



A-Level Physics

Scalars and Vectors

Question Paper

Time available: 88 minutes

Marks available: 63 marks

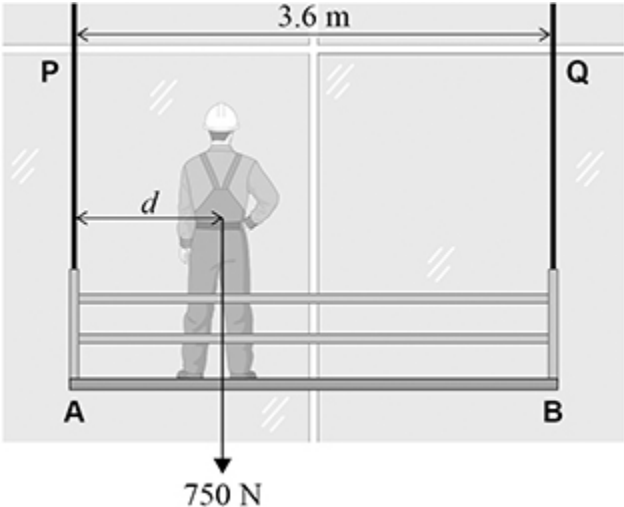
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1.

Figure 1 shows a worker of weight 750 N on a uniform platform. The weight of the worker is acting at a horizontal distance d from end **A**.

Throughout this question, assume that the platform is horizontal and that all cables obey Hooke's law.

Figure 1



The platform weighs 1800 N and is suspended by vertical cables **P** and **Q**. Each cable has an unstretched length of 3.0 m. The horizontal distance between **P** and **Q** is 3.6 m.

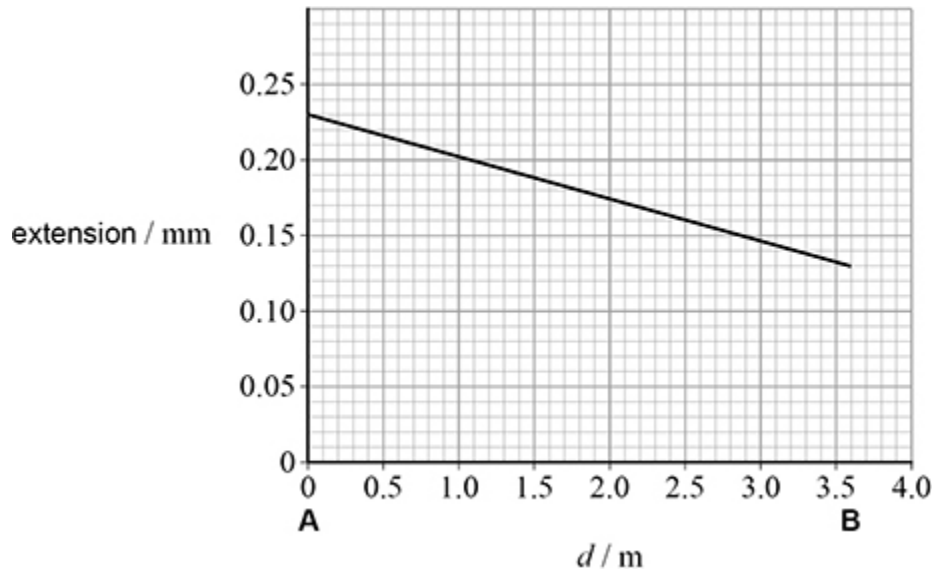
- (a) The worker moves to a position where the tension in the left-hand cable **P** is 1150 N. Calculate d for this position.

$d = \underline{\hspace{2cm}} \text{ m}$

(3)

Figure 2 shows how the extension of **P** varies with d as the worker walks slowly along the platform from **A** to **B**.

Figure 2



The worker moves to a position **X** where the strain in **P** is 6.0×10^{-5} .

