EPSOM COLLEGE

Physics Department

16+ Scholarship Paper SAMPLE

1 Hour

CANDIDATE NAME:

READ THESE INSTRUCTIONS FIRST

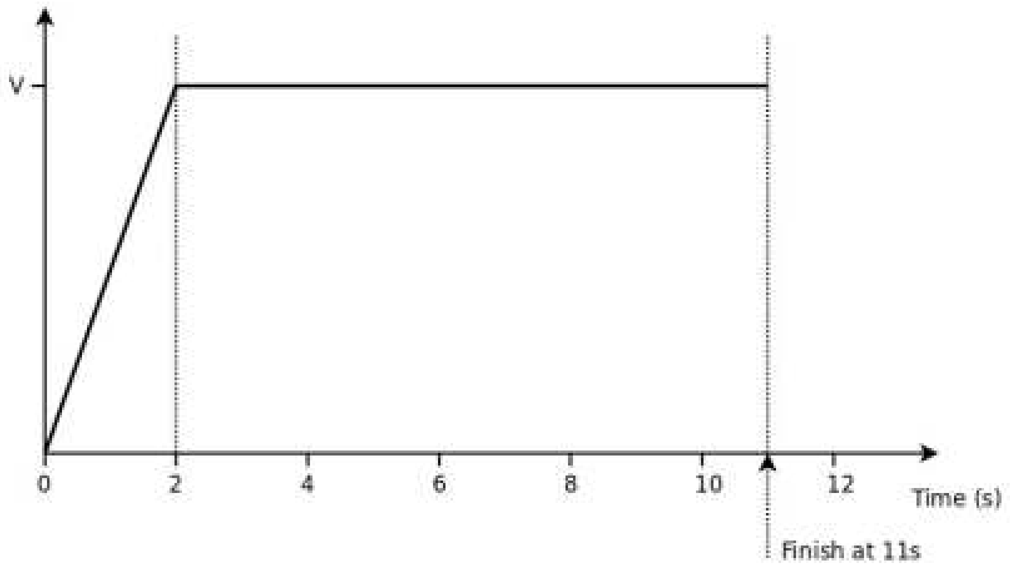
- Ensure you have filled in your name
- Write in black/blue pen – you may use an HB pencil for diagrams or graphs
- Answer ALL Questions
- Write answers in the spaces provided in this question paper
- You may lose marks if you do not show your working or if you do not use appropriate units
- Take the weight of 1.0kg to be 10N (acceleration of free fall = 10 m/s^2)
- You may use a calculator and the data and formula sheet provided
- This exam contains two sections:
    - Section A is long answer- spend 40 minutes here.
    - Section B is multiple Choice - spend 20 minutes here.
- The total mark for this paper is 58

Section A – Long Answer

Q1. 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]

....

....

....

(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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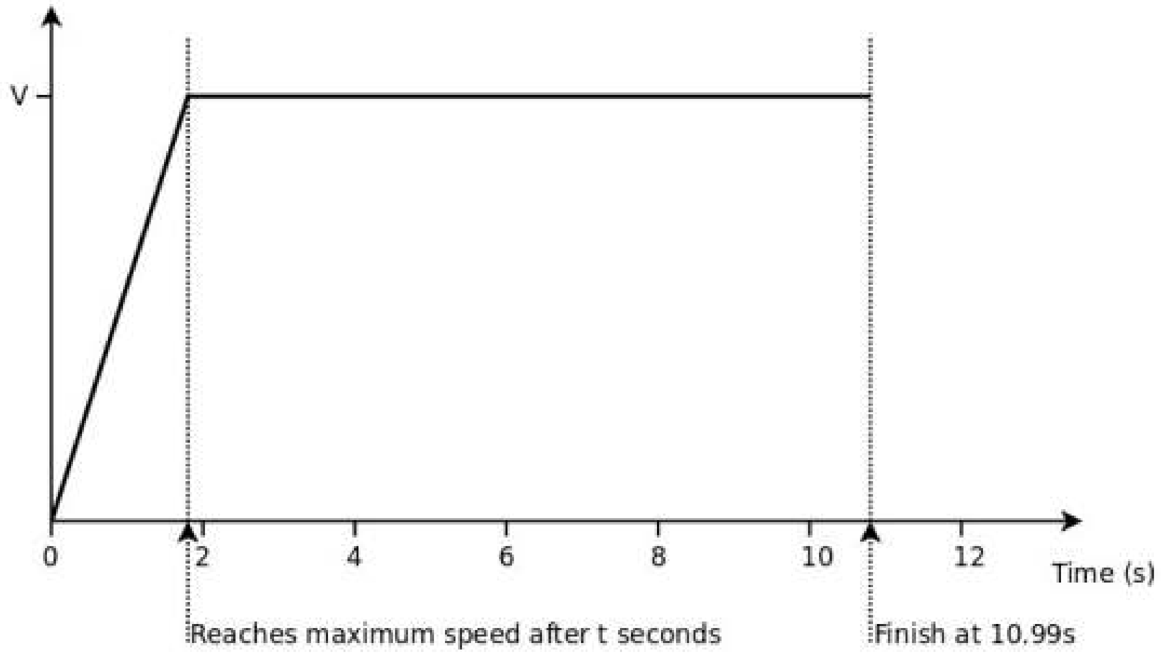
....

