, going up, accelerates from rest for a few moments before continuing upwards at a constant velocity.

A person in the elevator experiences a sensation of being heavier for the few moments during which the elevator initially accelerates from rest.

Explain why the person feels heavier in this case.

[5 marks]

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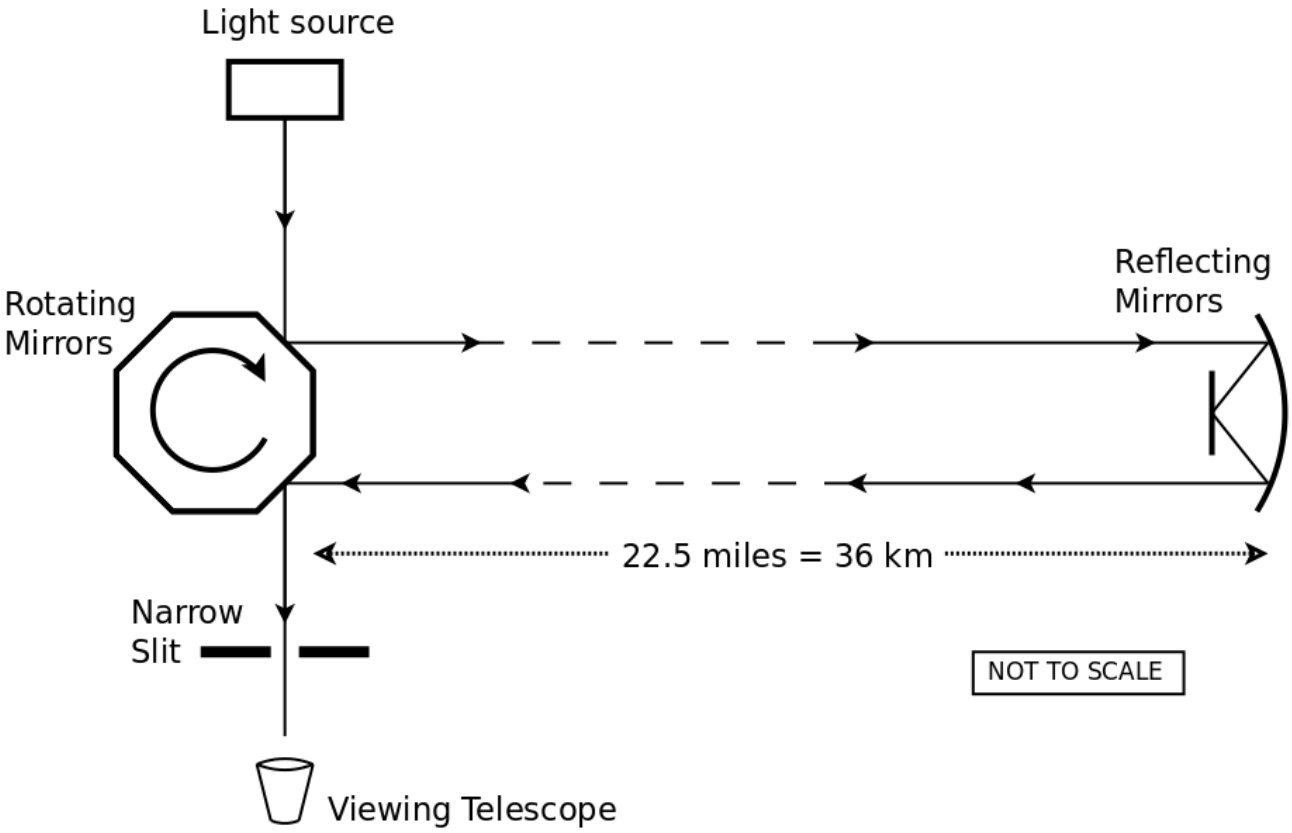
Section C: Longer Answer Questions

13. Measuring the Speed of Light

A method to make a direct measurement of the speed of light using a rotating mirror was originally developed by Leon Foucault who published his results in 1862. The method was later refined by Albert Michelson in 1926.

