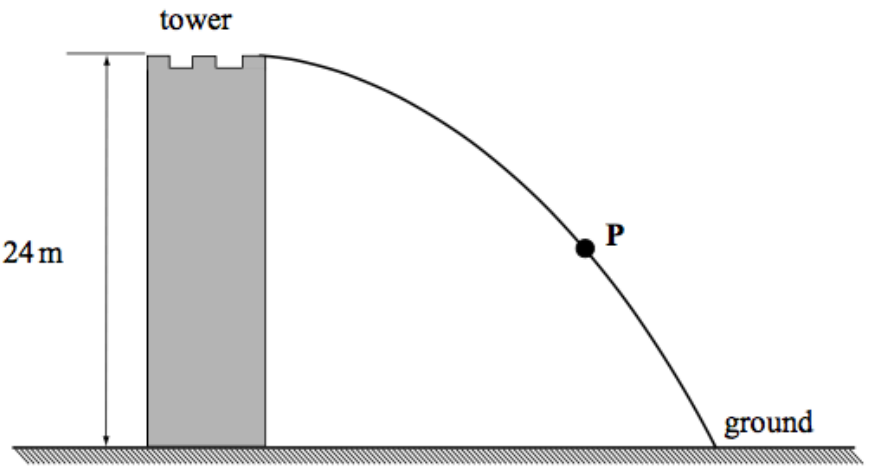
1)

Figure 3 shows the path of a ball thrown horizontally from the top of a tower of height 24 m which is surrounded by level ground.

Figure 3



(a) Using two labelled arrows, show on **Figure 3** the direction of the velocity, *v*, and the acceleration, *a*, of the ball when it is at point **P**.

(2 marks)

(b) (i) Calculate the time taken from when the ball is thrown to when it first hits the ground. Assume air resistance is negligible.

Answer ..... s

(2 marks)

(b) (ii) The ball hits the ground 27 m from the base of the tower. Calculate the speed at which the ball is thrown.

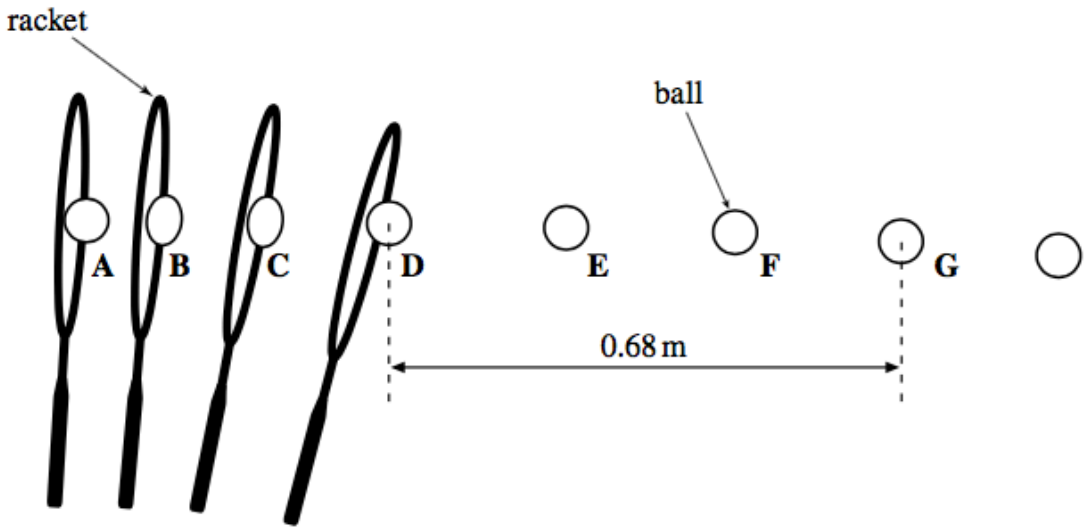
Answer ..... $m\,s^{-1}$

(2 marks)

2)

A digital camera was used to obtain a sequence of images of a tennis ball being struck by a tennis racket. The camera was set to take an image every 5.0 ms. The successive positions of the racket and ball are shown in **Figure 1**.

Figure 1



(a) The ball has a horizontal velocity of zero at **A** and reaches a constant horizontal velocity at **D** as it leaves the racket. The ball travels a horizontal distance of 0.68 m between **D** and **G**.

(a) (i) Show that the horizontal velocity of the ball between positions **D** and **G** in **Figure 1** is about 45 m s^{-1}.