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]

....

....

....

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

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[22]

Q2.

Ocean waves arrive at the beach roughly parallel to the shore line, even if they were not travelling parallel to the shore line when they were further out to sea.

The is question is about why waves on the ocean change direction as they approach the beach.

To a good approximation, the speed of waves in shallow water depends only on the depth of the water and the acceleration due to gravity. The equation is:

$c=\sqrt{g \times d}$ where c = wave speed d = depth of water

An **investigation** to verify this wave speed equation involved the following:

- A ripple tank was used to generate waves
- The time for the ripples to travel the length of the tank was recorded
- The depth of the water was changed and the measurement repeated

Results: Length of ripple tank = 70 cm

Depth of water / cm	Average time to travel length of ripple tank / s
0.5	3.1
0.7	2.6
1.1	2.1

(a) Use these results to verify that the wave speed equation is reasonable

HINT: $c=\sqrt{g \times d}$ can be written as $c=\sqrt{g} \times \sqrt{d}$

....

....

....

....

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[4 marks]

(b) Calculate the speed of water waves when the depth of the water is 90cm.

....

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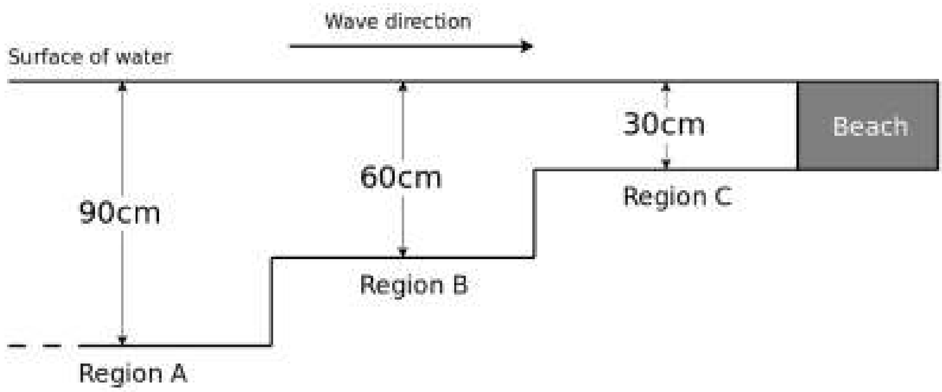
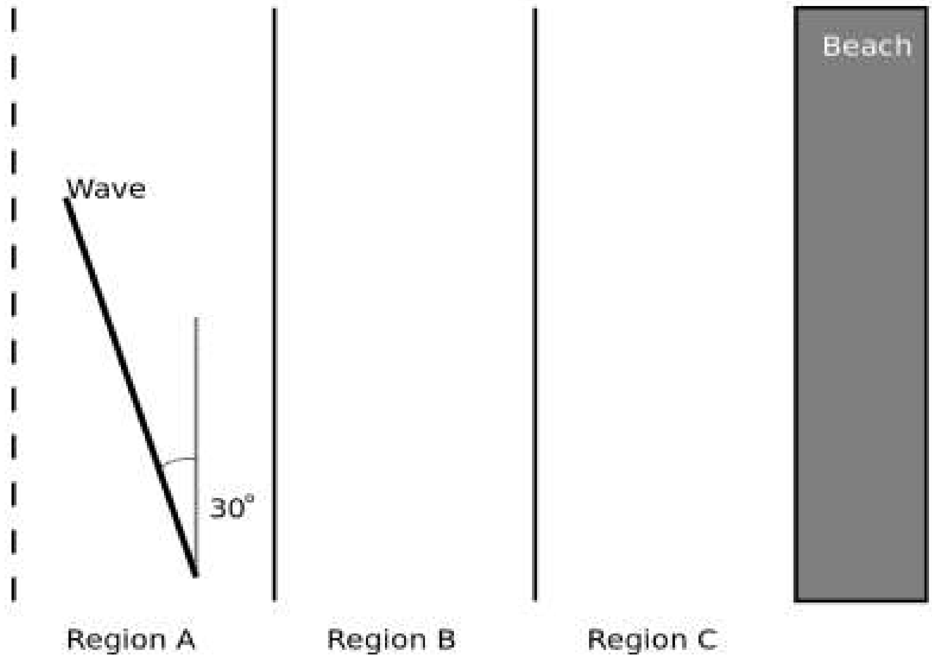
[2 mark]

The diagram shows an idealised cross-section of an area of water approaching a beach. The water gets shallower in three steps and then ends at the beach. Waves travel from the left towards the beach.



The same area of water is shown looking from above.



