Name:	
School:	

Total Mark	

2016 Physics Challenge

Time allowed: 1 hour

Attempt all questions

Write your answers on this question paper

You may use a calculator

Use g = 10 N / kg

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

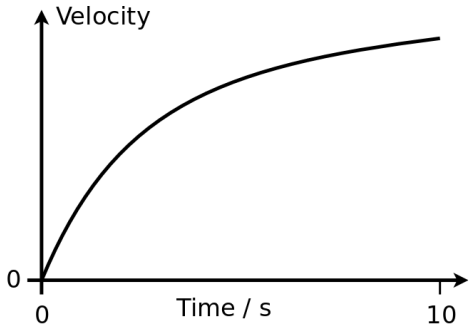
Section A: Multiple Choice Answers

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

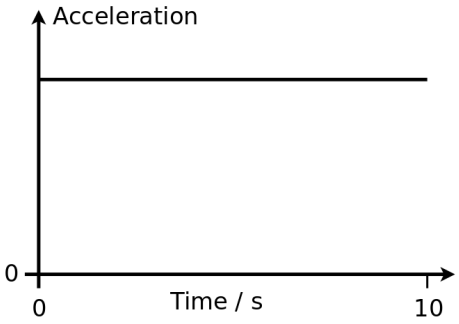
Question	0	1	2	3	4	5	6	7	8	9	10
Answer	C										

Section A: Multiple Choice Questions

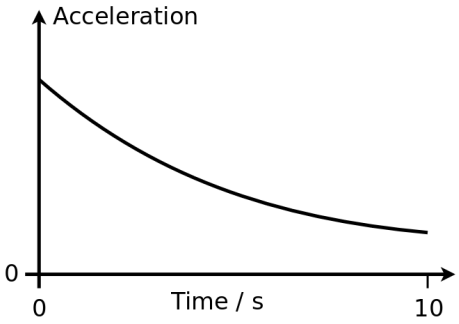
1. The velocity – time graph for an object's motion is shown below:



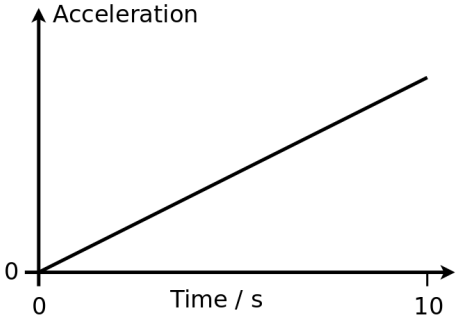
The corresponding acceleration – time graph is:



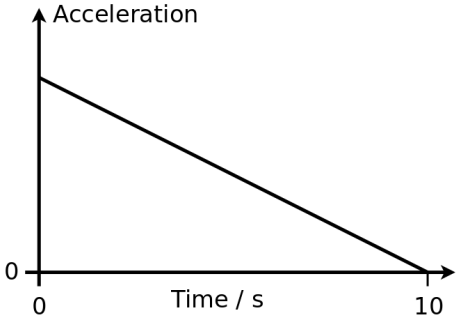
A.



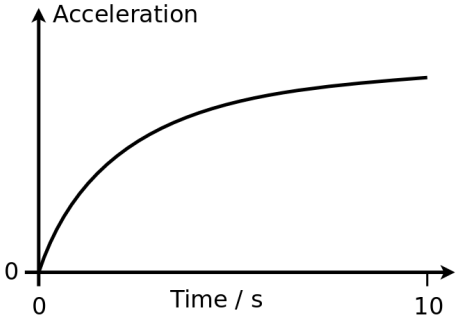
B.



C.



D.

