Answers to Sec 3 Physics WA3

Question 1

1 During the 2020 Tokyo Olympics, a diver jumps upwards from the diving platform, and enters the water below 2.3 s later as shown in Fig. 1.1. The diving platform is 10.0 m above the water level.

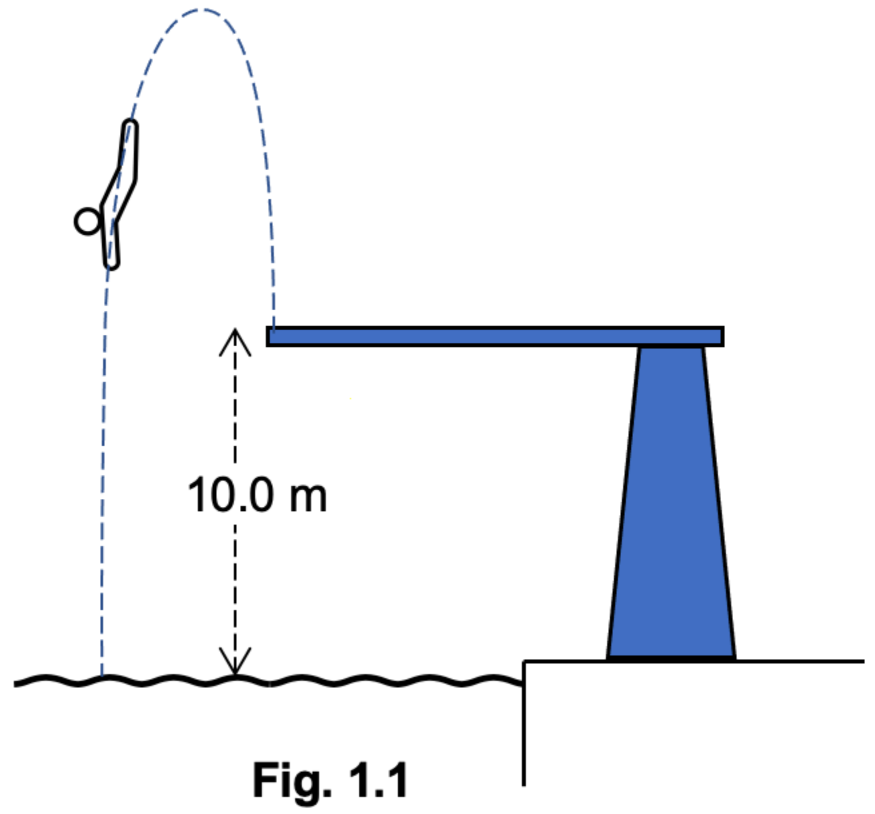


Fig. 1.1

(a) Determine the speed at which the diver leaves the platform.

speed = ………………… [2]

(b) Determine the speed at which the diver enters the water.

speed = ………………… [2]

(c) As the diver enters the water, she is decelerated at a rate of 25 m s^{-2}.
How far underwater is the diver when she is finally brought to rest?

depth underwater = ………………… [2]

- Similar to Assignment AS5.3 Q4 & Q5

4 A stone is thrown vertically upwards from ground level with a velocity of 40 m s^{-1}. The stone then falls back to the ground. By neglecting air resistance, determine

(a) the maximum height achieved by the stone as it rises,

height = …………………

(b) the total time of flight.

time = …………………

5 A stone is dropped from a cliff 80.0 m high and hits the water in the sea below. It decelerates at 20.0 m s^{-2} in the water and impacts the seabed 30.0 m below the surface.

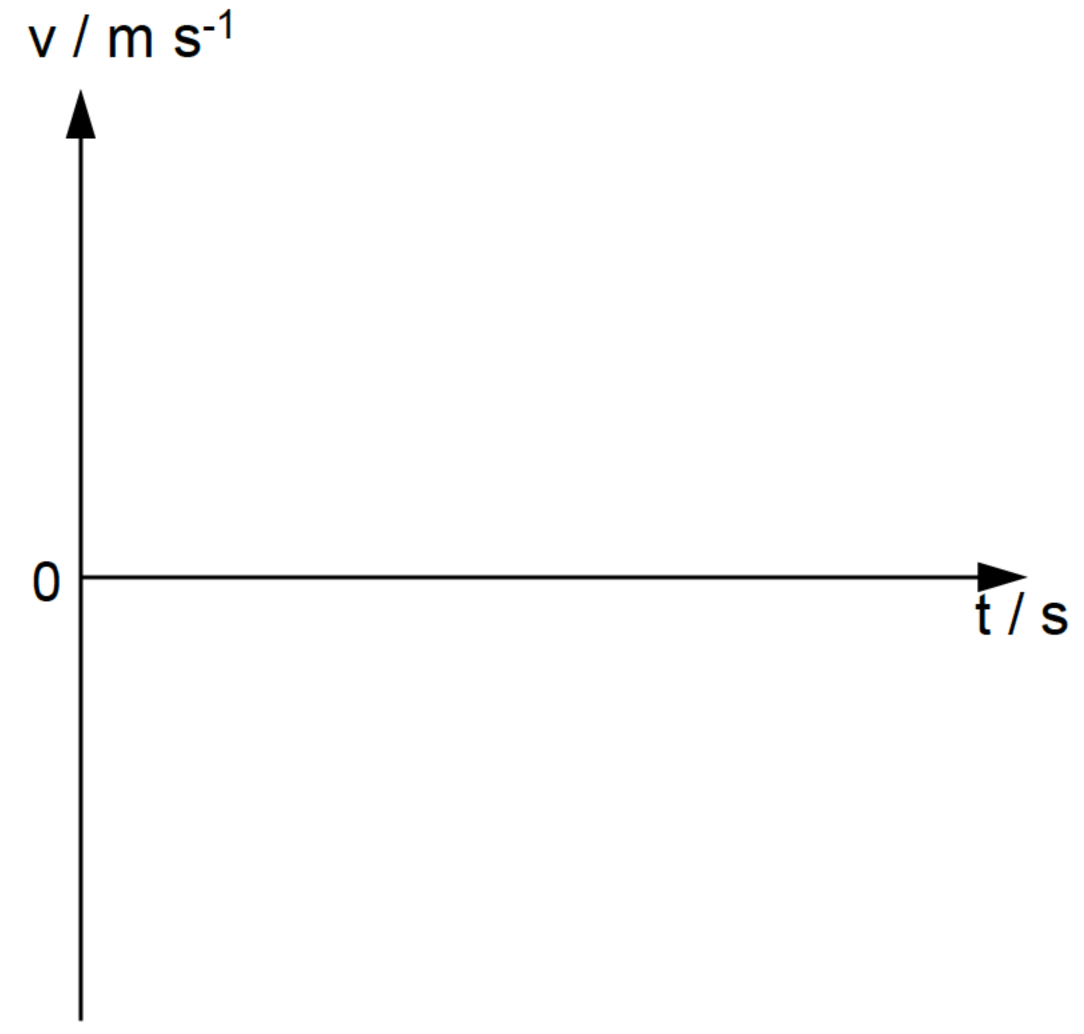
Calculate the:

(a) time it takes for the stone to reach the water.

(b) velocity of the stone when it hits the water.

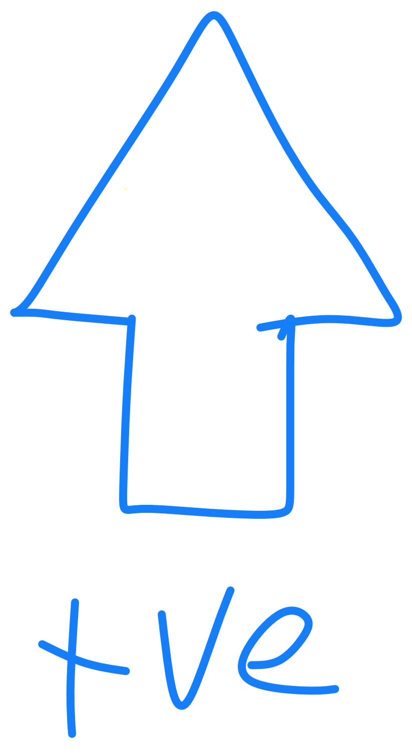
(c) time taken for the stone to travel through the water.

(d) velocity of the stone when it hits the seabed.



(e) Plot the velocity-time (v-t) graph and label the relevant information, to show the motion of the stone till it just hit the seabed.

1 During the 2020 Tokyo Olympics, a diver jumps upwards from the diving platform, and enters the water below 2.3 s later as shown in Fig. 1.1. The diving platform is 10.0 m above the water level.



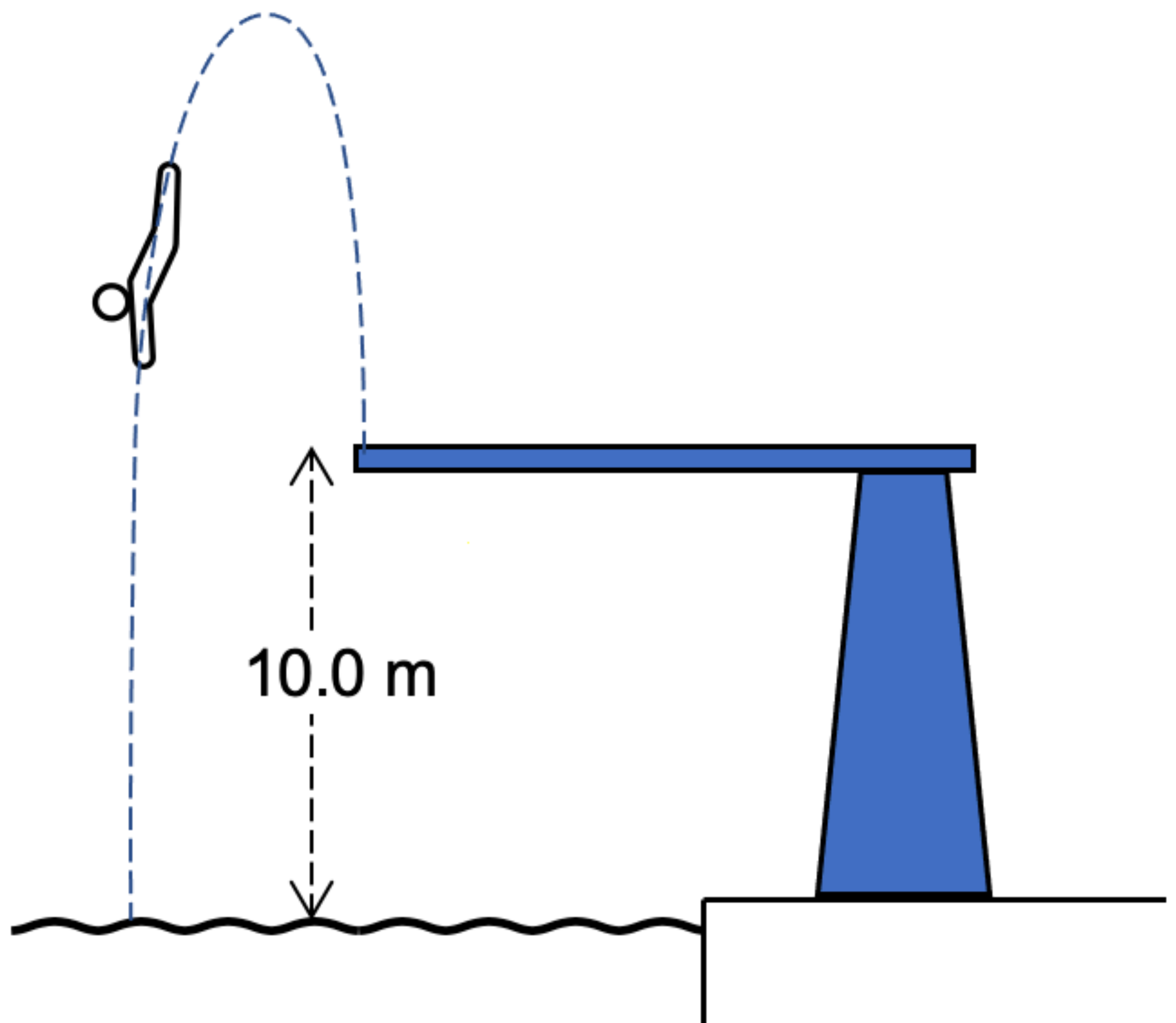
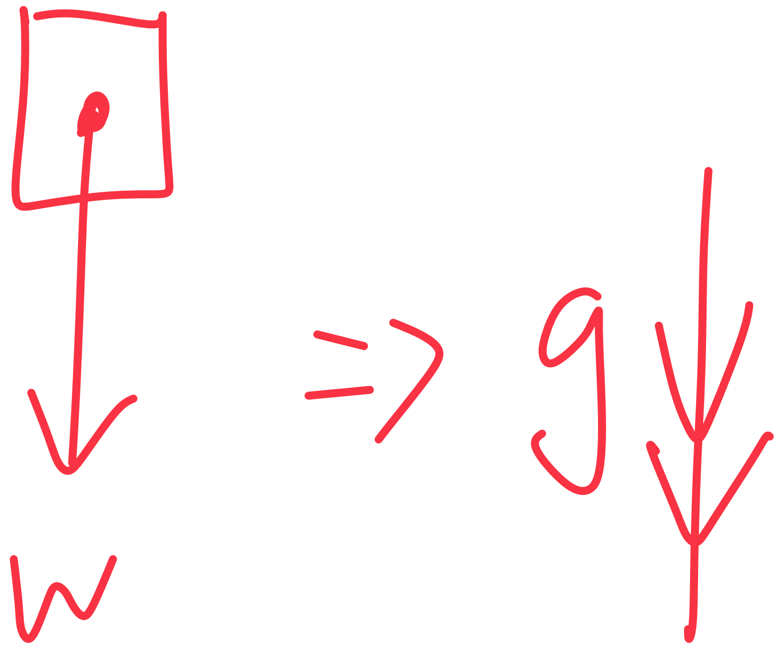