A wave is shown approaching the beach at an angle of 30° **to the shore line.**
As the wave crosses from Region A into Region B it changes direction.
The directions are related to the wave speeds by the following equation:

$$\frac{\sin(\theta_A)}{\sin(\theta_B)} = \frac{c_A}{c_B}$$

where θ_A and θ_B are angles measured to the **normal line** and c_A and c_B are the speeds of the wave in Region A and Region B respectively.

(c)(i) On the diagram above, indicate:

- The direction that the wave is travelling in **Region A**
- The approximate direction that the wave will be travelling in **Region B**

[2 mark]

(c)(ii) Calculate the direction of the wave in **Region B** relative to the shore line.

....

....

....

....

....

[3 marks]

(d) The waves enter Region A at a rate of one wave every 10 seconds.

Determine the wavelength of the waves in Region A.

....

....

[2 marks]

(e) The diagram below shows the cross section, and the view from above, for a different section of water.
The cross section is a more realistic gently sloping gradient where the depth changes gradually from 90 cm to zero as the waves approach the beach.

On the view from above, **sketch** the **position and shape** of the waves between the wave shown and the shore.

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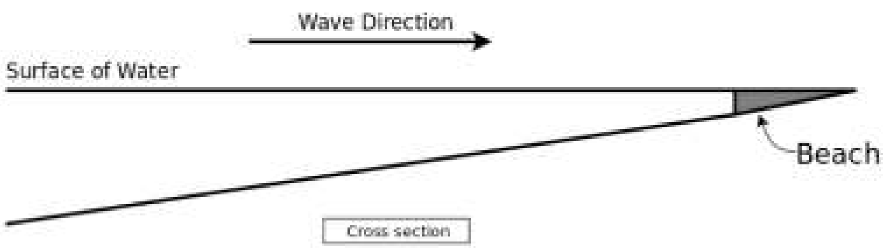
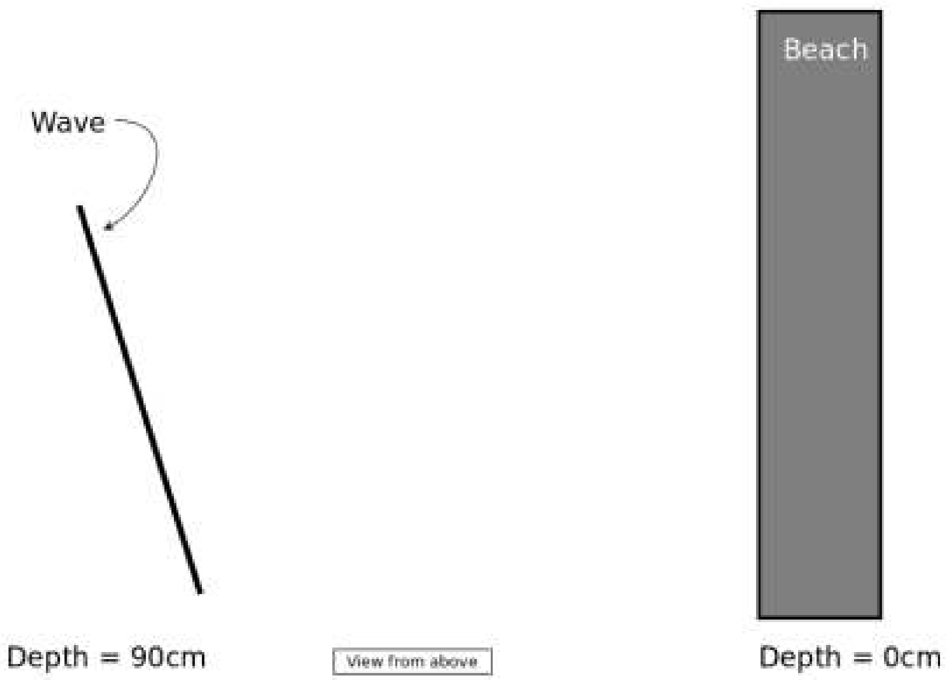


Cross section



View from above

Section B – Multi Choice

You are advised to spend 20 minutes here. Each Question is worth 2 marks. Circle the correct answer.

Q3.

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
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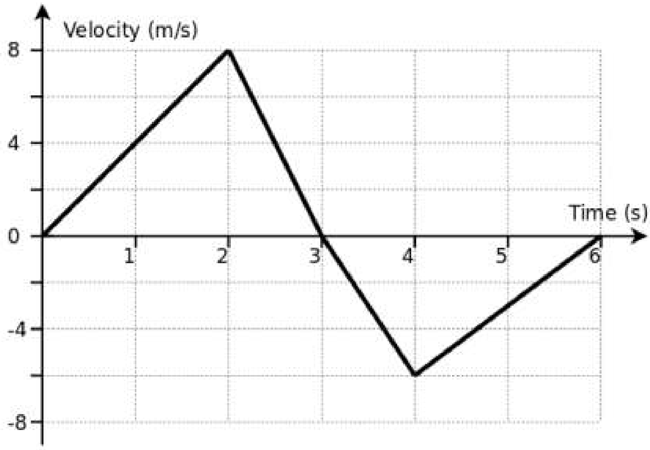
D. 12 m
E. 21 m



Q4.