A simplified diagram of the apparatus is shown below.



A narrow light beam from the source was reflected off one face of the rotating mirror, travelled to an adjacent mountain top 36 km away and returned to be observed through the telescope, as shown.

The mirror's rate of rotation was slowly increased from rest.

At very specific rates of rotation an image of the light source became visible in the viewing telescope.

(a)(i) Explain why the light source can only be seen at very specific rates of rotation

[2 mark]

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(a)(ii) What is the minimum **angle** of rotation of the mirror so that the light source can be observed in the viewing telescope?

[1 mark]

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(a)(iii) The minimum **rate** of rotation to allow the light source to be observed was found to be 31,000 rpm (revolutions per minute).

Use this information to calculate the speed of light

[4 marks]

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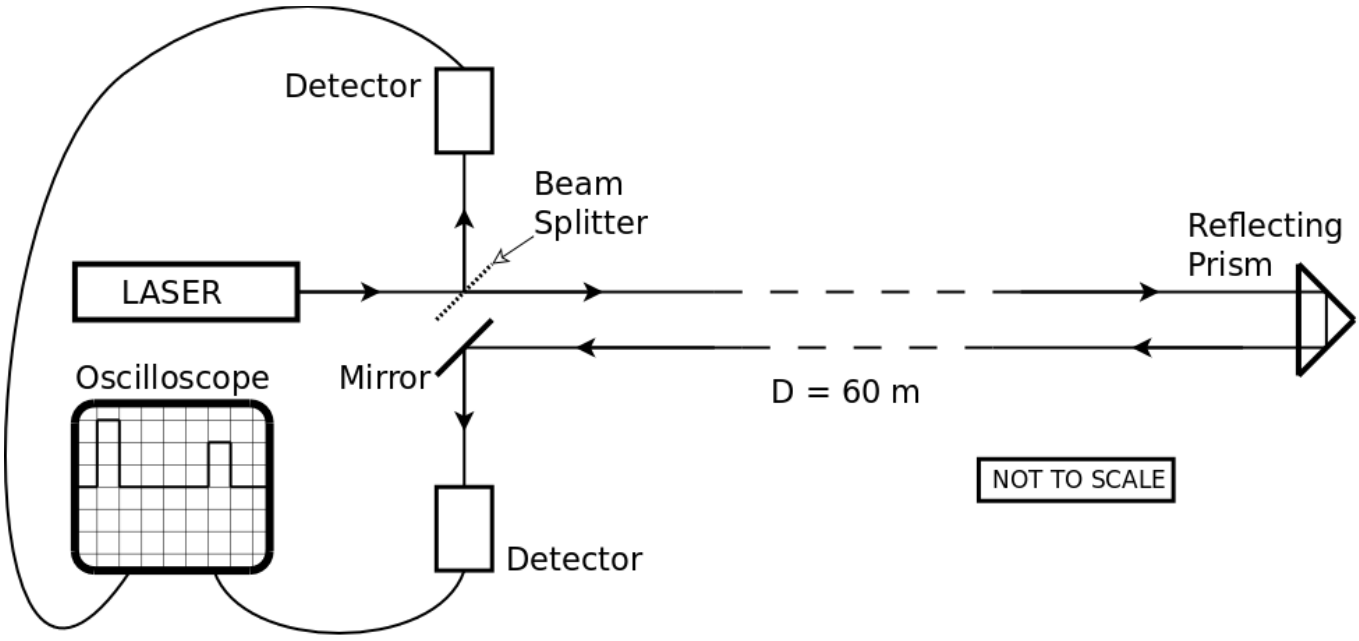
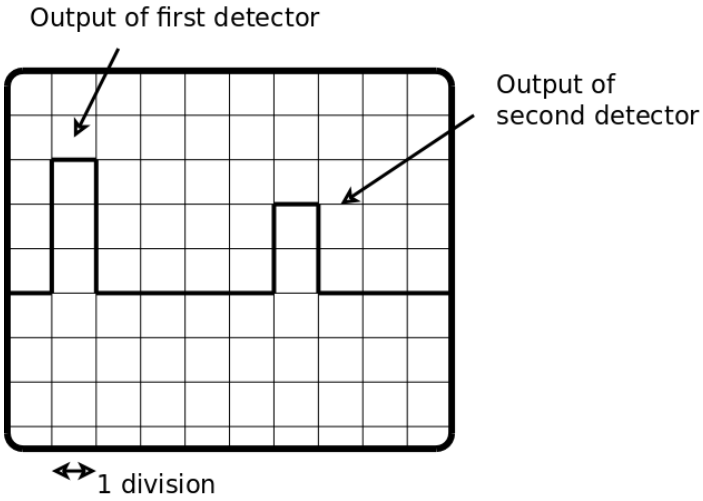
A student tries to measure the speed of light directly in the school laboratory.