(b) Determine d for position **X**.

$$d = \text{_____} \text{ m}$$

(2)

(c) The cable material has a Young modulus of $1.9 \times 10^{11} \text{ N m}^{-2}$.

Calculate the tensile stress in **P** when the worker is at **X**.

$$\text{tensile stress} = \text{_____} \text{ N m}^{-2}$$

(1)

(d) The original cables **P** and **Q** are replaced.

The table below shows how the properties of the original cables compare with the replacement cables.

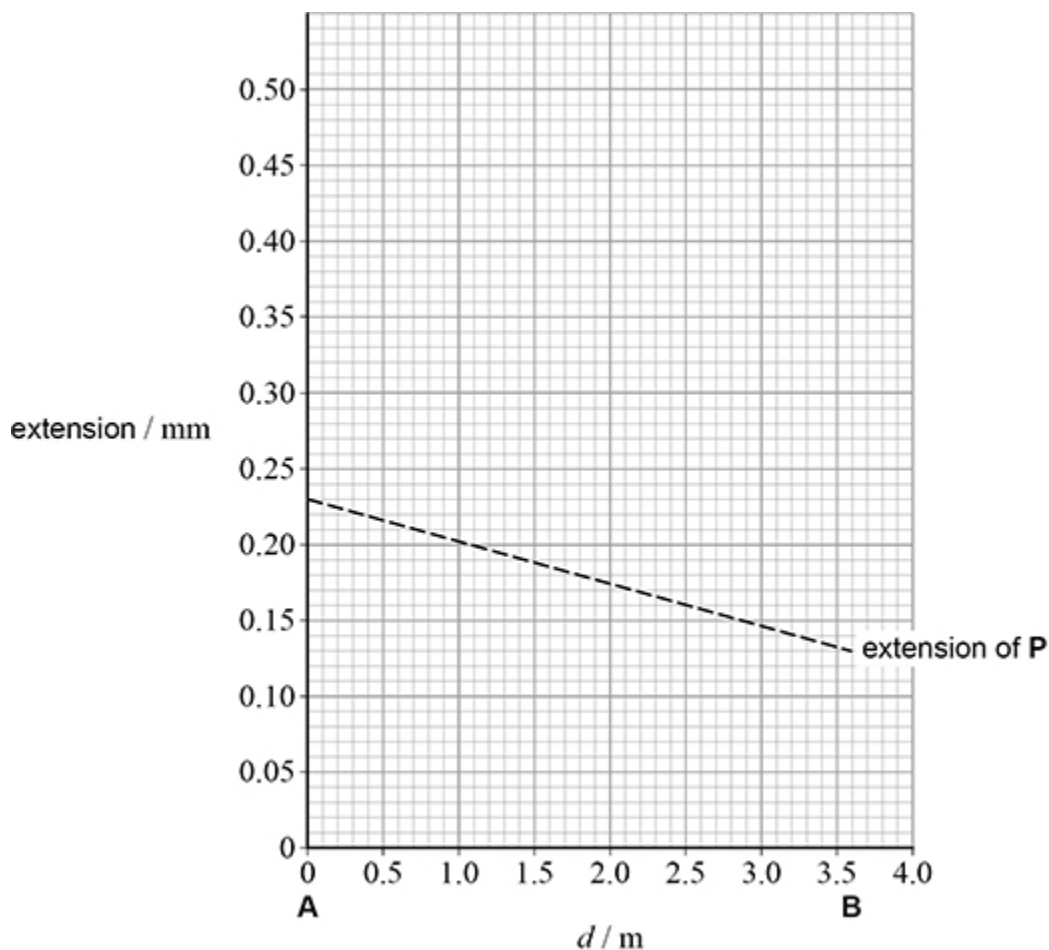
	Unstretched length	Radius	Young modulus of cable material
Original cables	L	r	E
Replacement cables	L	$\frac{r}{2}$	$2E$

After the cables have been replaced, the worker walks slowly from **A** to **B**.