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
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Q5.

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

The two objects that have the same mass are:

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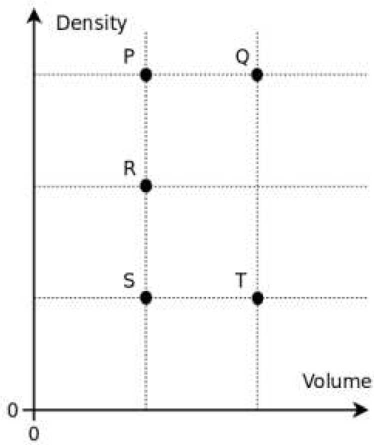
C. R & Q
D. R & T
E. None



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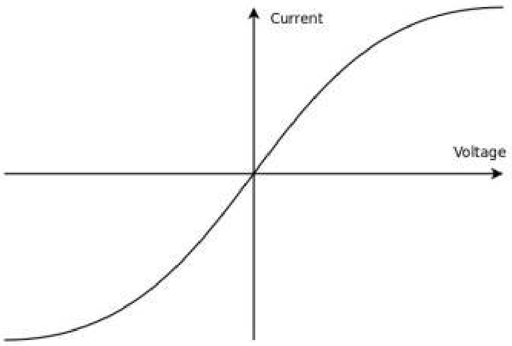
The voltage – current graph for a filament light bulb is shown below.



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

Q7.

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:

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B. 46°
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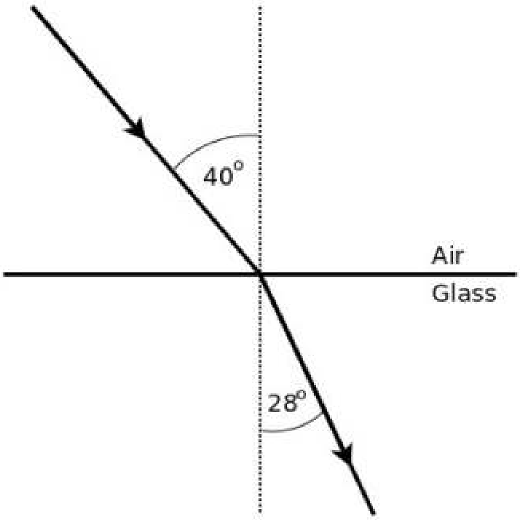
E. None, because TIR will occur above the critical angle



Q8.

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:

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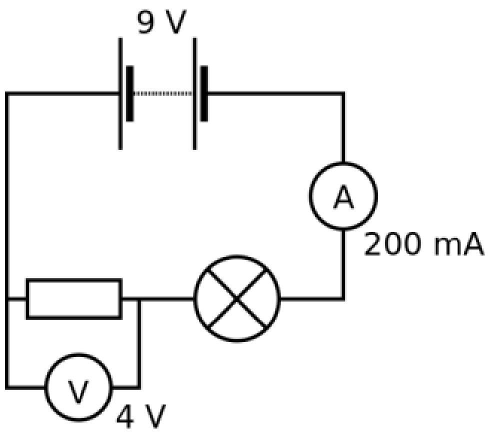
B. 20 Ω

C. 25 Ω

D. 45 Ω

E. 65 Ω



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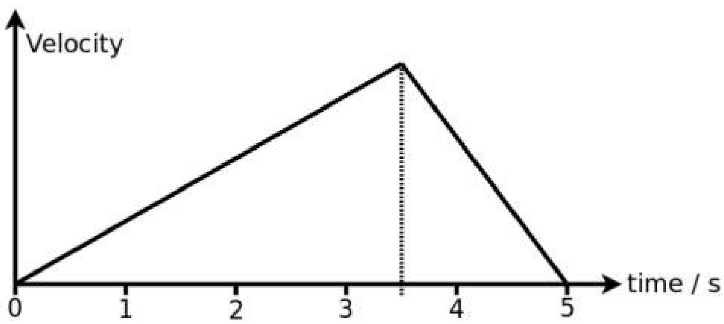
The velocity-time graph shows the performance of an F1 car as it accelerates from a standing start for 3.5 seconds and then brakes, coming to a stop in 1.5 seconds. In doing so it covers a total distance of 100 m.



The maximum velocity of the car is:

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B. 29 m/s

C. 40 m/s

D. 67 m/s

E. 100 m/s

Q10.

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:

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C. 170 seconds
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Q11.

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:

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B. 34 mA
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Q12.

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

END OF PAPER

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Section A – Long Answer

Q1. In this question you are asked to consider the effect of wind speed on the timing of a sprinter in a 100 m race.