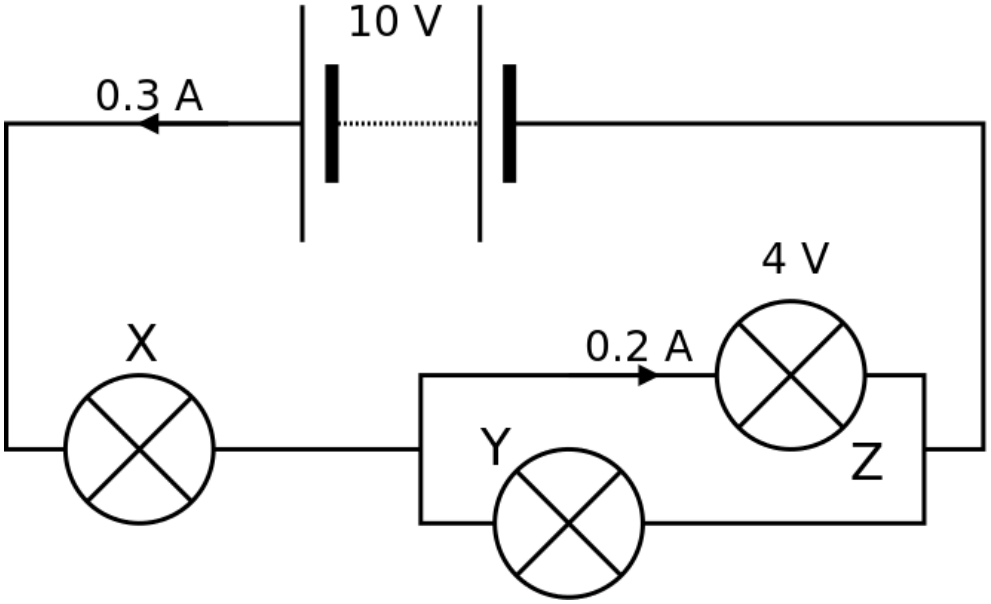


E.

2. A circuit contains a battery and three bulbs, X, Y and Z.

The battery has an emf of 10V and a current of 0.3A flows through the battery.

There is a potential difference of 4V across **bulb Z** through which a current of 0.2A flows.



The potential difference across **bulb X** is:

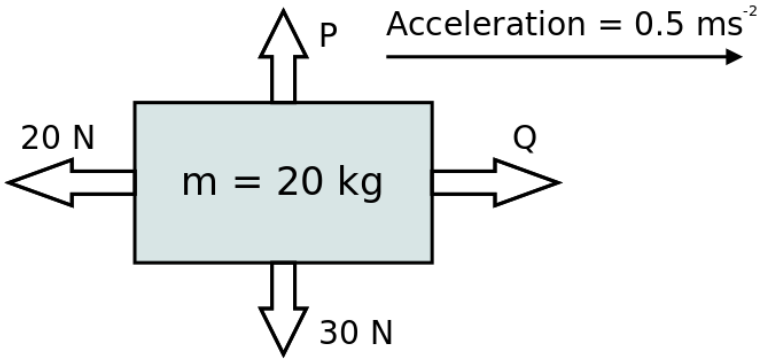
A. 2V
B. 4V
C. 6V
D. 8V
E. 10V

3. For the circuit shown in Question 2 above, which bulb is the dimmest?

i.e. which bulb is the least bright?

A. All the bulbs are the same brightness
B. Bulb Y & Z are equally dim
C. Bulb X
D. Bulb Y
E. Bulb Z

4. An object with a mass of 20 kg accelerates at 0.5 ms^{-2} to the right as shown.



There are four forces acting on the object. The forces labelled P and Q are:

A. P = 20 N Q = 20 N
B. P = 20 N Q = 30 N
C. P = 30 N Q = 10 N
D. P = 30 N Q = 20 N
E. P = 30 N Q = 30 N

5. Which of the following combinations of units is a unit of **power**?

A. kilowatts x hours (kWh)
B. Joules x seconds (Js)
C. Newtons x meters (Nm)
D. Volts x Amps (VA)
E. Joules x meters (Jm)

