

Q1.(a) Indicate with ticks (✓) in the table below which of the quantities are vectors and which are scalars.

	Velocity	Speed	Distance	Displacement
vector				
scalar				

(2)

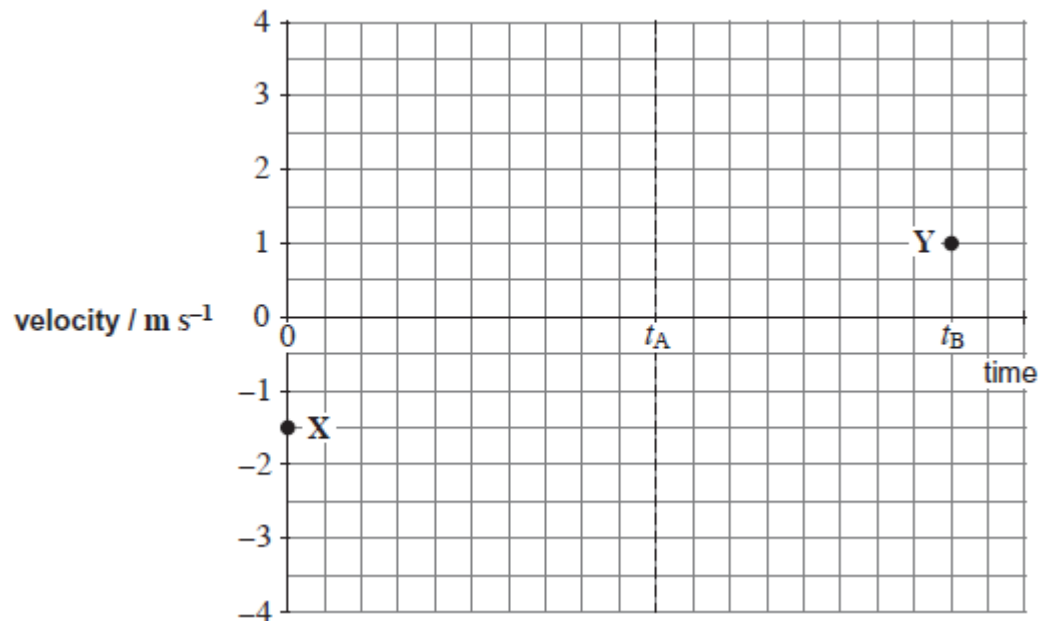
- (b) A tennis ball is thrown vertically downwards and bounces on the ground. The ball leaves the hand with an initial speed of  $1.5 \text{ m s}^{-1}$  at a height of  $0.65 \text{ m}$  above the ground. The ball rebounds and is caught when travelling upwards with a speed of  $1.0 \text{ m s}^{-1}$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

Assume that air resistance is negligible.

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

(3)

- (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 the graph, 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.



(3)

- (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.

horizontal velocity = ..... m s<sup>-1</sup>

(3)  
(Total 11 marks)

**Q2.** The diagram below shows an electric two-wheeled vehicle and driver.



- (a) The vehicle accelerates horizontally from rest to 27.8 m s<sup>-1</sup> in a time of 4.6 s. The mass of the vehicle is 360 kg and the rider has a mass of 82 kg.
- (i) Calculate the average acceleration during the 4.6 s time interval. Give your answer to an appropriate number of significant figures.

acceleration = .....  $\text{m s}^{-2}$

(2)

- (ii) Calculate the average horizontal resultant force on the vehicle while it is accelerating.

resultant force = ..... N

(2)

- (b) State and explain how the horizontal forward force on the vehicle has to change for **constant** acceleration to be maintained from 0 to  $27.8 \text{ m s}^{-1}$ .

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(3)

- (c) The electric motors drive both wheels of the vehicle.

Add labelled force arrows to the diagram to show the horizontal forces acting on the vehicle when it is moving at a constant speed.

(2)

- (d) The vehicle now accelerates to a constant speed of  $55 \text{ m s}^{-1}$ . The useful power output of the motors is  $22 \text{ kW}$  at this speed.

Calculate the horizontal resistive force acting on the vehicle.

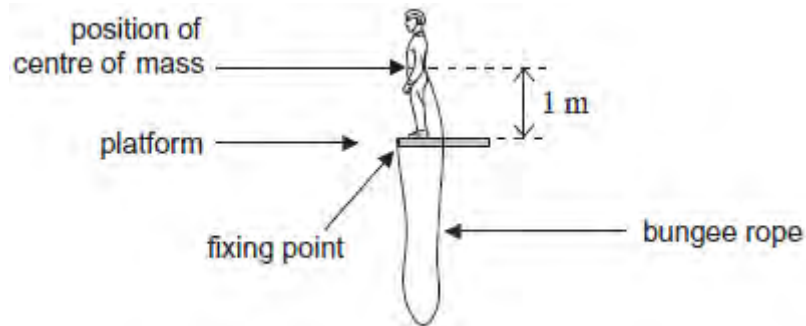
horizontal resistive force = ..... N

(2)  
(Total 11 marks)

**Q3.** The diagram below shows a bungee jumper of mass  $75 \text{ kg}$  about to step off a raised platform. The jumper comes to a halt for the first time when his centre of mass has fallen through a distance of  $31 \text{ m}$ .