Draw on **Figure 3** a line to show the variation of the extension of the replacement left-hand cable with d .

The original line from **Figure 2** is shown on **Figure 3** as a dashed line to help you.

Figure 3



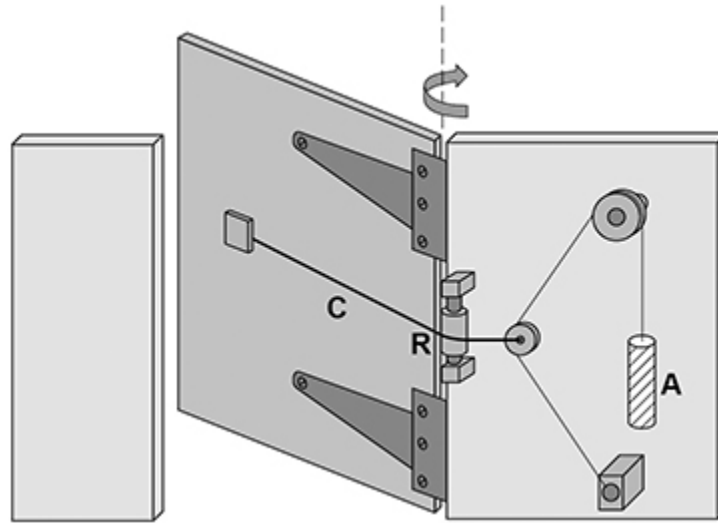
(3)

(Total 9 marks)

2.

Figure 1 shows a garden gate with a pulley system designed to close the gate.

Figure 1



The pulley system raises weight **A** when the gate is opened. When the gate is released, **A** falls. The horizontal cable **C** passes over pulley **R**. The tension in cable **C** causes the gate to close.

Weight **A** is a solid cylinder with the following properties:

diameter = 4.8×10^{-2} m

length = 0.23 m

weight = 35 N

The table below gives the density of three available materials.

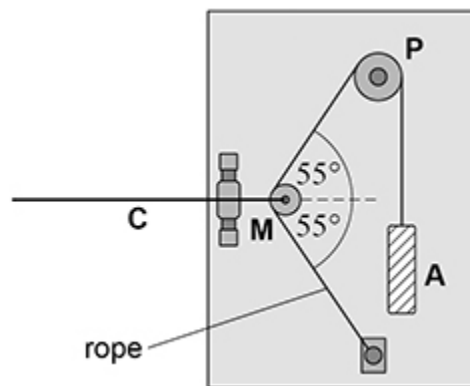
Material	Density / kg m^{-3}
concrete	2.4×10^3
iron	7.8×10^3
brass	8.6×10^3

(a) Deduce which **one** of the three materials is used for **A**.

(3)

Figure 2 shows the pulley arrangement when the gate is closed.

Figure 2



Pulleys **P** and **M** are frictionless so that the tension in the rope attached to **A** is equal to the weight of **A**.

A weighs 35 N and the weight of moveable pulley **M** is negligible.

(b) Calculate the tension in the horizontal cable **C** when the gate is closed.

tension = _____ N

(2)

(c) Pulley **M** is pulled to the left as the gate is opened.

Explain why this increases the tension in the horizontal cable **C**.

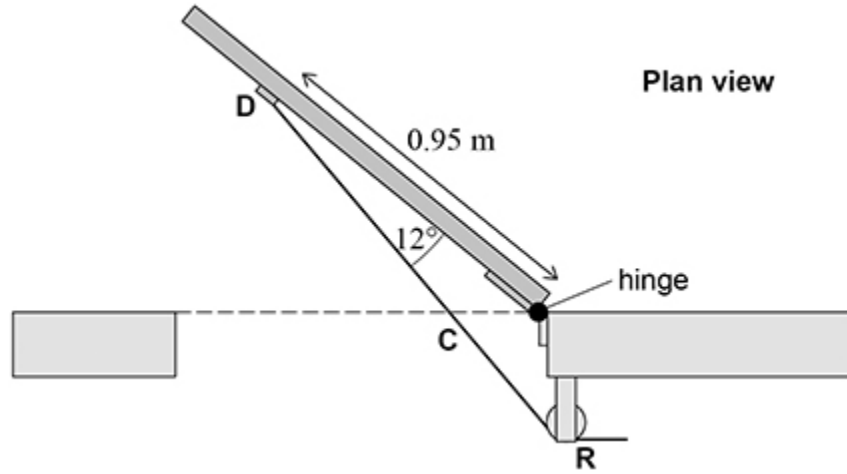
(2)