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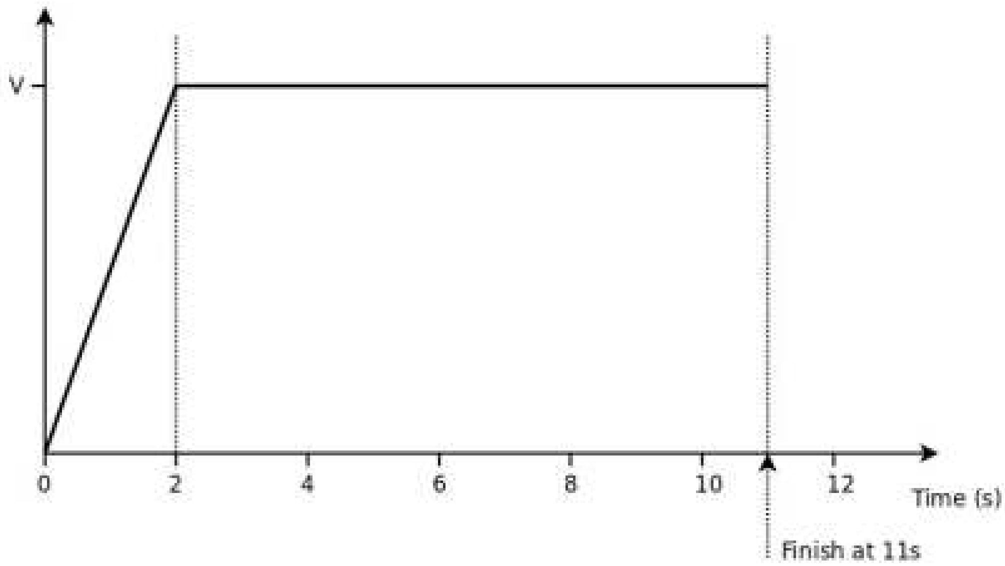


(a) Use the graph to show v = 10 m/s

[3 marks]

Area = 100m ∴ $\frac{1}{2} \times 2 \times V + 9 \times V = 100$

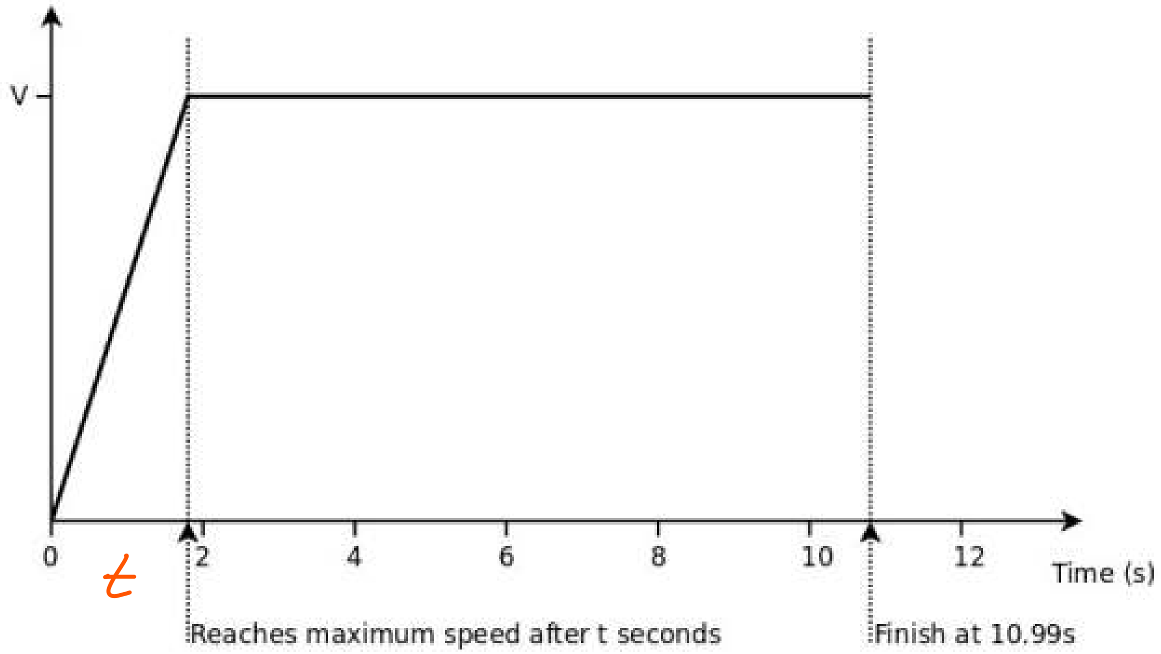
(b) Calculate the resultant force acting on the sprinter when they are accelerating given that they have a mass of 70 kg.

[2 mark]

$F = ma \quad = m\left(\frac{v-u}{t}\right)$

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]

$V = 10$ Area still $= 100$

$\therefore \frac{1}{2} \times t \times 10 = 10 \times (10.99 - t)$

Solve for t

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

[3 marks]

extra force = $F_{new} - F_{old}$

$F_{new} = m\left(\frac{v-u}{t}\right) - F_{old}$

$F_{new} =$

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]

answer to d = $0.7u^2$
rearrange & solve for u.

(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]

Any sensible & well explained reason.

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

[3 marks]

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

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[2 mark]

[22]

Q2.

Ocean waves arrive at the beach roughly parallel to the shore line, even if they were not travelling parallel to the shore line when they were further out to sea.

The is question is about why waves on the ocean change direction as they approach the beach.