Fig. 1.1

RECALL:



DIRECTION OF "g" IS ALWAYS DOWN

(a) Determine the speed at which the diver leaves the platform.

TAKING UPWARDS TO BE +VE

$u = ?$

$a = -10\ m/s^2$

$t = 2.3\ s$

$s = -10\ m$

$$s = ut + \tfrac{1}{2}at^2$$

$$-10 = 2.3u + \tfrac{1}{2}(-10)2.3^2$$

$u = 7.15\ m/s$ OR $u = 7.2\ m/s$

(b) Determine the speed at which the diver enters the water.

CHECK u & v WILL HAVE OPPOSITE SIGNS

$u = 7.15\ m/s$ (FROM (a))

$v = ?$

$a = -10\ m/s^2$

$t = 2.3\ s$

$v = u + at$

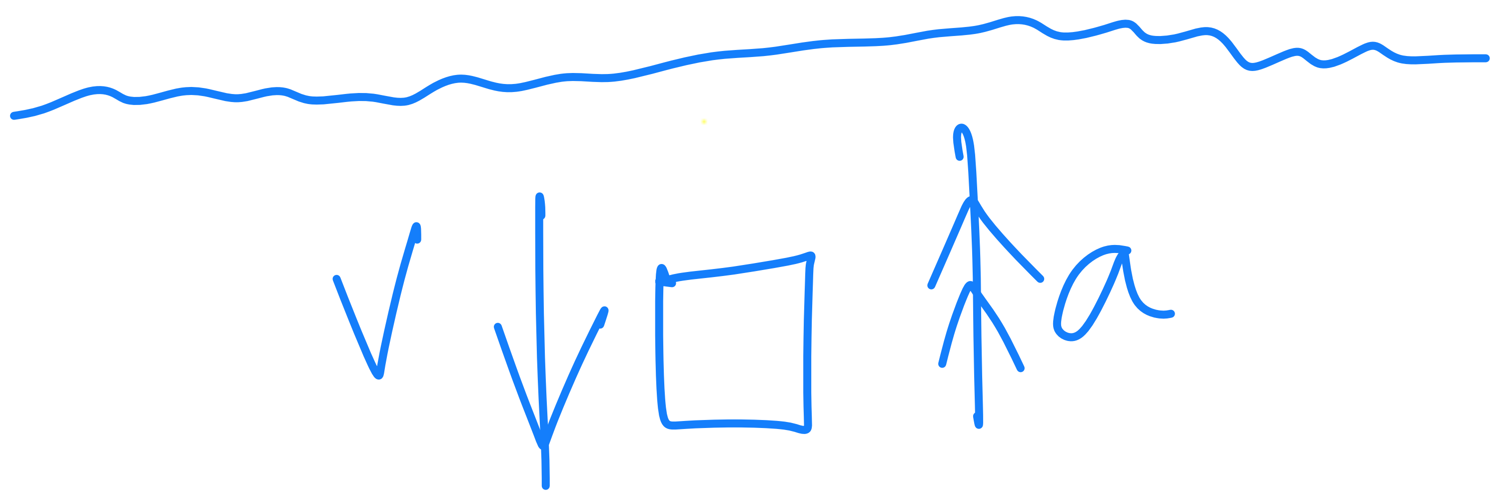
$= 7.15 + (-10)2.3$

$= -15.9\ m/s$

speed = ...16 ms^{-1}.... [2]

(c) As the diver enters the water, she is decelerated at a rate of 25 m s^{-2}.
How far underwater is the diver when she is finally brought to rest?