6. A sound wave and a radio wave, both travelling in air, have the **same frequency**.

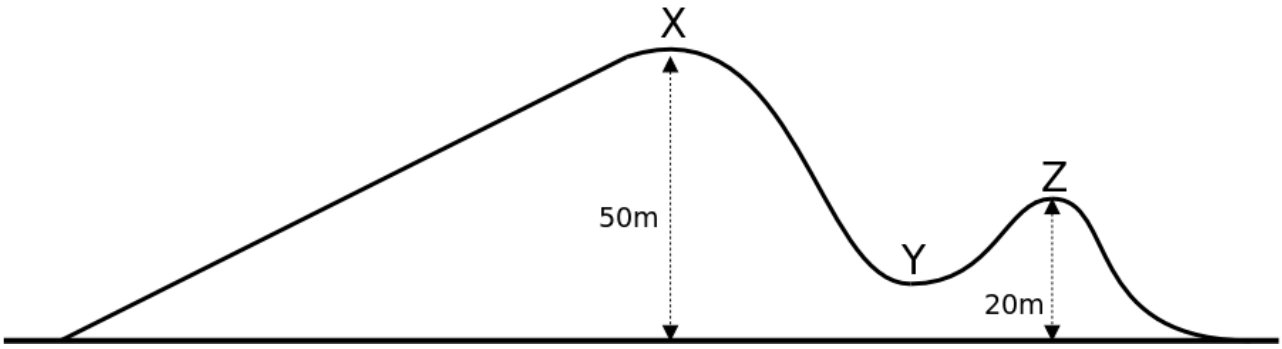
Which of the following statements is correct?

A. The wavelength of the radio wave is greater
B. The wavelength of the sound wave is greater
C. The radio wave and the sound wave have the same wavelength
D. Which wave has the greater wavelength depends on the frequency
E. There is not enough information to make a valid conclusion

7. On an amusement park roller coaster ride, the car is momentarily stationary at the very top of the ride, 50 m above the ground at point X.

Being a Physics roller coaster, the effects of friction and air resistance can all be ignored.

The car then plunges down the slope to point Y and up the other side to point Z, which is 20 m above the ground.



The speed of the car on the roller coaster at point Z is:

A. $31.6\,m\,s^{-1}$
B. $24.5\,m\,s^{-1}$
C. $20.0\,m\,s^{-1}$
D. $14.1\,m\,s^{-1}$
E. Impossible to calculate without knowing the mass of the car

8. When a gas in a sealed container with a fixed volume is heated the pressure increases because:

I. The particles of the gas hit the walls of the container more often
II. The particle collisions are concentrated on a smaller area
III. The particles are moving faster and so collisions exert a greater force
IV. The particles are more massive and so collisions exert a greater force

A. I and II only
B. I and III only
C. II and III only
D. III and IV only
E. I, II, III and IV

9. In a Hookes law experiment, a student uses a ruler with a ½ mm scale rather than the more usual 1 mm scale to measure the extension of the spring. They repeat the measurements several times.

Which line in the table below describes the benefits of these measurement techniques?

	Using a ½ mm scale:	Repeating the measurements:
A.	Increases the accuracy of the readings	Increases the reliability of the readings
B.	Increases the accuracy of the readings	Ensures the investigation is a fair test
C.	Increases the precision of the readings	Increases the reliability of the readings
D.	Increases the precision of the readings	Ensures the investigation is a fair test
E.	Increases the reliability of the readings	Increases the reliability of the readings

10. There are two isotopes of carbon. Carbon-14 is radioactive. Carbon-12 is stable.

The half life of Carbon-14 is 5730 years. Carbon-14 is produced naturally in the atmosphere and absorbed by all living things. Therefore, in all living things, the ratio of Carbon-14 to Carbon-12 is the same and remains constant.

In a sample of dead organic material, the ratio of Carbon-14 to Carbon-12 is found to be 4/5 of the expected value for living material.

The best estimate of the age of the dead organic material is:

A. 1150 years
B. 1840 years
C. 2870 years
D. 4580 years
E. 5730 years

Section B: Short Answer Questions

11. It is easy to walk along on a dry flat surface such as a pavement. However, it is very difficult to walk along on ice due to the fact that the friction forces are very much reduced on ice.