The bungee rope has an unextended length of  $19 \text{ m}$  and a stiffness of  $380 \text{ N m}^{-1}$ .

Ignore the effects of air resistance and the mass of the rope in this question. Treat the jumper as a point mass located at the centre of mass.



- (a) (i) Calculate the extension of the bungee rope when the centre of mass of the jumper has fallen through  $31 \text{ m}$ .

extension ..... m

(1)

- (ii) Calculate the resultant force acting on the jumper when he reaches the lowest point in the jump.

resultant force ..... N

(2)

- (b) Calculate the extension of the rope when the jumper's acceleration is zero.

extension ..... m

(2)

- (c) The extension of the bungee rope is 5.0 m when the jumper's centre of mass has fallen through a distance of 25 m.

Use the principle of conservation of energy to calculate the speed of the jumper in this position.

speed ..... m s<sup>-1</sup>

(4)

- (d) The bungee jump operator intends to use a bungee rope of the same unextended length but with a much greater stiffness. The rope is to be attached in the same way as before.

Explain, with reference to the kinetic energy of the jumper, any safety concerns that may arise as the jumper is slowed down by the new rope.

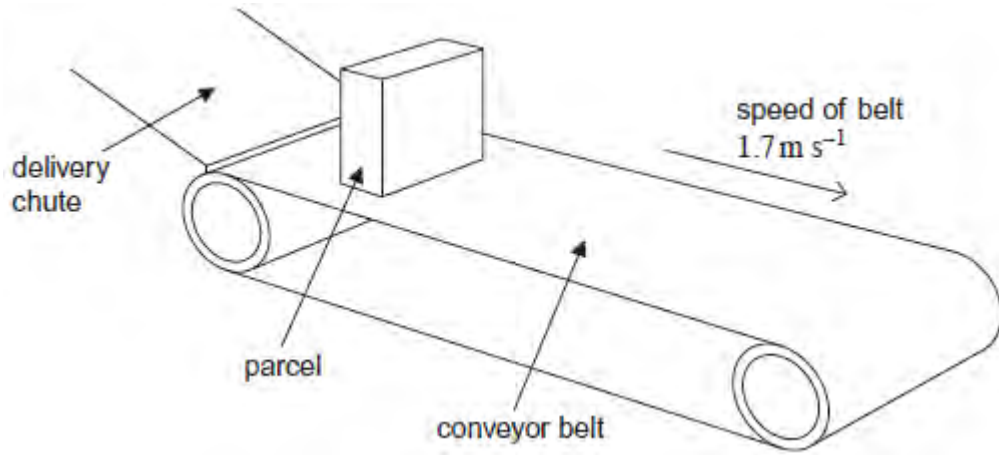
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(3)

(Total 12 marks)

- Q4.(a)** A parcel of mass 15 kg drops from a delivery chute onto a conveyor belt as shown in **Figure 1**.  
The belt is moving at a steady speed of 1.7 m s<sup>-1</sup>.  
The parcel lands on the moving belt with negligible speed and initially starts to slip. It takes 0.82 s for the parcel to gain enough speed to stop slipping and move at the same speed as the conveyor belt.

**Figure 1**



- (i) Calculate the change in kinetic energy of the parcel during the first 0.82 s.

change in kinetic energy ..... J

(2)

- (ii) The average horizontal force acting on the parcel during the first 0.82 s is 31 N.

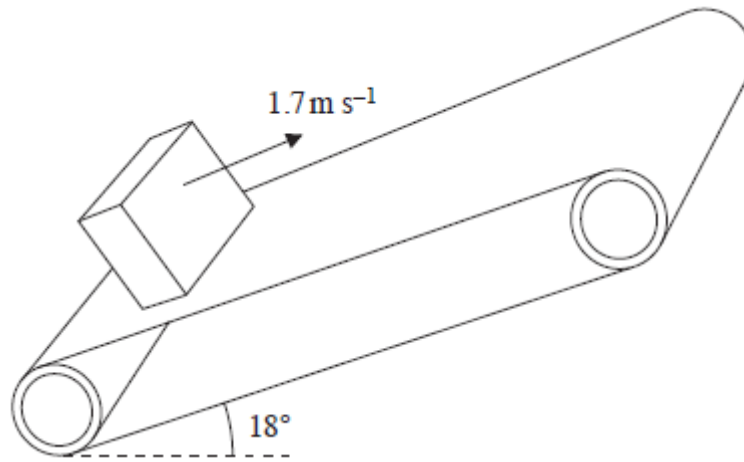
Calculate the horizontal distance between the parcel and the end of the delivery chute 0.82 s after the parcel lands on the conveyor belt. Assume that the parcel does not reach the end of the conveyor belt.

horizontal distance ..... m

(2)

- (b) At a later stage the parcel is being raised by another conveyor belt as shown in **Figure 2**.

**Figure 2**



This conveyor belt is angled at  $18^\circ$  to the horizontal and the parcel moves at a steady speed of  $1.7 \text{ m s}^{-1}$  without slipping.

Calculate the rate at which work is done on the parcel.

rate at which work is done ..... W

(3)  
(Total 7 marks)