To a good approximation, the speed of waves in shallow water depends only on the depth of the water and the acceleration due to gravity. The equation is:

$c = \sqrt{g \times d}$ where c = wave speed d = depth of water

An **investigation** to verify this wave speed equation involved the following:

- A ripple tank was used to generate waves
- The time for the ripples to travel the length of the tank was recorded
- The depth of the water was changed and the measurement repeated

Results: Length of ripple tank = 70 cm

Depth of water / cm	Average time to travel length of ripple tank / s
0.5	3.1
0.7	2.6
1.1	2.1

(a) Use these results to verify that the wave speed equation is reasonable

HINT: $c = \sqrt{g \times d}$ can be written as $c = \sqrt{g} \times \sqrt{d}$

$c = \sqrt{g \times d}$ calculated for all data

$c = \frac{d}{t}$ " " " "

Statement of similarity

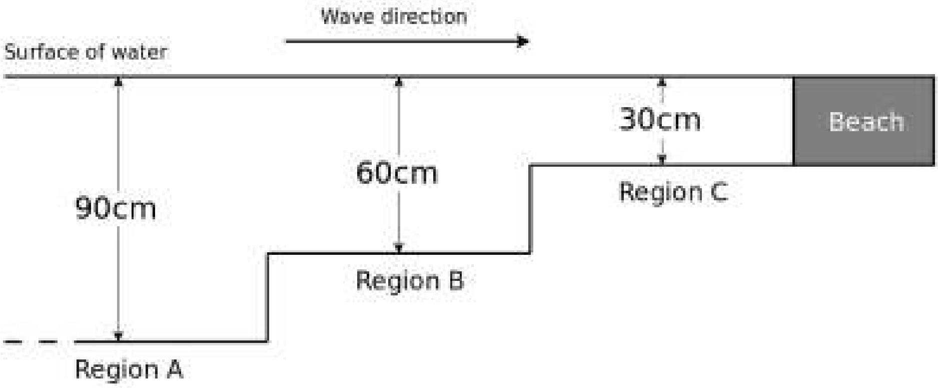
[4 marks]

(b) Calculate the speed of water waves when the depth of the water is 90cm.

$c = \sqrt{g \times d}$ $d = 0.9$

[2 mark]

The diagram shows an idealised cross-section of an area of water approaching a beach. The water gets shallower in three steps and then ends at the beach. Waves travel from the left towards the beach.



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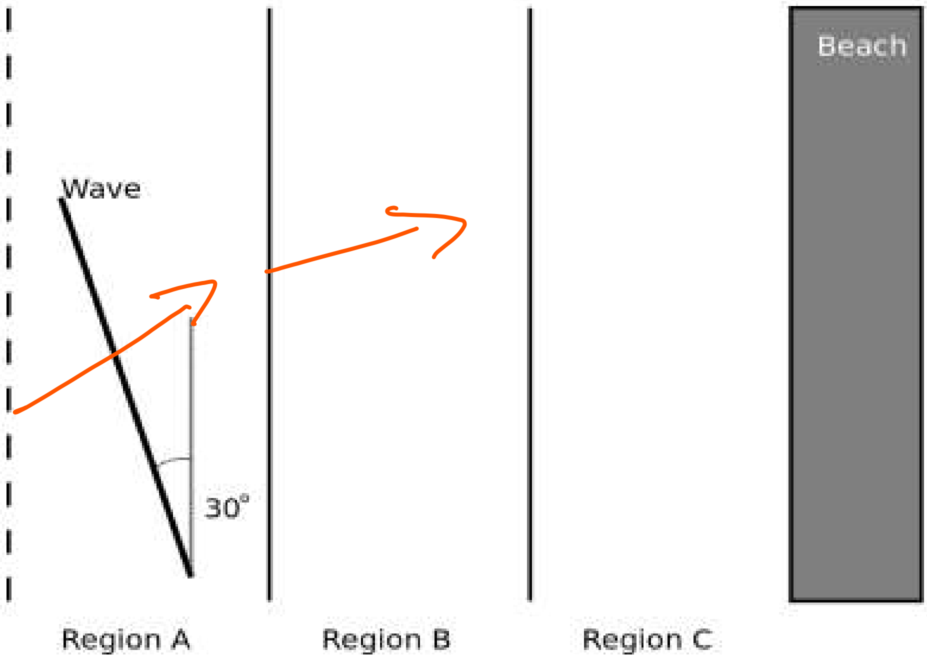


A wave is shown approaching the beach at an angle of 30° **to the shore line.**
As the wave crosses from Region A into Region B it changes direction.
The directions are related to the wave speeds by the following equation:

$$\frac{\sin(\theta_A)}{\sin(\theta_B)} = \frac{c_A}{c_B}$$

where θ_A and θ_B are angles measured to the **normal line** and c_A and c_B are the speeds of the wave in Region A and Region B respectively.