Explain why friction is necessary for us to walk along on a surface.

[5 marks]

…….

…….

……

……

……

……

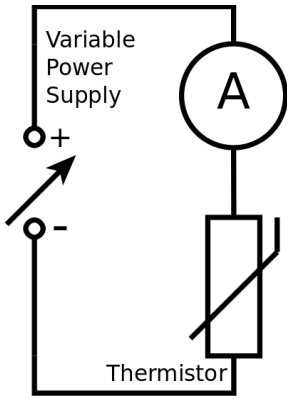
……

……

……

……

12. The electrical properties of a thermistor are investigated using the circuit shown:



- ❏ At low voltages, the current increases as the voltage increases
- ❏ As the voltage is increased further, the current starts to rise more rapidly
- ❏ At a certain voltage the current continues to increase even though the supply voltage remains constant
- ❏ After a short time, with the same constant supply voltage, the current increases very rapidly and the thermistor is destroyed

Explain these observations

[5 marks]

……

……

……

……

……

……

……

……

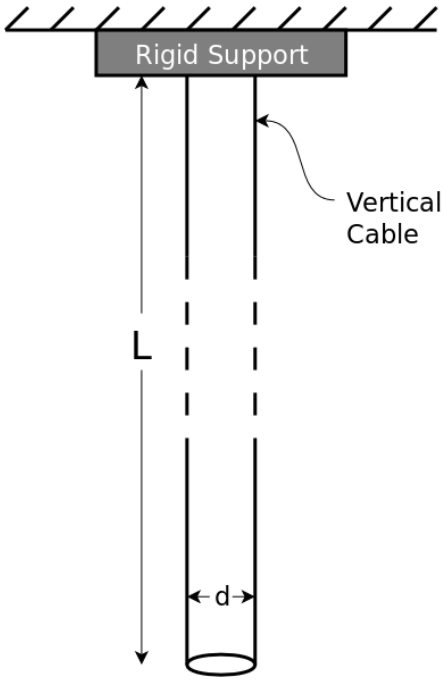
……

……

Section C: Longer Answer Questions

13. **This question is about designing an elevator in a tall building.**

A cable that hangs vertically has a maximum possible length beyond which it can no longer support it's own weight.



(a) For a steel cable with a diameter of 4 cm and a length of 1 m, show that the **mass** of the cable is approximately 10 kg.

d = 4 cm

L = 1 m

Density of steel = 8000 kg m^{-3}

.....

.....

.....

.....

[2 marks]

Stress (σ) is defined as Force ÷ Cross sectional Area and has units of Pascals (Pa).

Stress = F / A i.e. $\sigma = F / A$

(b) Calculate the stress at the top of the 1 m cable, shown above, where it is joined to the rigid support.

.....

.....

.....

.....

[2 marks]

The **maximum** stress that a steel cable under tension can withstand, before it breaks, is 400 MPa.

This is often referred to as the *ultimate tensile strength* of the material.

(c) Calculate the maximum length of a steel cable with a diameter of 4 cm that can be hung vertically from a suitable rigid support such that it can support it's own weight.

.....

.....

.....

.....

.....

[2 marks]

(d) Explain what effect increasing the diameter of the cable would have on the maximum length of the cable calculated in part (c).

.....

.....

.....

.....

.....

[2 marks]

Consider an elevator, supported by the same steel cable, with the following specifications:

- ❏ Mass of elevator = 2000 kg
- ❏ Maximum mass of passengers = 1400 kg
- ❏ Maximum acceleration / deceleration = 2.5 $m s^{-2}$
- ❏ Maximum permitted stress in cable = ¼ ultimate tensile strength of cable

(e) Calculate the maximum force exerted on the **on the elevator** by the cable.

.....

.....

.....

.....

[3 marks]

(f) Hence calculate the maximum length of the elevator cable when using the same steel cable with a diameter of 4 cm.

.....

.....

.....

.....

.....

.....

.....

[3 marks]

14. 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 $c=\sqrt{g}\times\sqrt{d}$

.....