(3 marks)

(a) (ii) Calculate the horizontal acceleration of the ball between **A** and **D**.

answer = ... $m\,s^{-2}$

(1 mark)

(b) At **D**, the ball was projected horizontally from a height of 2.3 m above level ground.

(b) (i) Show that the ball would fall to the ground in about 0.7 s.

(3 marks)

(b) (ii) Calculate the horizontal distance that the ball will travel after it leaves the racket before hitting the ground. Assume that only gravity acts on the ball as it falls.

answer = ... m

(2 marks)

(b) (iii) Explain why, in practice, the ball will not travel this far before hitting the ground.

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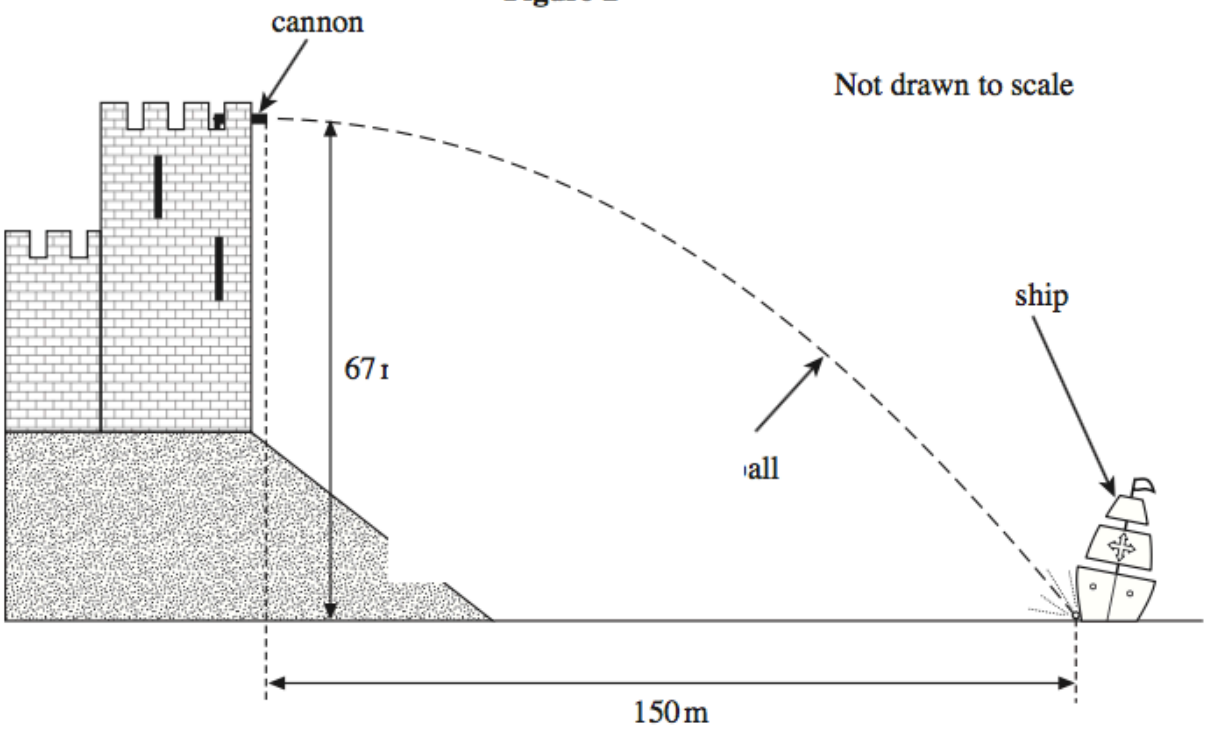
(2 marks)

3)

In a castle, overlooking a river, a cannon was once employed to fire at enemy ships. One ship was hit by a cannonball at a horizontal distance of 150 m from the cannon as shown in **Figure 2**. The height of the cannon above the river was 67 m and the cannonball was fired horizontally.

Figure 2



(a) (i) Show that the time taken for the cannonball to reach the water surface after being fired from the cannon was 3.7 s. Assume the air resistance was negligible.

(2 marks)

(a) (ii) Calculate the velocity at which the cannonball was fired. Give your answer to an appropriate number of significant figures.

answer = ... $m\,s^{-1}$

(2 marks)

(a) (iii) Calculate the vertical component of velocity just before the cannonball hit the ship.

answer = ... $m\,s^{-1}$

(2 marks)

(a) (iv) By calculation or scale drawing, find the magnitude and direction of the velocity of the cannonball just before it hit the ship.

velocity = ... $m\,s^{-1}$

direction = ...