(d) **Figure 3** shows a plan view with the gate open. The horizontal cable **C** passes over pulley **R** and is attached to the door at **D**.

The angle between the door and the horizontal cable **C** is 12° .

The horizontal distance between the hinge and **D** is 0.95 m.

Figure 3



The tension in the horizontal cable **C** is now 41 N.

Calculate the moment of the tension about the hinge.

moment = _____ N m

(2)

- (e) The same system is attached to an identical gate with stiffer hinges. Now the system does not supply a sufficiently large moment to close the gate.

Discuss **two** independent changes to the design to increase the moment about the hinges due to horizontal cable **C**.

1 _____

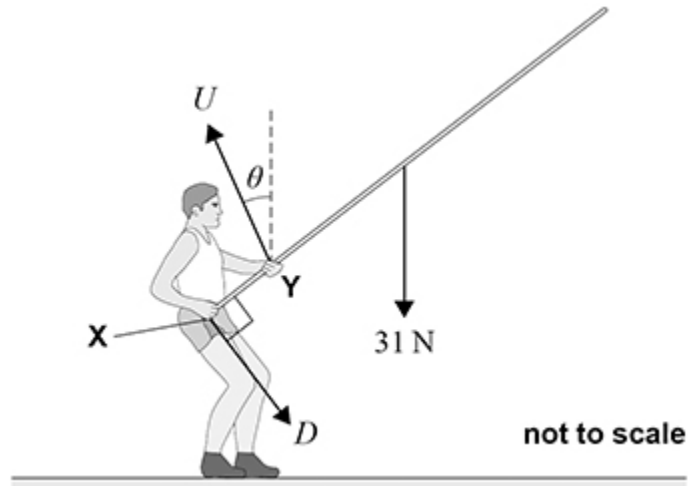
2 _____

(4)
(Total 13 marks)

3.

Figure 1 shows an athlete holding a vaulting pole at an angle of 40° to the horizontal.

Figure 1



Forces D and U are exerted on the pole by the athlete's right and left hands respectively.

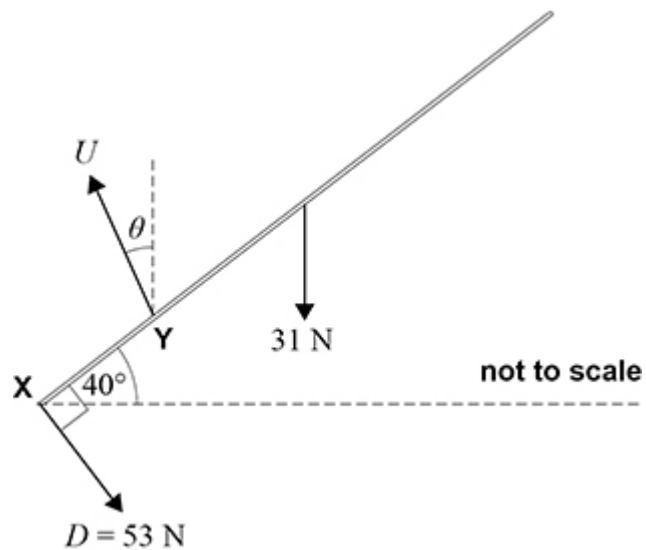
U is applied at point Y at an angle θ to the vertical.