(c)(i) On the diagram above, indicate:

- The direction that the wave is travelling in **Region A**
- The approximate direction that the wave will be travelling in **Region B**

[2 mark]

(c)(ii) Calculate the direction of the wave in **Region B** relative to the shore line.

$$\frac{c_A}{c_B} = \frac{\sin(\theta_a)}{\sin(\theta_b)} \qquad \frac{c_A}{c_B} \text{ from data}$$

$$\theta_b = \sin^{-1}\left[\frac{c_B \sin(30)}{c_A}\right]$$

[3 marks]

(d) The waves enter Region A at a rate of one wave every 10 seconds.

Determine the wavelength of the waves in Region A.

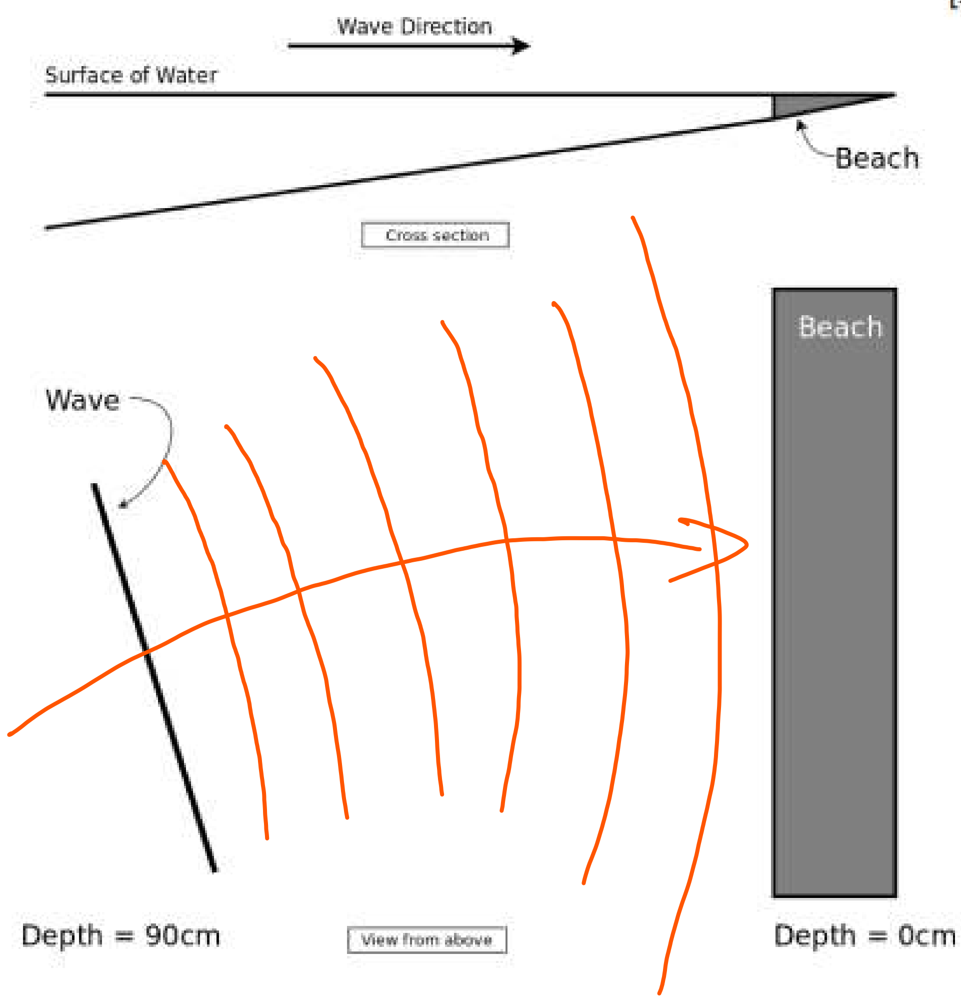
$c = f\lambda \quad f = \frac{1}{10}$

[2 marks]

(e) The diagram below shows the cross section, and the view from above, for a different section of water.
The cross section is a more realistic gently sloping gradient where the depth changes gradually from 90cm to zero as the waves approach the beach.

On the view from above, **sketch** the **position and shape** of the waves between the wave shown and the shore.

[3 marks]



Section B – Multi Choice

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Q3.

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:

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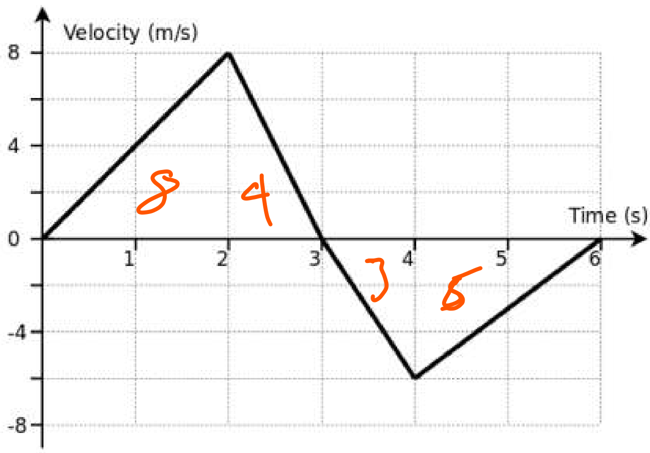

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The graph shows the Volume and Density of several different objects.