(4 marks)

(b) (i) Calculate the loss in gravitational potential energy of the cannonball.
mass of the cannonball = 22 kg

answer = ... J

(1 mark)

(b) (ii) Describe the energy changes that take place from the moment the cannonball leaves the cannon until just before it hits the water. Include the effects of air resistance.

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(2 marks)

4)

A steel ball has a diameter of 2.2×10^{-2} m.

(a) Calculate the weight of the steel ball. Give your answer to an appropriate number of significant figures.

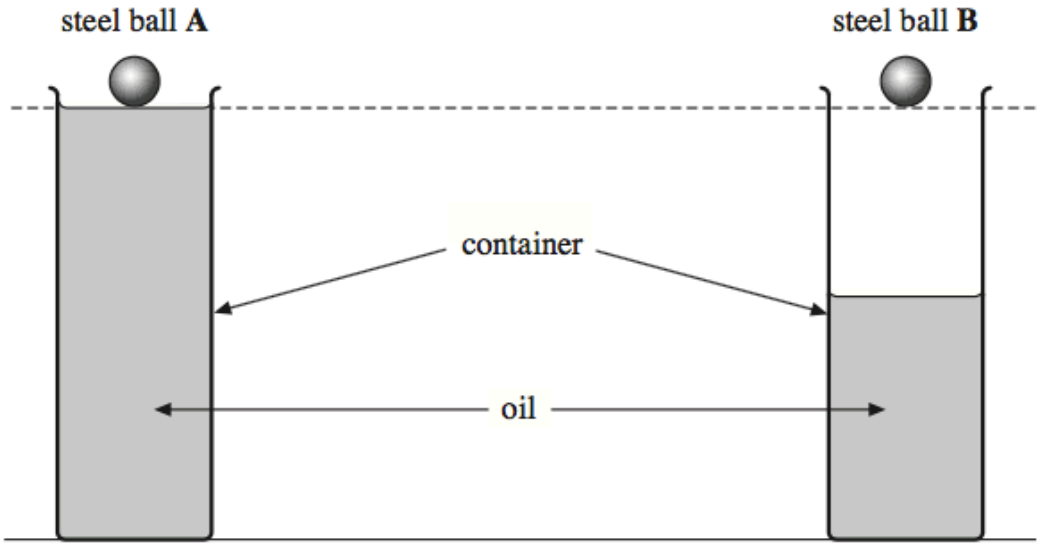
density of steel = 8100 kg m^{-3}

weight ..... N

(4 marks)

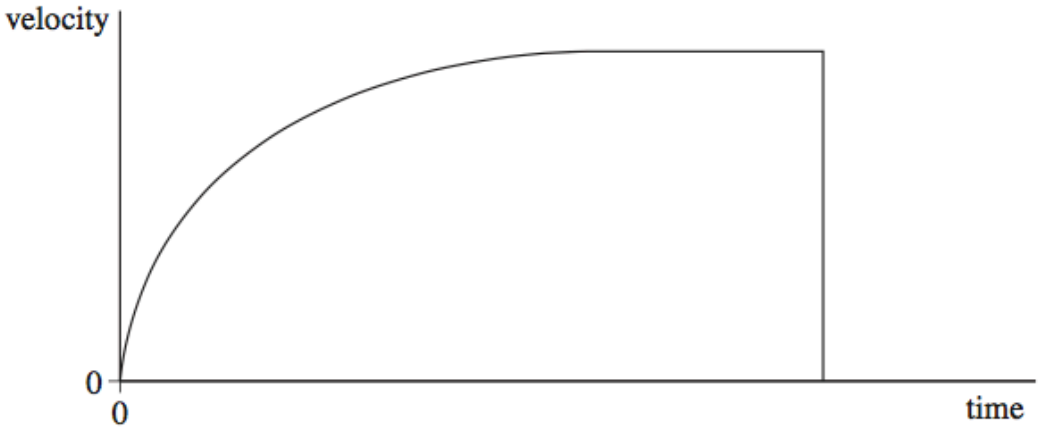
(b) **Figure 3** shows two identical steel balls dropped from rest into containers of oil.

Figure 3



(b) (i) **Figure 4** shows the velocity-time graph for steel ball **A**.

Figure 4



Explain the shape of the graph in **Figure 4**. Your account should include

- how the velocity and acceleration of the steel ball vary with time
- reference to how Newton's First and Second laws of motion apply in this situation.

The quality of written communication will be assessed in your answer.