The magnitude of D is 53 N and is applied at 90° to the pole at X .

The uniform pole is in equilibrium. It has a weight of 31 N .

Figure 2 shows the forces acting on the pole.

Figure 2



(a) Determine, using a scale Figure, θ and the magnitude of U .

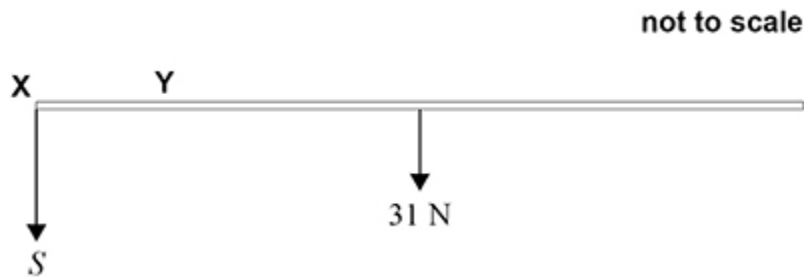
$$\theta = \text{_____}^\circ$$

$$\text{magnitude of } U = \text{_____} N$$

(4)

- (b) The athlete now moves the pole to a horizontal position. The pole is held stationary in this position.
The athlete's right hand applies a force S vertically downwards at X as shown in **Figure 3**.
The athlete's left hand applies a force V at Y .

Figure 3



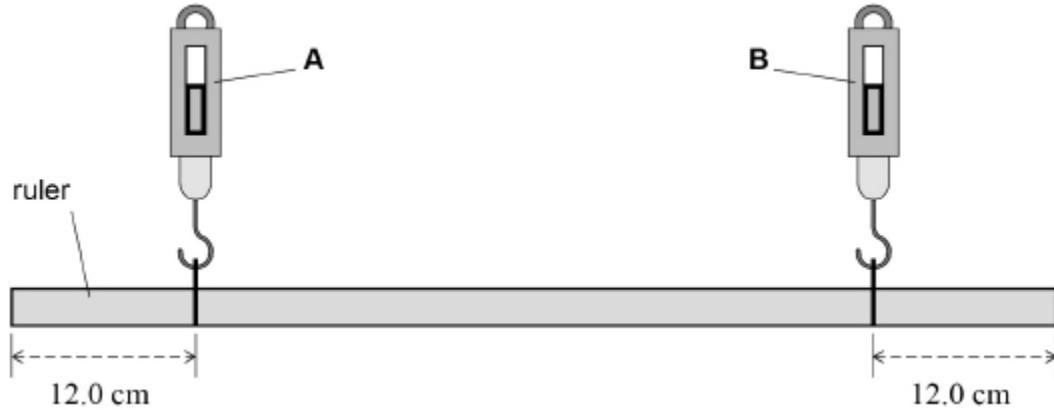
Discuss the differences between the magnitudes and directions of force U in **Figure 1** and force V applied at Y in **Figure 3**.

(3)
(Total 7 marks)

4. A student investigates moments by suspending a 100 cm ruler from two force meters, **A** and **B**. **A** and **B** are attached to the ruler 12.0 cm from each end. Their supports are adjusted to make **A** and **B** vertical and the ruler horizontal.

Figure 1 is a simplified diagram of the experiment.

Figure 1



- (a) The ruler is uniform and weighs 1.12 N.