They use a laser beam that is modulated at a frequency of 1 MHz so that the beam produces 1×10^6 short pulses per second. The beam is split so that one beam goes directly to a detector and the other beam goes via a 60 m long corridor, is reflected and travels back down the corridor to a second mirror and detector.

The outputs of the two detectors are combined and displayed on an oscilloscope screen.



The timebase on the oscilloscope is set to 0.1 μs per division.



One big square is one division.

Horizontally, one division is 0.1 μs

1 μs = 1 x 10^{-6} s

The vertical axis measures voltage

The oscilloscope display shows the pulse arriving from the first detector and then the pulse from the second detector arriving some time later

(b)(i) Use the information on the diagrams to calculate the speed of light as measured by the student.

[3 marks]

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(b)(ii) Explain why the return signal has produced a smaller peak on the oscilloscope display

[1 mark]

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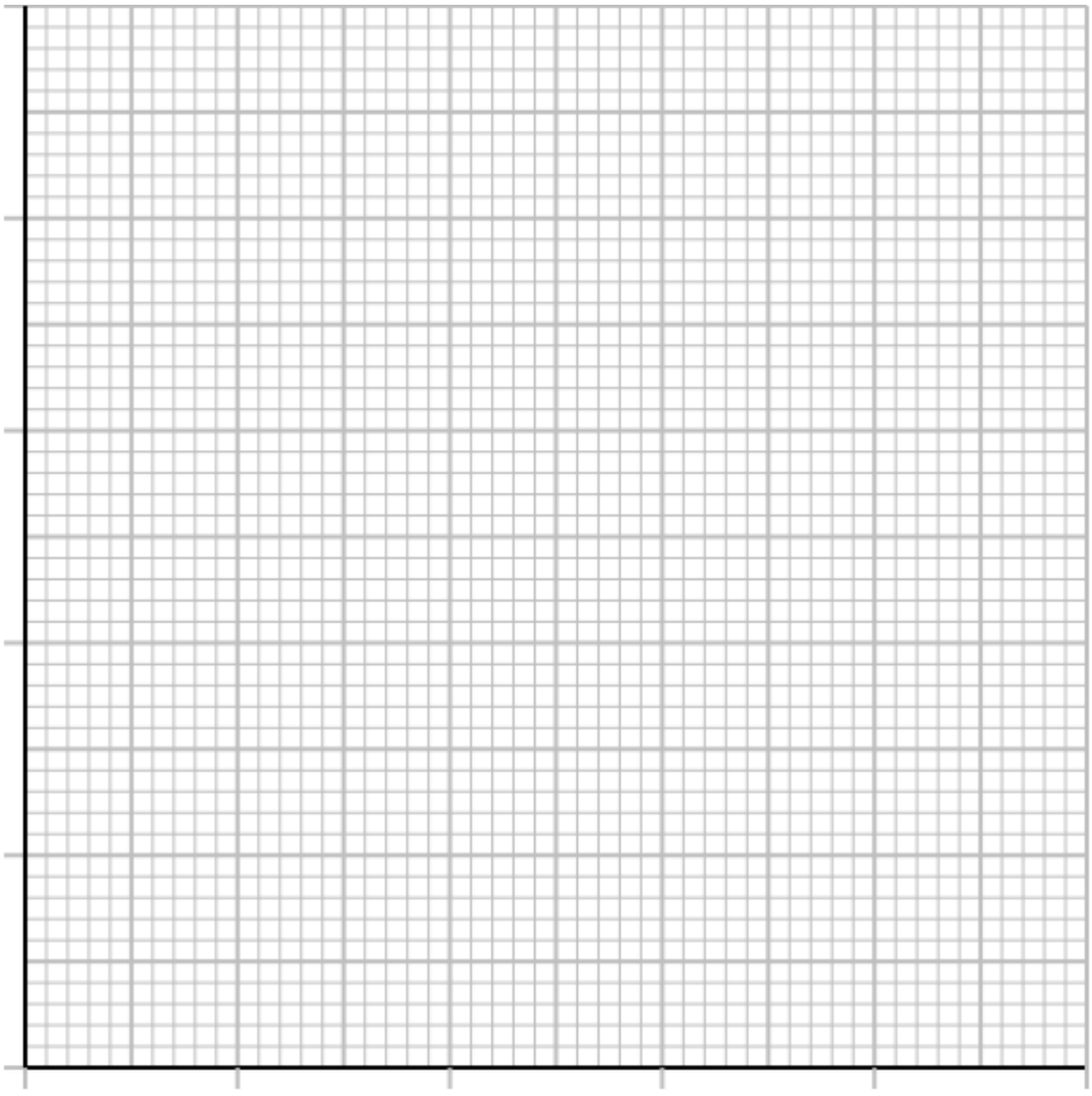
The student decides that the value obtained for the speed of light is not very good and repeats the experiment using different distances (D) along the corridor.