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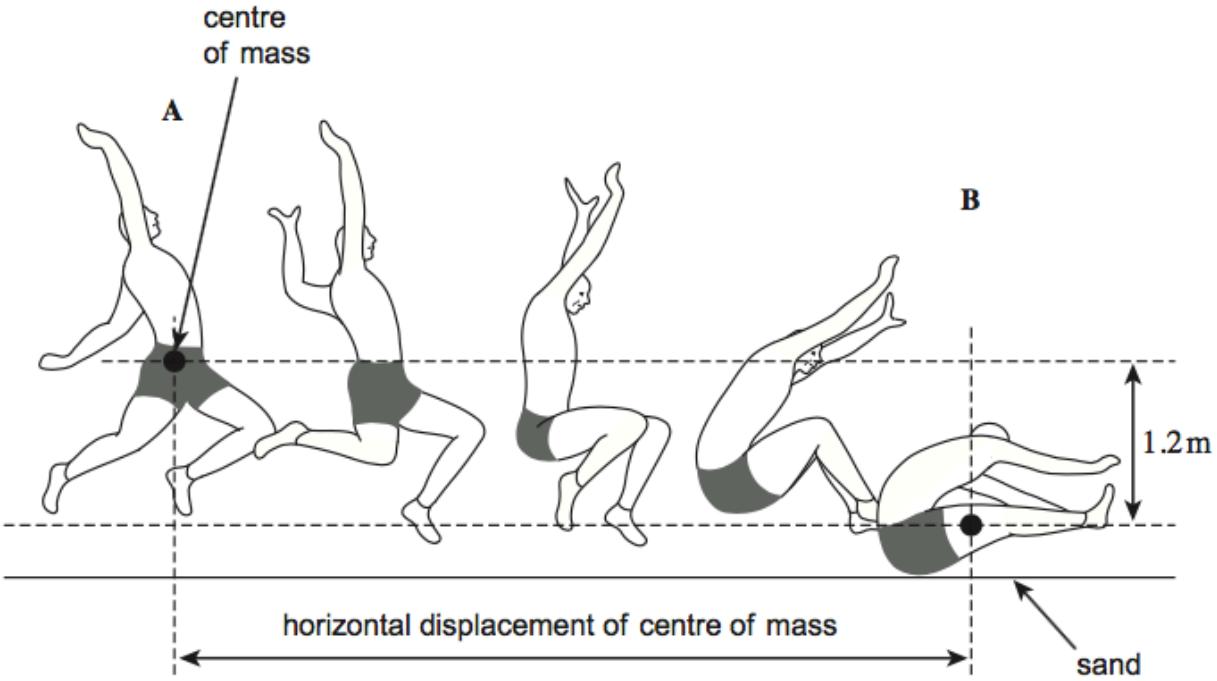
(6 marks)

5)

The motion of a long jumper during a jump is similar to that of a projectile moving under gravity. **Figure 2** shows the path of an athlete above the ground during a long jump from half-way through the jump at position **A**, to position **B** at which contact is made with sand on the ground. The athlete is travelling horizontally at **A**.

Figure 2



(a) During this part of the jump, the centre of mass of the athlete falls 1.2 m.

(a) (i) Calculate the time between positions **A** and **B**.

[3 marks]

time ..... s

(a) (ii) The athlete is moving horizontally at **A** with a velocity of $8.5\,\text{m}\,\text{s}^{-1}$. Assume there is no air resistance. Calculate the horizontal displacement of the centre of mass from **A** to **B**.

[2 marks]

horizontal displacement ..... m

(b) (i) The athlete in **Figure 2** slides horizontally through the sand a distance of $0.35\,\text{m}$ before stopping.

Calculate the time taken for the athlete to stop. Assume the horizontal component of the resistive force from the sand is constant.

[2 marks]

time ..... s

(b) (ii) The athlete has a mass of $75\,\text{kg}$. Calculate the horizontal component of the resistive force from the sand.

[3 marks]

horizontal component of resistive force ..... N

6)

The world record for a high dive into deep water is 54 m.

(a) Calculate the loss in gravitational potential energy (gpe) of a diver of mass 65 kg falling through 54 m.

loss in gpe = ... J
(2 marks)

(b) Calculate the vertical velocity of the diver the instant before he enters the water. Ignore the effects of air resistance.

velocity = ... $m\,s^{-1}$
(2 marks)

(c) Calculate the time taken for the diver to fall 54 m. Ignore the effects of air resistance.

time = ... s
(2 marks)

(d) Explain, with reference to energy, why the velocity of the diver is independent of his mass if air resistance is insignificant.