Determine the reading on **A**.

reading = _____ N

(1)

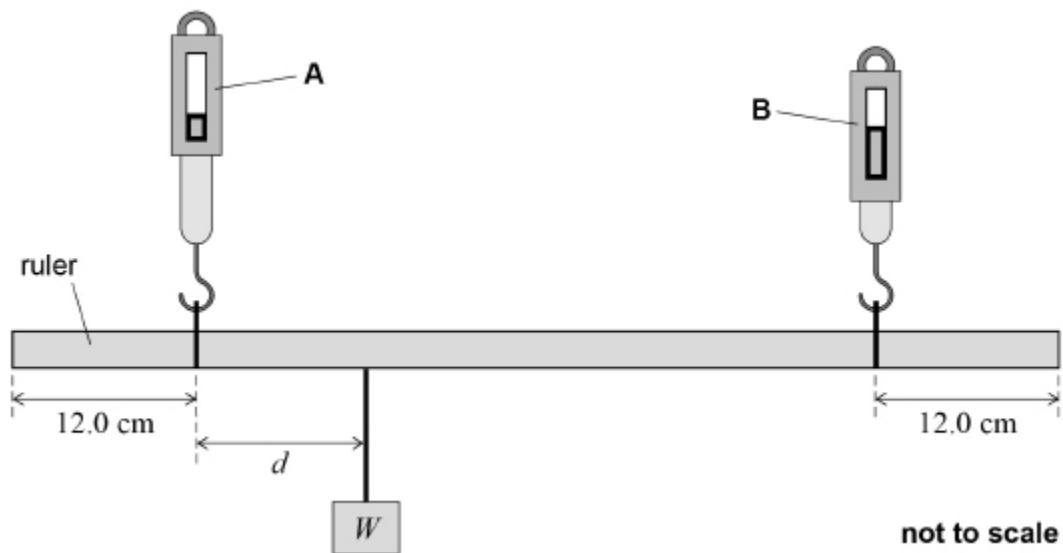
- (b) The student suggests that the forces exerted on the ruler by **A** and **B** act as a couple.

Discuss whether his suggestion is correct.

(2)

- (c) The student hangs a mass of weight W on the ruler between **A** and **B**, as shown in **Figure 2**.
He adjusts the supports so that **A** and **B** are again vertical and the ruler is horizontal. The mass hangs at a distance d from **A**.

Figure 2



The reading on **A** is 0.82 N and the reading on **B** is 0.62 N.

Determine

- W
- d .

$$W = \text{_____ N}$$

$$d = \text{_____ m}$$

(4)

- (d) A second student sets up the same apparatus as shown in **Figure 2**. She suspends the mass in the same position on the ruler as in question (c). She moves the supports to make **A** and **B** vertical but does not make the ruler horizontal.

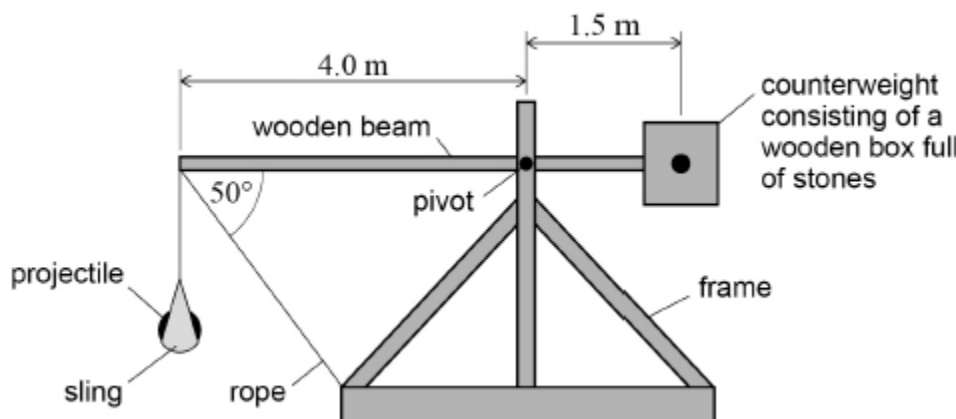
Discuss whether the readings on **A** and **B** taken by this student are different to those in question (c).

(2)
(Total 9 marks)

5.

Figure 1 shows a simplified catapult used to hurl projectiles a long way.

Figure 1



The counterweight is a wooden box full of stones attached to one end of the beam. The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.

The beam is held horizontal by a rope attached to the frame.