TAKING DOWN AS +ve



DID YOU DRAW A FREE-BODY DIAGRAM?

IN DECELERATION v & a WILL ALWAYS HAVE OPPOSITE SIGNS

$u = 15.9\ m/s$ (FROM (b))

$v = 0\ m/s$ (REST)

$a = -25\ m/s^2$

$s = ?$

$v^2 = u^2 + 2as$

$0 = 15.9^2 + 2(-25)s$

$s = 5.02$

depth underwater = ...5.0 m.... [2]

Question 2

2 Fig. 2.1 shows the speed-time graph of a 5.0 g pebble dropped from the 20th storey of a building. The pebble eventually reaches a final speed v_2 during its fall.

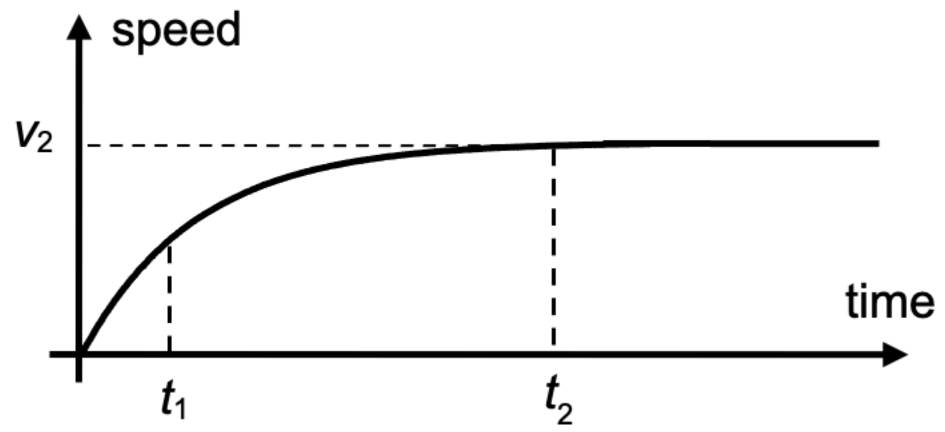


Fig. 2.1

(a) Calculate the weight of the pebble.

weight = ... [1]

(b) Describe how the speed of the pebble varies from t_1 to t_2.

....

.... [1]

(c) Explain, with respect to the forces acting on the pebble, how the motion changes between t_1 and t_2.

....

....

....

.... [2]

(d) A denser pebble with the same dimensions is dropped from the same location. State and explain how the final speed of this pebble would be different from the pebble illustrated in Fig. 2.1.

....

....

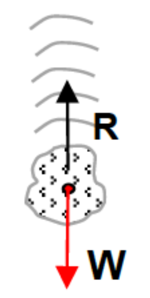
....

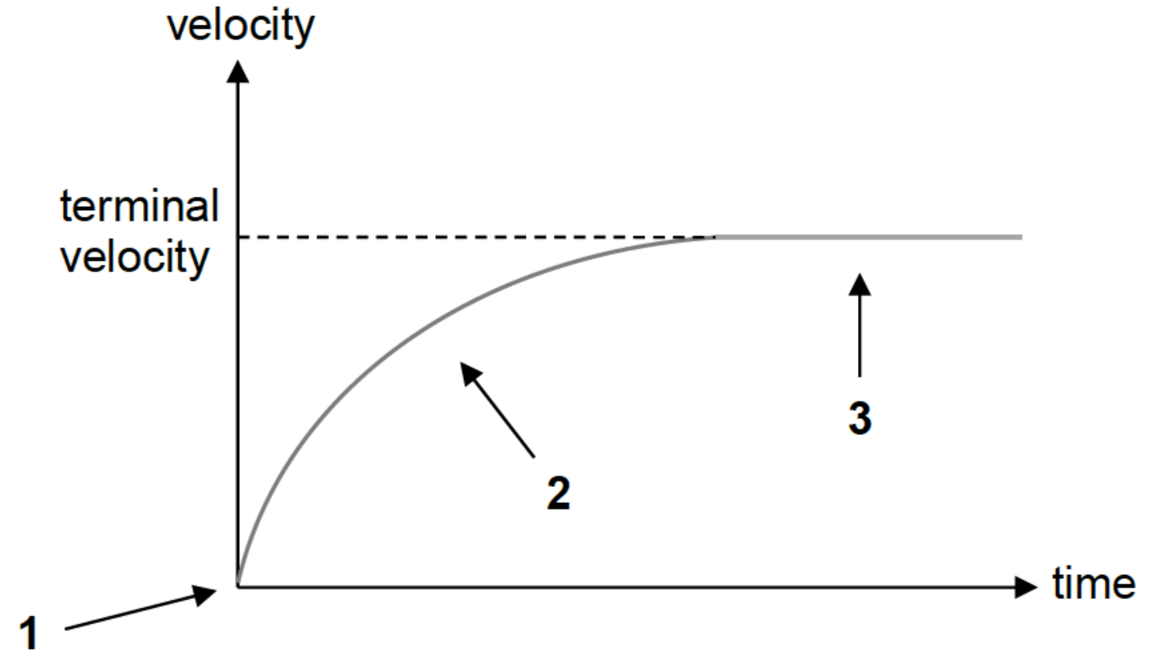
.... [2]

- Similar to Chapter 6 Notes p19

6.5.2 Terminal Velocity

When a body falls vertically through air, the air resistance R can act on it.
The air resistance R increases with increasing velocity.





Stage of motion	Forces on the body	F_{net} & acceleration a
1. When a body is just released (at t = 0)	R = 0, only force is weight W	$F_{net} = W$ hence a = g
2. As the body falls, the velocity of the body increases	R increases, W remains constant	$F_{net} = W - R$ F_{net} decreases hence a decreases (< g)
3. When terminal velocity is reached	R = W	$F_{net} = W - R = 0$ hence a = 0

Eventually when the downward force of gravity W (weight) on the object is equal to the air resistance R on the body, the body will fall with a **terminal velocity**.
This is the constant maximum velocity of the body.