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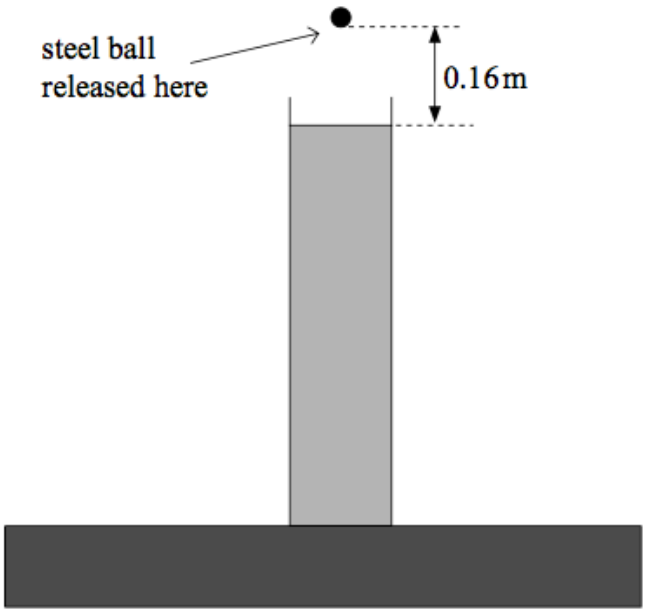
(3 marks)

7)

A steel ball is released from rest above a cylinder of liquid, as shown in **Figure 3**. The ball descends vertically in the air then in the liquid until it reaches the bottom of the cylinder.

Figure 3



(a) The vertical distance from the bottom of the ball at the point where it is released to the liquid surface is 0.16 m.

(a) (i) Calculate the time taken, t_o, by the ball to fall to the liquid surface from the point where it is released. Give your answer to an appropriate number of significant figures.

answer.....s

(3 marks)

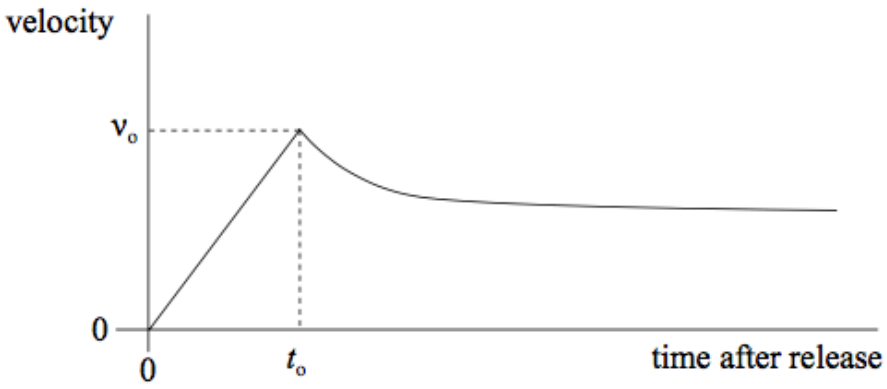
(a) (ii) Calculate the velocity, v_o, of the ball on reaching the liquid.

answer.....m s^{-1}

(2 marks)

(b) **Figure 4** below shows how the velocity of the ball changed after it was released.

Figure 4



Describe and explain how the acceleration of the ball changed after it entered the liquid until it reached the bottom of the cylinder.

The quality of your written answer will be assessed in this question.

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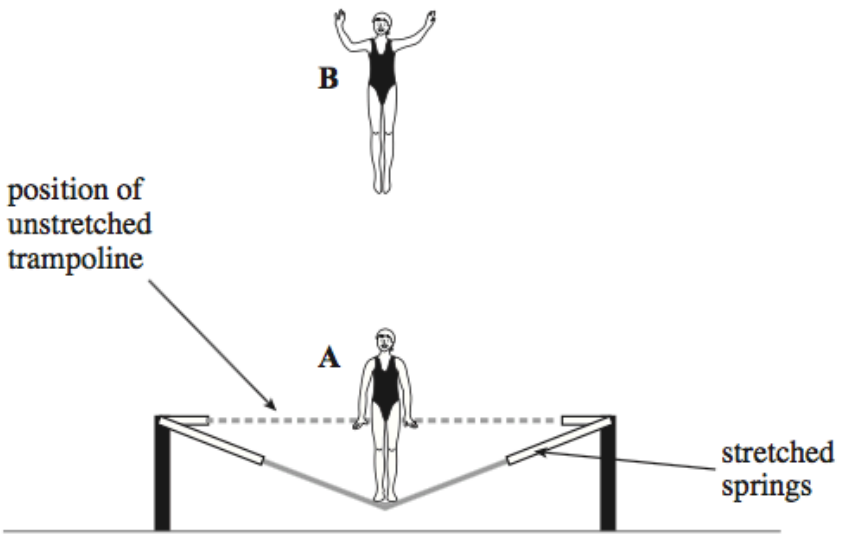
(6 marks)

8)

Figure 4 shows a gymnast trampolining.