- (a) The catapult is designed so that the weight of the beam and the weight of the **empty** wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

(2)

- (b) The stones in the counterweight have a total mass of 610 kg and the projectile weighs 250 N.

Calculate the tension in the rope.

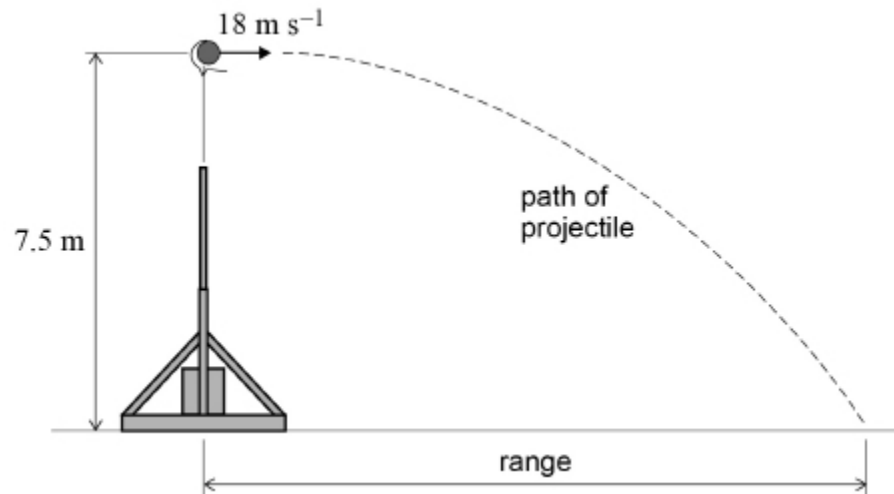
tension = _____ N

(5)

- (c) When the rope is cut, the counterweight rotates clockwise. When the beam is vertical it is prevented from rotating further. The projectile is then released horizontally with a velocity of 18 m s^{-1} , as shown in **Figure 2**.

The projectile is released at a height of 7.5 m above ground level.

Figure 2



The range of the catapult is the horizontal distance between the point where the projectile is released to the point where it lands.

Calculate the range.
Ignore air resistance.

range = _____ m

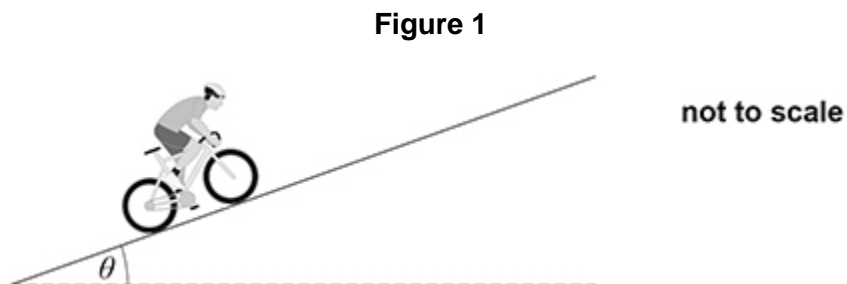
(2)

- (d) In another release, the sling is adjusted so that a projectile of the same mass is released just before the wooden beam is vertical. The projectile is not released horizontally.

Discuss the effect this change has on the range of the catapult.

(3)
(Total 12 marks)

- 6.** (a) **Figure 1** shows a cyclist going up a hill.



The angle θ of the slope of the hill is constant.
The total mass m of the cyclist and bicycle is 65 kg.

Write an expression for the component of the total weight parallel to the slope.

(1)

- (b) The useful power output of the cyclist is 310 W.
The cyclist has a steady speed of 1.63 m s⁻¹.

Assume that air resistance is negligible at this speed.