The net force $F_{net} = 0$, acceleration a = 0, hence velocity is constant.

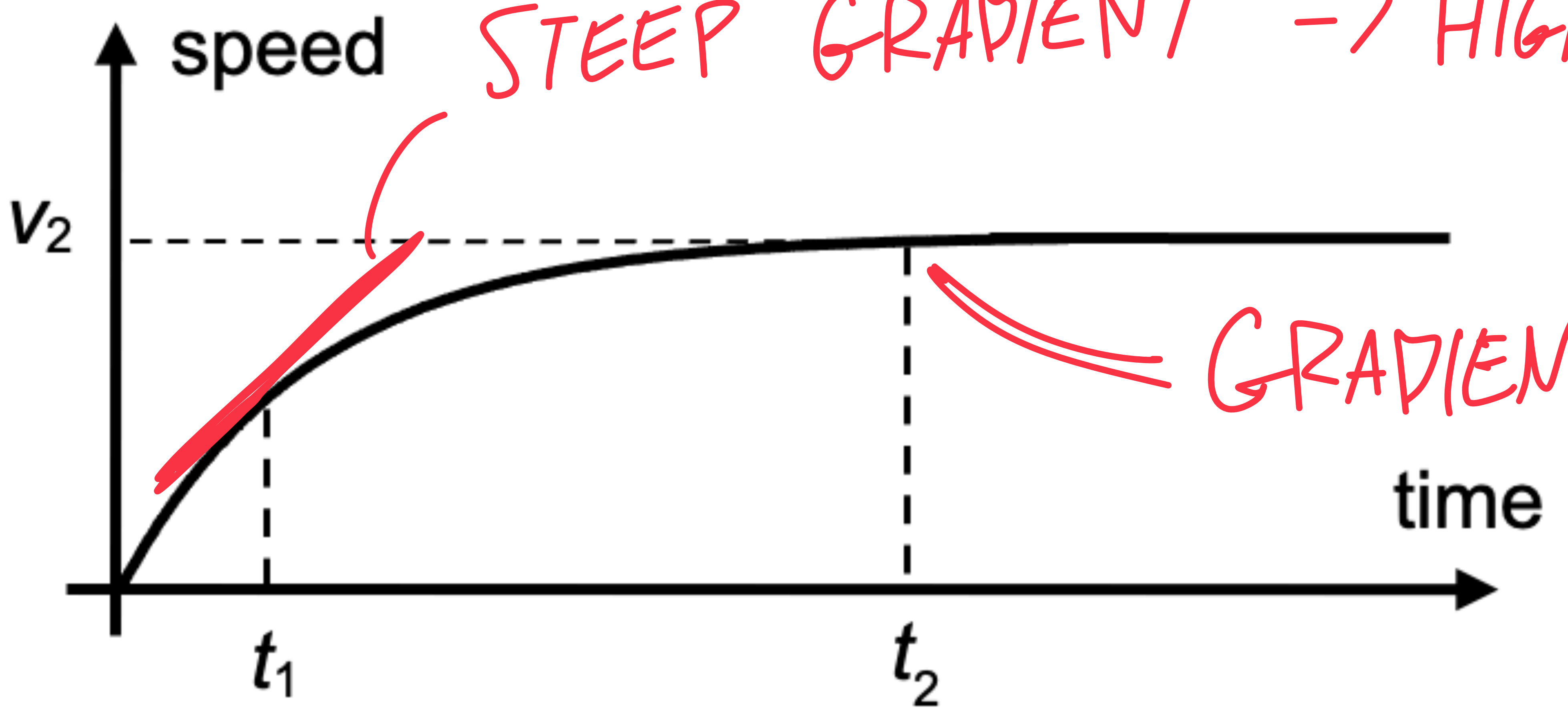
Example 6.5.3
A 50 kg parachutist falls through the air.
(a) Calculate the net force acting on him and his net acceleration:
(i) At the start of his fall.

(ii) After falling for a while and he experiences an air resistance of 60 N opposing his motion.

(iii) When he opens his parachute and the air resistance increases to 475 N.

(b) As his acceleration decreases to zero, he reaches terminal velocity. What is the magnitude of the air resistance for this to happen?

2 Fig. 2.1 shows the speed-time graph of a 5.0 g pebble dropped from the 20th storey of a building. The pebble eventually reaches a final speed v_2 during its fall.



STEEP GRADIENT => HIGH ACCELERATION

GRADIENT = 0 => CONSTANT VELOCITY (ZERO ACCELERATION)

Fig. 2.1

(a) Calculate the weight of the pebble.

$m = 5.0g = 0.0050\ kg$

2 sig. fig.