Figure 4



In travelling from her lowest position at **A** to her highest position at **B**, her centre of mass rises 4.2 m vertically. Her mass is 55 kg.

(a) Calculate the increase in her gravitational potential energy when she ascends from position **A** to position **B**.

answer = ... J

(2 marks)

(b) The gymnast descends from position **B** and regains contact with the trampoline when it is in its unstretched position. At this position, her centre of mass is 3.2 m below its position at **B**.

(b) (i) Calculate her kinetic energy at the instant she touches the unstretched trampoline.

answer = ... J

(1 mark)

(b) (ii) Calculate her vertical speed at the same instant.

answer = ... $m\,s^{-1}$

(2 marks)

(c) Draw an arrow on **Figure 4** to show the force exerted on the gymnast by the trampoline when she is in position **A**.

(1 mark)

(d) As she accelerates upwards again from position **A**, she is in contact with the trampoline for a further 0.26 s. Calculate the average acceleration she would experience while she is in contact with the trampoline, if she is to reach the same height as before.

answer = ... $m\,s^{-2}$

(2 marks)

(e) On her next jump the gymnast decides to reach a height above position **B**. Describe and explain, in terms of energy and work, the transformations that occur as she ascends from her lowest position **A** until she reaches her new position above **B**.

The quality of your written communication will be assessed in this question.

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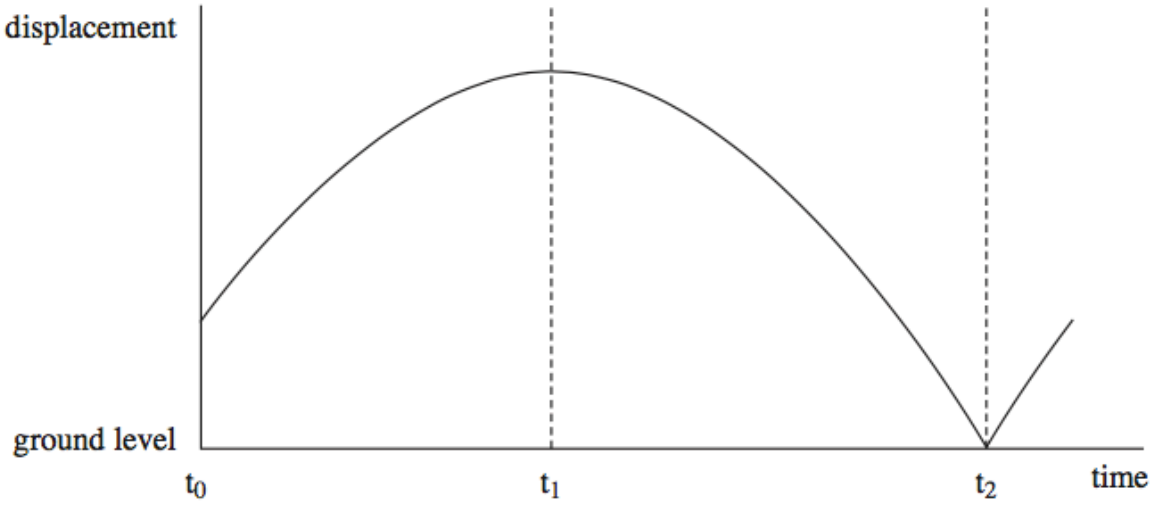
(6 marks)

9)

A boy throws a ball vertically upwards and lets it fall to the ground. **Figure 1** shows how displacement relative to the ground varies with time for the ball.

Figure 1



(a) (i) State which feature of a displacement-time graph represents the velocity.