The two objects that have the same mass are:

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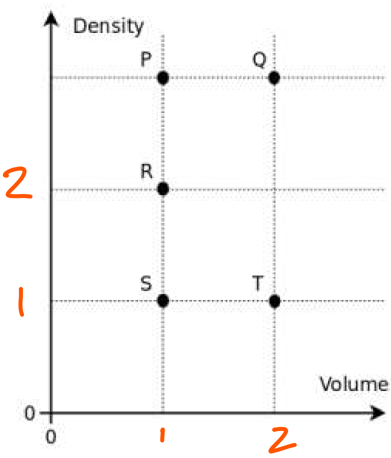

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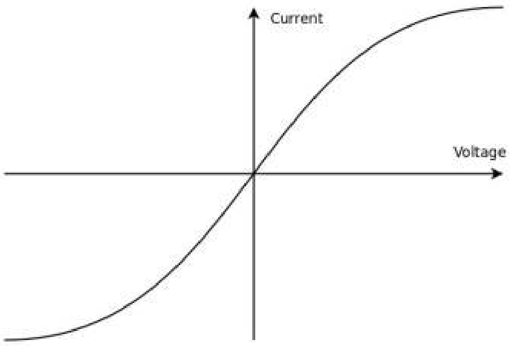
The voltage – current graph for a filament light bulb is shown below.



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A. Resistance of the filament increases as the current increases
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When the angle of incidence is increased to 80°, the angle of refraction will be approximately:

A. 28°
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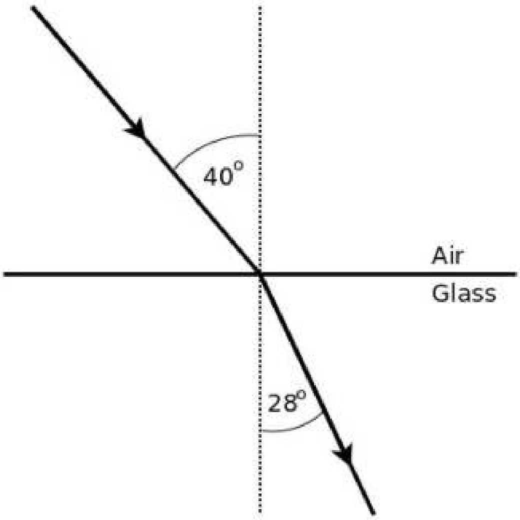
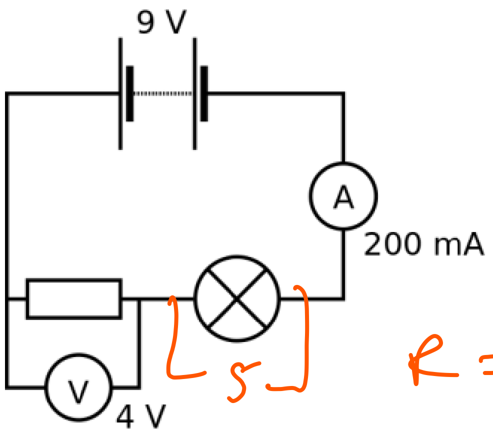


Q8.

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:

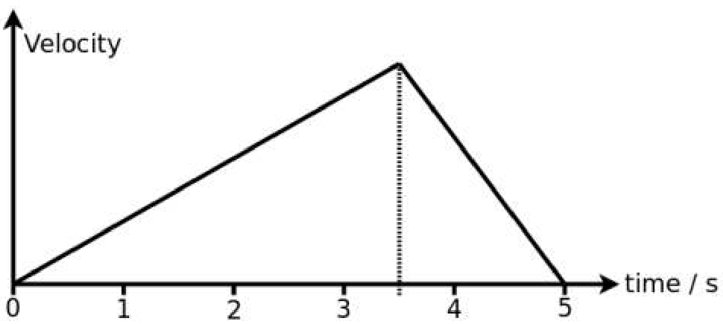
A. 0.025 Ω
B. 20 Ω
C. 25 Ω
D. 45 Ω
E. 65 Ω



$R = \frac{V}{I} = \frac{5}{0.2}$

Q9.

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.



Area = 100

The maximum velocity of the car is:

$\frac{1}{2} \times 3.5 \times V + \frac{1}{2} \times 1.5 \times V = 100$

$1.75 + 0.75 = 2.5V = 100$

$V = \frac{100}{2.5}$

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

Q10.

$P \cdot t = Q = mc\Delta t$

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).

$2400 \times t = 4200 \times 1.2 \times 85$

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
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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:

$Q = It$

$I = \frac{1400\,mAh}{24\,h}$

A. 0.38 mA
B. 34 mA
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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:

$F = ma \qquad a = \frac{300}{1300}$

A. 0.23 m/s² to the left
B. 0.50 m/s² to the right
C. 0.60 m/s² to the left
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E. 2.20 m/s² to the left

END OF PAPER