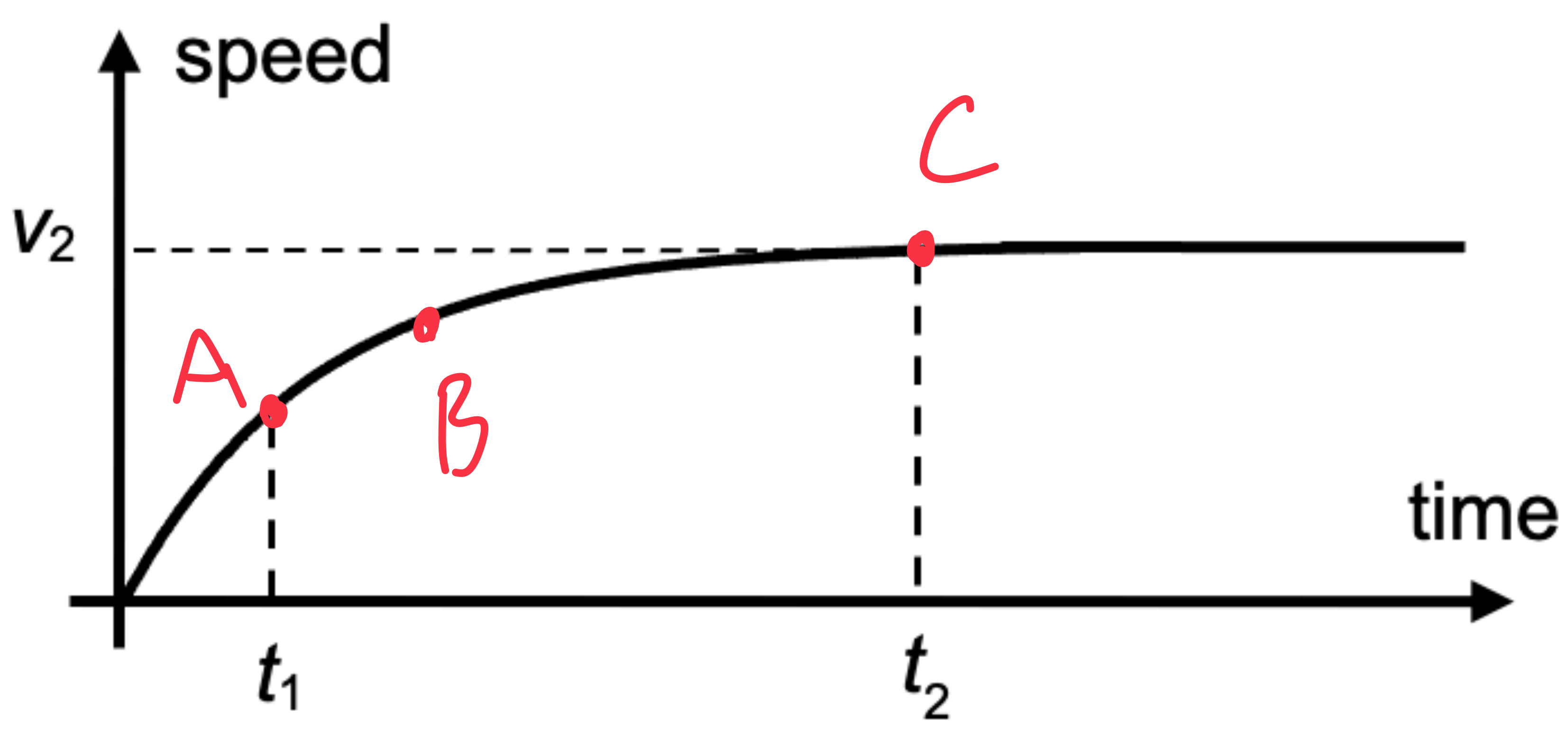
$W = mg = 0.0050 \times 10$

weight = 0.050 N [1]

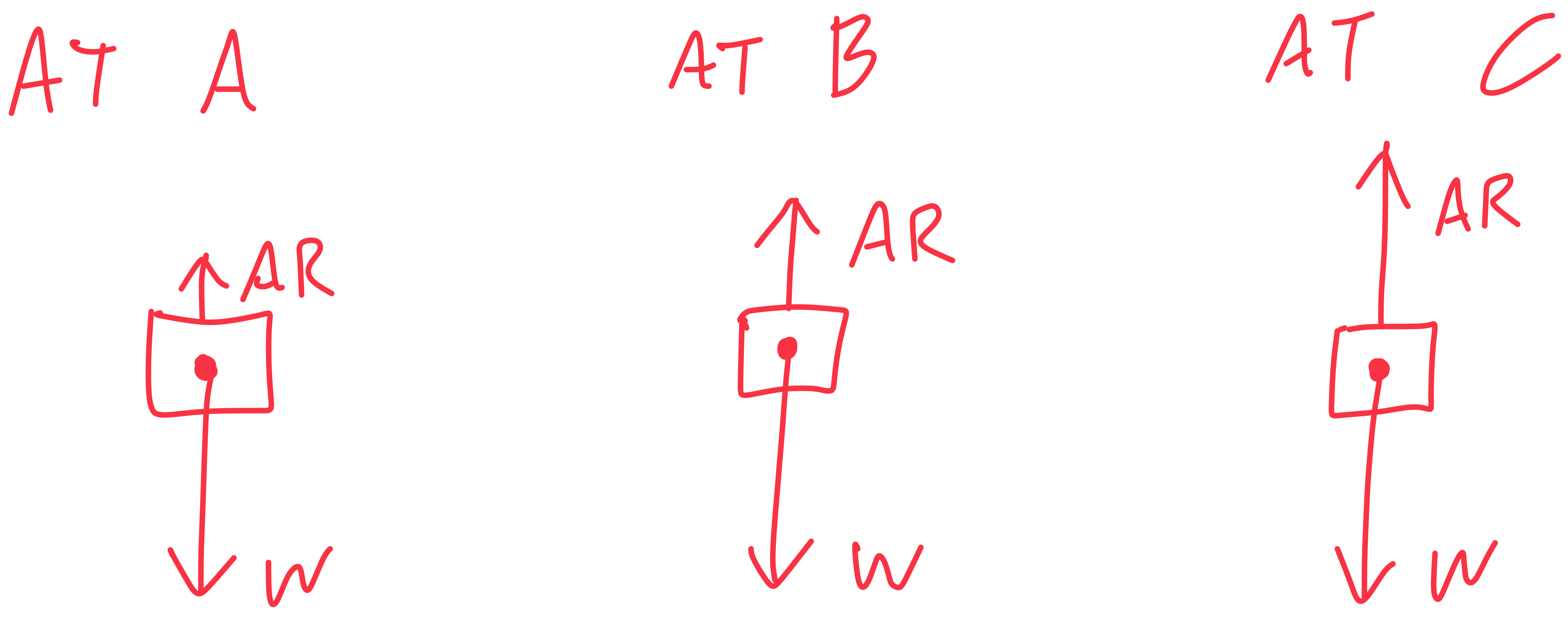
(b) Describe how the speed of the pebble varies from t_1 to t_2.