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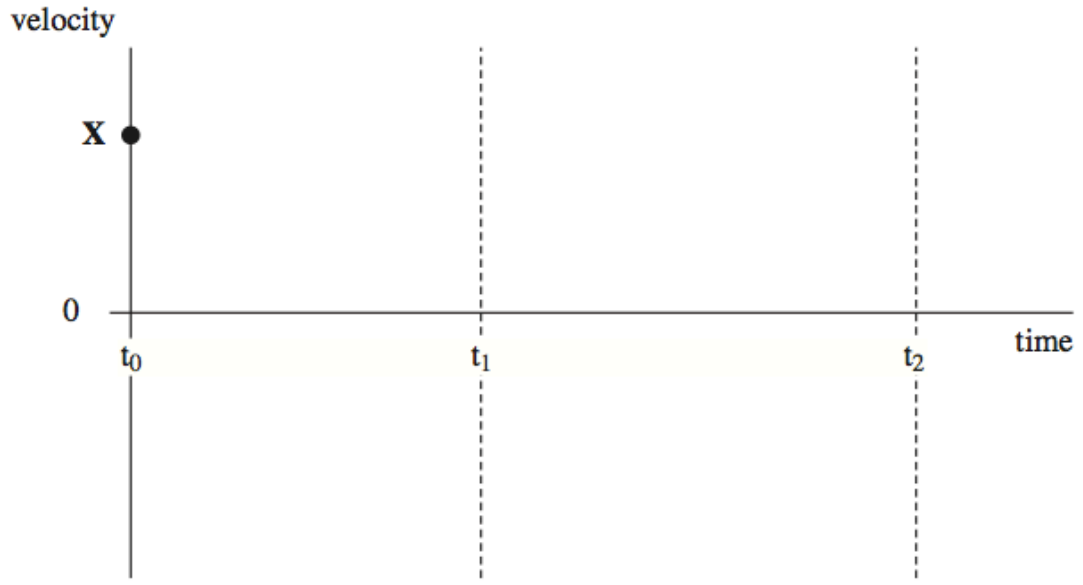
(1 mark)

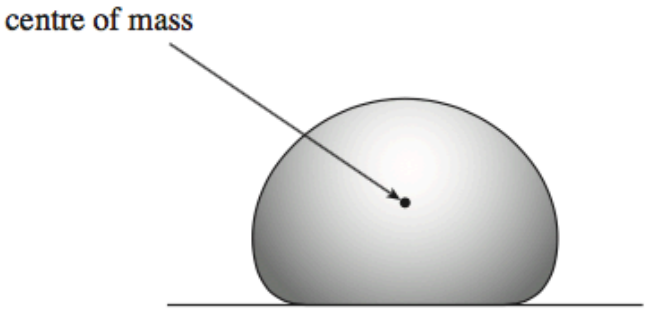
(a) (ii) On the axes below, draw the shape of the velocity-time graph for the ball between t_0 and t_2. The starting point is labelled **X**.

(3 marks)



(b) **Figure 2** shows the ball deforming as it contacts the ground, just at the point where it is stationary for an instant and has reached maximum deformation.

Figure 2



(b) (i) Explain how Newton's third law of motion applies to **Figure 2**.

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(2 marks)

(b) (ii) Explain why there is a resultant upward force on the ball in **Figure 2**.

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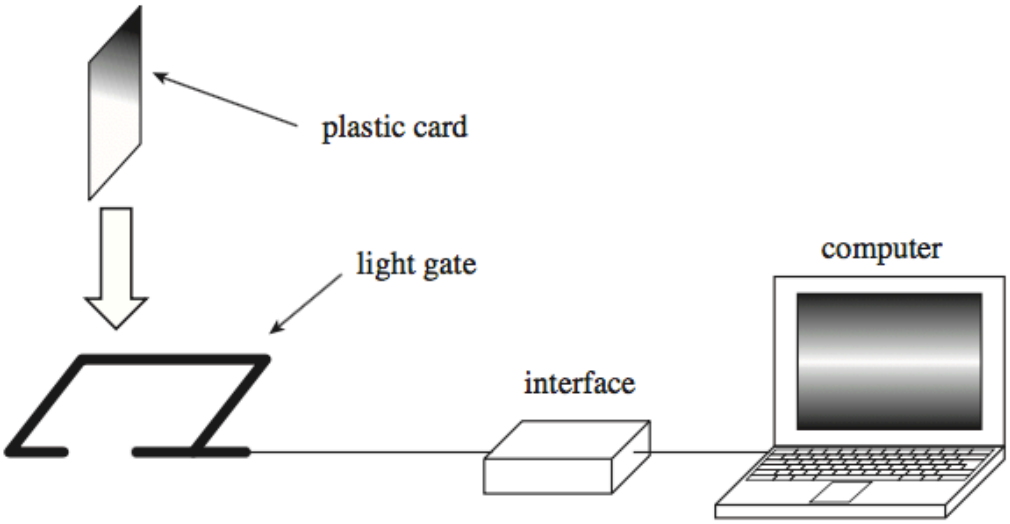
(2 marks)

10)

A student measures the acceleration due to gravity, g, using the apparatus shown in **Figure 3**. A plastic card of known length is released from rest at a height of 0.50 m above a light gate. A computer calculates the velocity of the card at this point, using the time for the card to pass through the light gate.