.....

.....

.....

.....

.....

.....

.....

[4 marks]

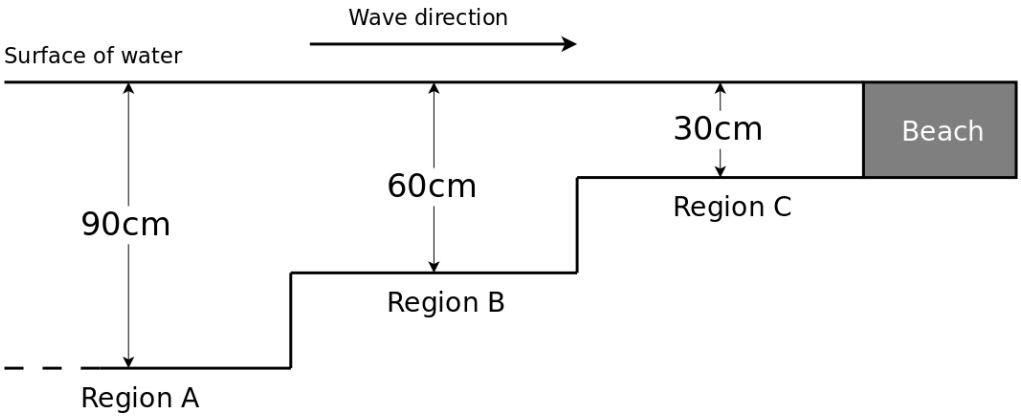
(b) Calculate the speed of water waves when the depth of the water is 90cm.

.....

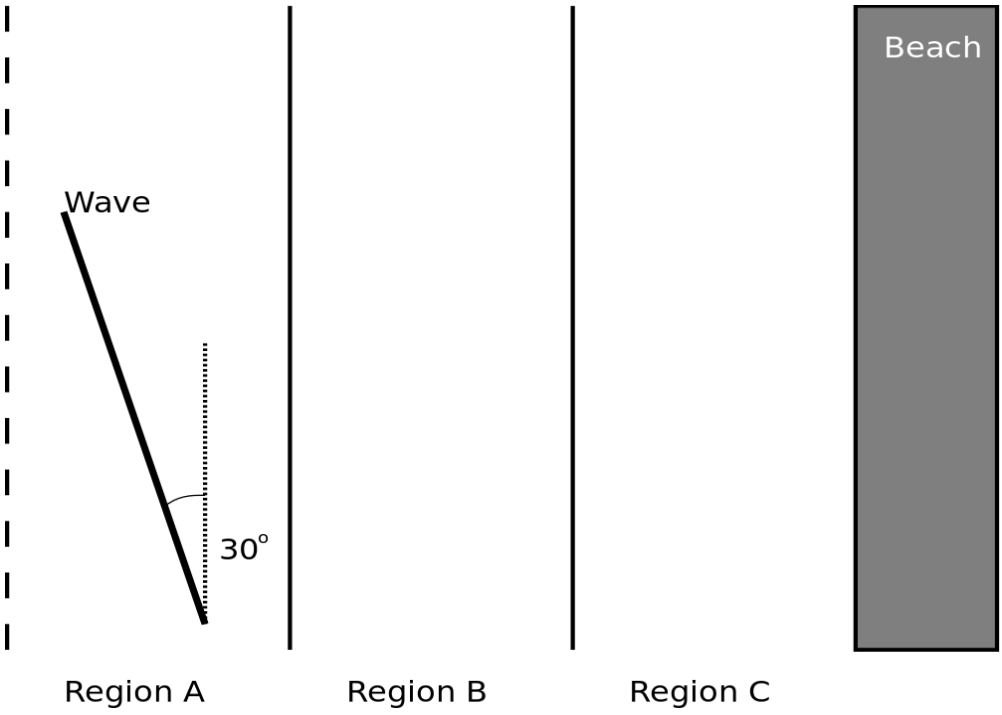
.....

[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.

.....