DECREASING ACCELERATION

(c) Explain, with respect to the forces acting on the pebble, how the motion changes between t_1 and t_2.

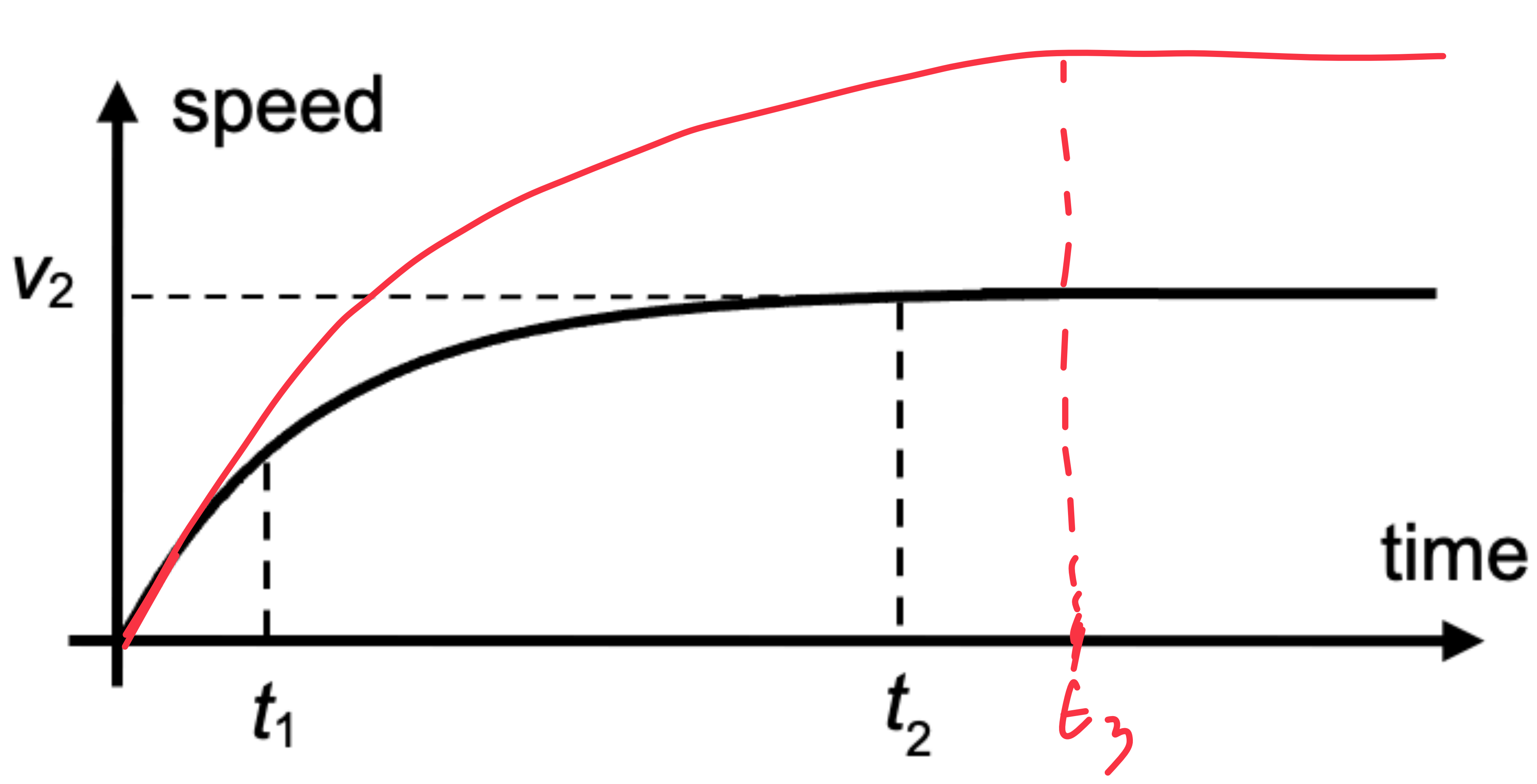


AS SPEED INCREASES, AIR RESITSANCE WILL INCREASE.
WEIGHT REMAINS UNCHANGED.
RESULTANT FORCE DECREASES RESULTING IN A DECREASING ACCELERATION.