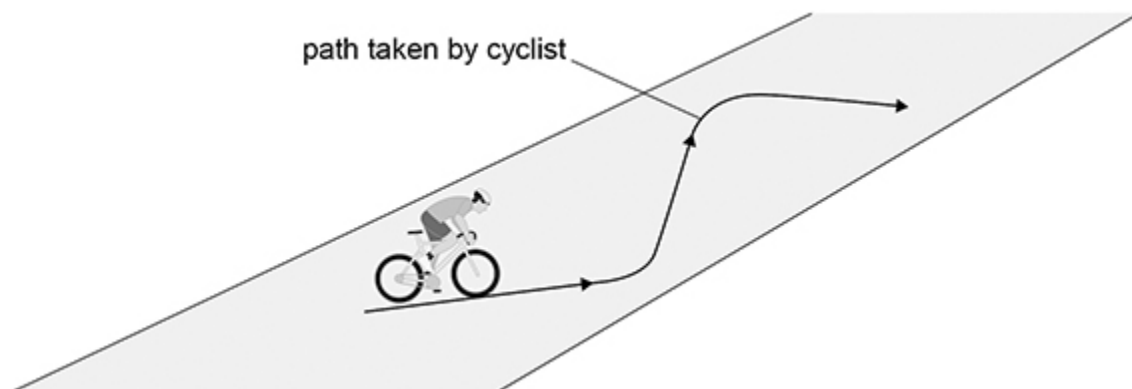
Calculate θ .

$$\theta = \text{_____}^\circ$$

(2)

Figure 2 shows an alternative 'zig-zag' path taken by the cyclist up the same hill. She maintains a steady speed of 1.63 m s⁻¹.

Figure 2



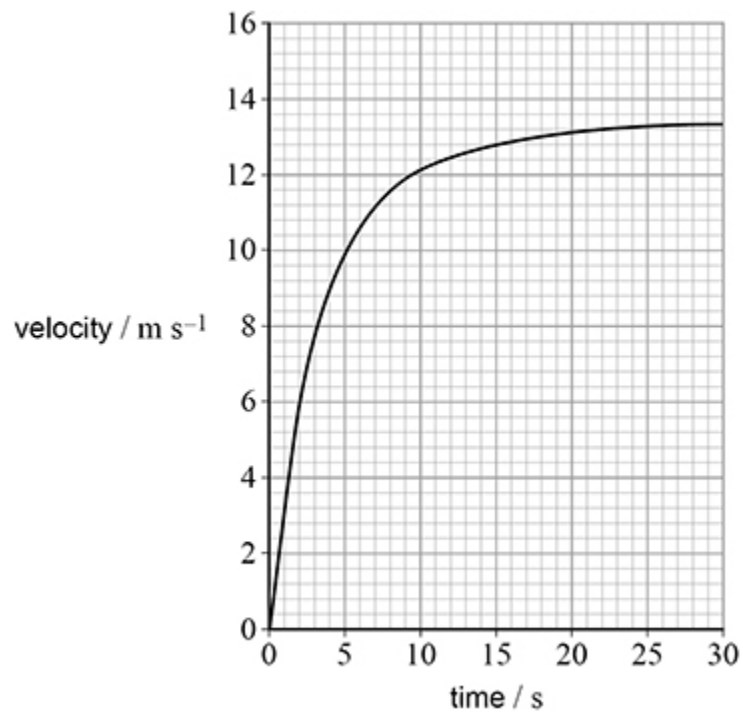
- (c) Discuss how her useful power output when taking the path in **Figure 2** compares with her useful power output in part (b).

(3)

The cyclist reaches the top of the hill. She then travels back down the hill in a straight line. The bicycle rolls freely without the cyclist pushing the pedals or applying the brakes.

Figure 3 shows the variation of her velocity with time as she goes down the hill.

Figure 3



- (d) Determine the acceleration of the cyclist 10.0 s after she begins to go down the hill.

acceleration = _____ m s^{-2}

(3)

- (e) Energy transfers occur as the cyclist travels down the hill.

Outline how these energy transfers explain the shape of the graph in **Figure 3**.

(4)

(Total 13 marks)