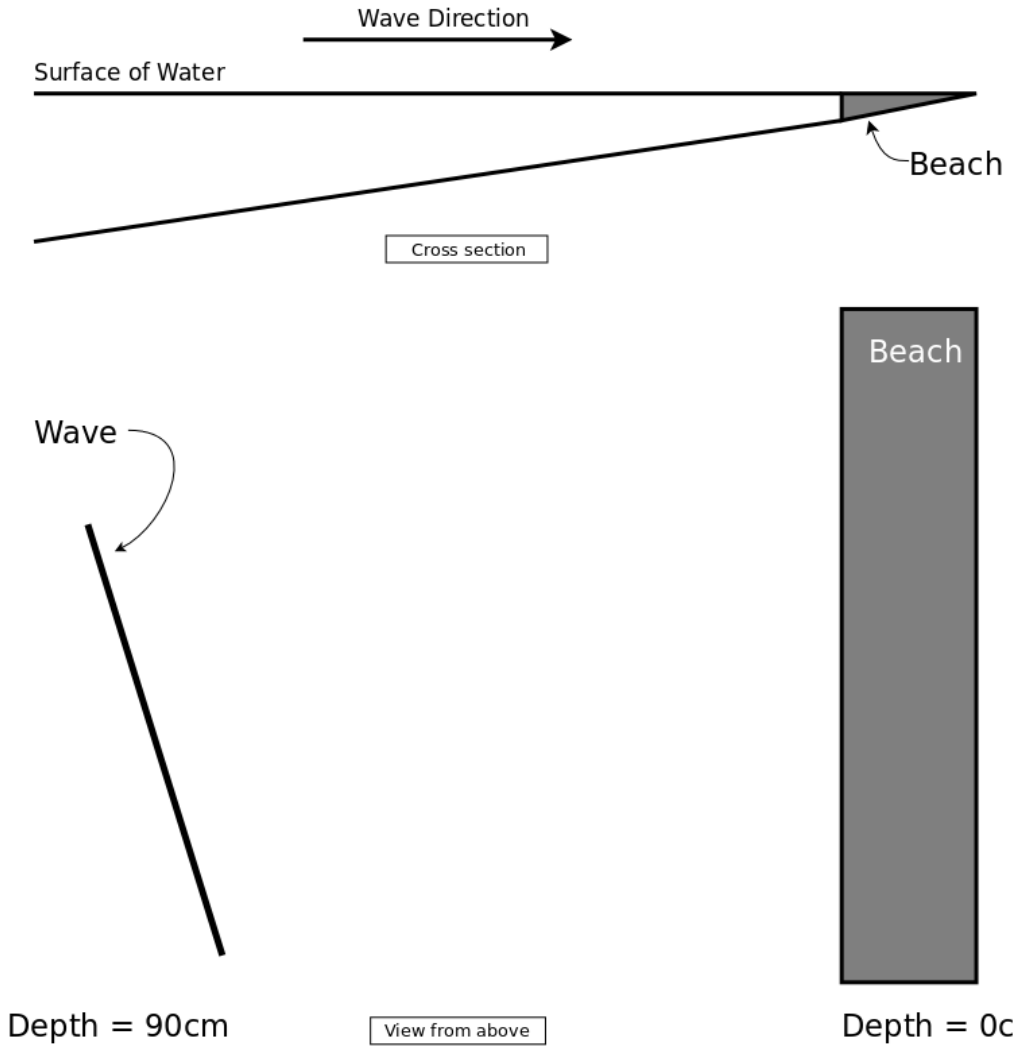
.....

[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.

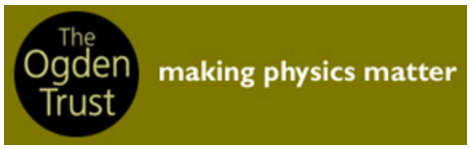
On the view from above, **sketch** the **position and shape** of the waves between the wave shown and the shore.

[3 marks]



END OF PAPER

BPhO sponsors



Cambridge University

- **Trinity College**
- **Cavendish Laboratory**