Figure 3



(a) The computer calculated a value of 3.10 ms^{-1} for the velocity of the card as it travelled through the light gate. Calculate a value for the acceleration due to gravity, g, from these data.

answer = ... ms^{-2}

(2 marks)

(b) The student doubles the mass of the card and finds a value for g that is similar to the original value. Use the relationship between *weight*, *mass* and g to explain this result.

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(1 mark)

(c) State and explain **one** reason why the card would give more reliable results than a table tennis ball for this experiment.

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(2 marks)

11)

(a) Indicate with ticks (✓) in **Table 1** which of the quantities are vectors and which are scalars.

[2 marks]

Table 1

	Velocity	**Speed**	**Distance**	**Displacement**
vector				
scalar				

(b) A tennis ball is thrown vertically downwards and bounces on the ground. The ball leaves the hand with an initial speed of $1.5\ \text{m s}^{-1}$ at a height of $0.65\ \text{m}$ above the ground. The ball rebounds and is caught when travelling upwards with a speed of $1.0\ \text{m s}^{-1}$.

Assume that air resistance is negligible.

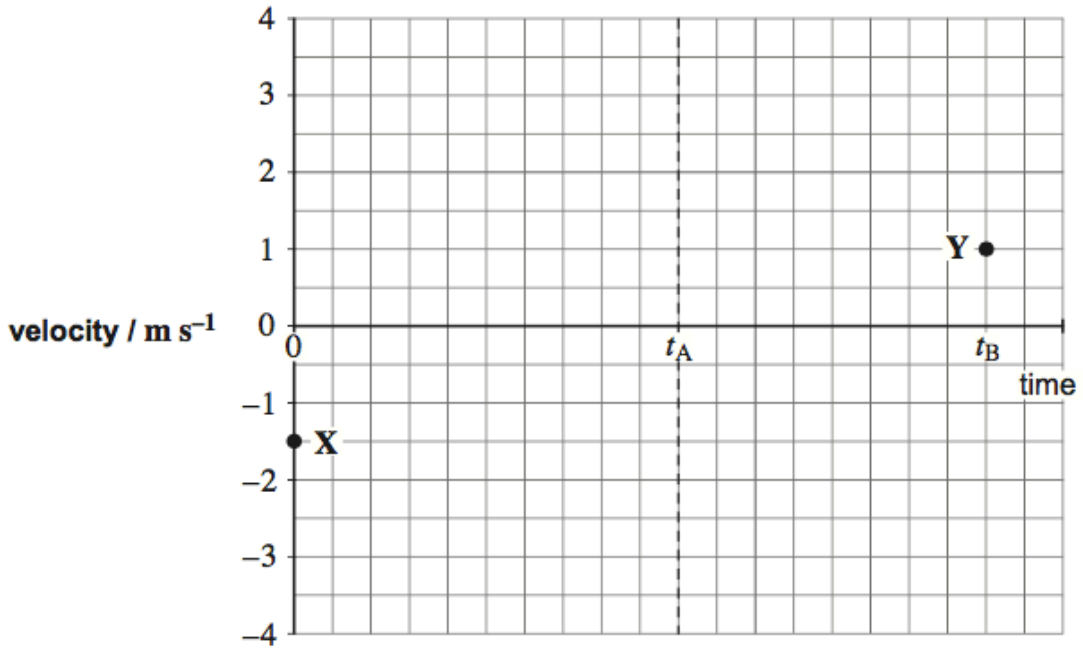
(b) (i) Show that the speed of the ball is about $4\ \text{m s}^{-1}$ just before it strikes the ground.

[3 marks]

(b) (ii) The ball is released at time $t = 0$. It hits the ground at time t_A and is caught at time t_B. On **Figure 1**, sketch a velocity–time graph for the vertical motion of the tennis ball from when it leaves the hand to when it returns. The initial velocity **X** and final velocity **Y** are marked on **Figure 1**.

[3 marks]

Figure 1



(c) In a game of tennis, a ball is hit horizontally at a height of 1.2 m and travels a horizontal distance of 5.0 m before reaching the ground. The ball is at rest when hit.

Calculate the initial horizontal velocity given to the ball when it was hit.

[3 marks]

horizontal velocity = ... m s^{-1}