The results are shown in the table:

D/m	t/μs
30	0.3
45	0.4
60	
75	0.6
90	0.7

(c)(i) Plot a graph of the results

[3 marks]



(c)(ii) The student realises that the detectors are giving a systematic error.

Explain how the graph shows this **and**

state the effect of the systematic error on the result obtained for (b)

[2 marks]

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(c)(iii) Using the graph, or otherwise, determine a value for the speed of light for these results

[3 marks]

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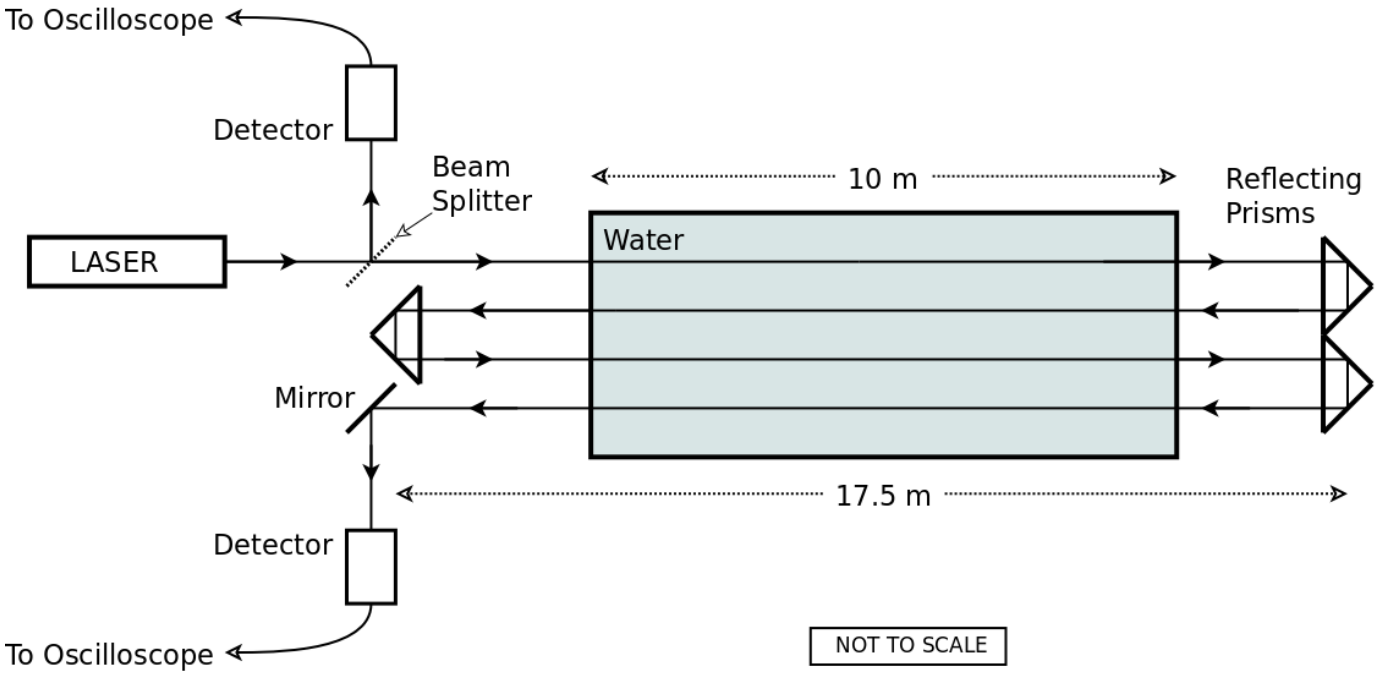
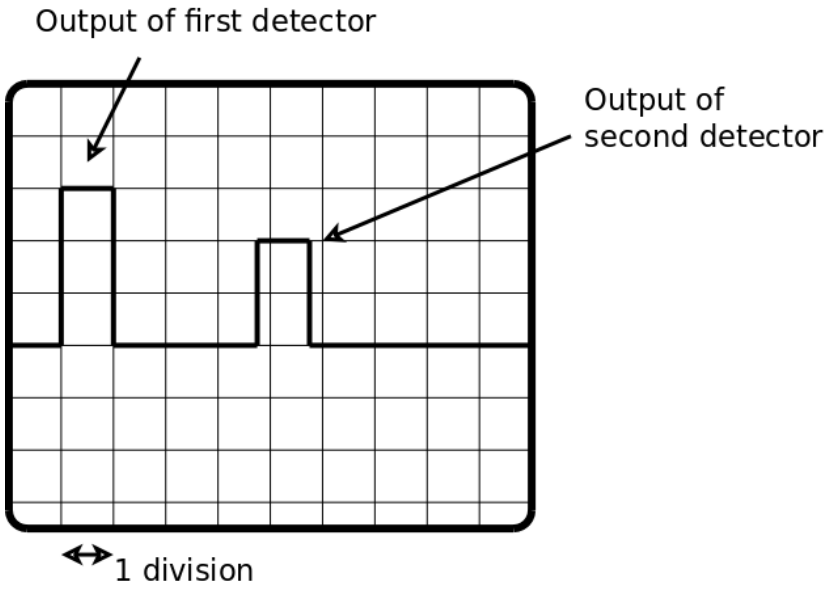
The student now tries to determine the speed of light in water by bouncing the light beam several times through a water tank as shown in the diagram below.



The student uses the same detectors and the settings on the oscilloscope remain unchanged.

The water tank is 10 m long, the distance between the reflecting prisms is 17.5 m.



(d) Using the results shown on the oscilloscope trace and the results from part (c), determine the speed of light in water

[5 marks]

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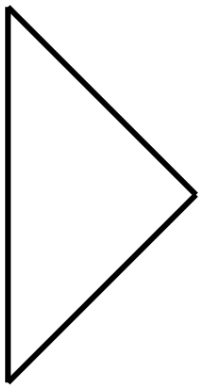
In the original Michelson experiment a mirror was used to reflect the light.

In the laboratory based experiment, the student used prisms to return the light beam along the corridor.

(e)(i) Explain how the prism is used to 'reflect' the light beam. You may add to the diagram of the prism to help explain your answer.

[2 marks]



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(e)(ii) Describe the advantage of using a prism instead of a mirror to reflect the beam

[1 marks]

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(e)(iii) By making suitable numerical estimates or suggesting likely values, explain why the reduction of the speed of light in the glass of the prisms is unlikely to have any measurable effect on the results obtained by the student.

[3 marks]

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END OF PAPER