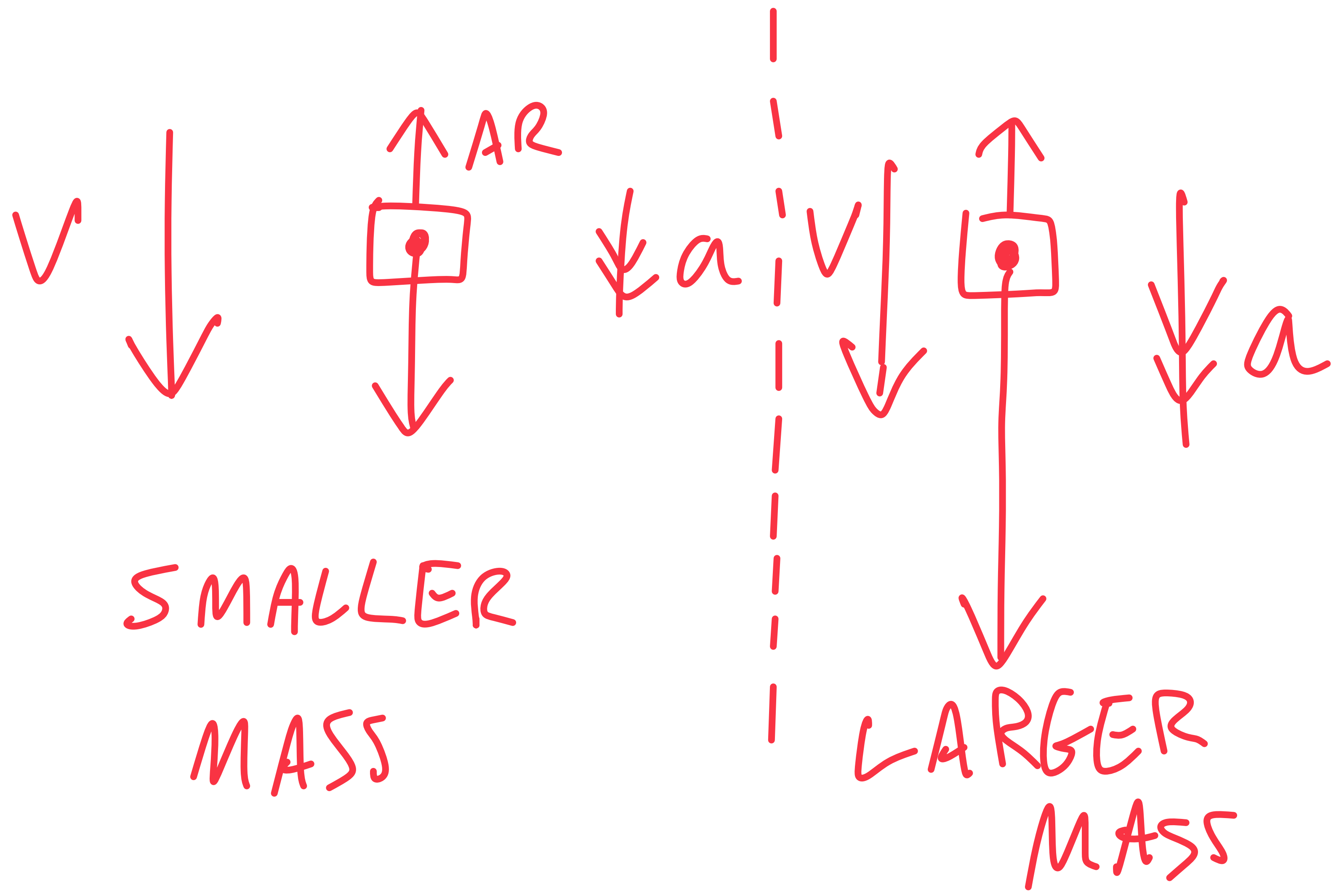


- WEIGHT REMAINS CONSTANT
- AIR RESISTANCE (AR) INCREASES

(d) A denser pebble with the same dimensions is dropped from the same location. State and explain how the final speed of this pebble would be different from the pebble illustrated in Fig. 2.1.



WHEN MOVING AT SPEED V_1



FINAL SPEED WILL BE HIGHER.

WEIGHT IS LARGER, SO RESULTANT FORCE IS LARGER AT ANY GIVEN AIR RESISTANCE (SPEED).

AIR RESISTANCE NEEDS TO GROW TO A LARGER MAGNITUDE THAN THE ORIGINAL PEBBLE IN ORDER TO MATCH WEIGHT AND RESULT IN RESULTANT FORCE OF ZERO. WHEN THIS HAPPENS PEBBLE WILL BE MOVING AT A FASTER SPEED.

Question 3

3 A man of mass 80 kg is standing on a weighing scale inside an elevator, as shown in Fig. 3.1. The mass of the elevator is 600 kg.

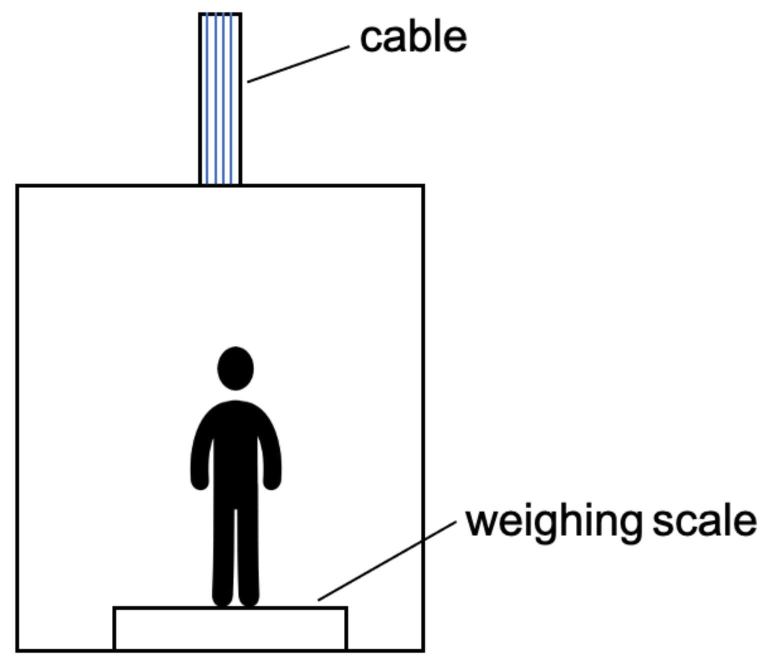


Fig. 3.1

(a) Consider the scenario where the elevator is stationary.

Student A claims that the normal contact force exerted by the weighing scale on the man and the gravitational force exerted by Earth on the man is an action-reaction pair, since these two forces are equal in magnitude and opposite in direction.

Student B claims these two forces are *not* an action-reaction pair.

State 2 reasons why Student B is correct.

....

....

....

.... [2]

(b) Now consider the scenario where the elevator is moving downwards and decelerating at a rate of 1.5 m s^{-2}. Determine the reading on the weighing scale in newtons.

reading = ... [2]

- (a) is Similar to Chapter 6 Notes p20

6.6 Newton's Third Law of Motion (Action & Reaction)

Newton's Third Law of Motion states that **the force which body A exerts on body B is always equal in magnitude and opposite in direction to the force which body B exerts on body A.**

Newton's third law tells us that
- forces always occur in pairs called action and reaction forces,
- each pair of such forces are always
  - equal in magnitude;
  - opposite in direction;
  - acting on different bodies;
  - of the same nature.

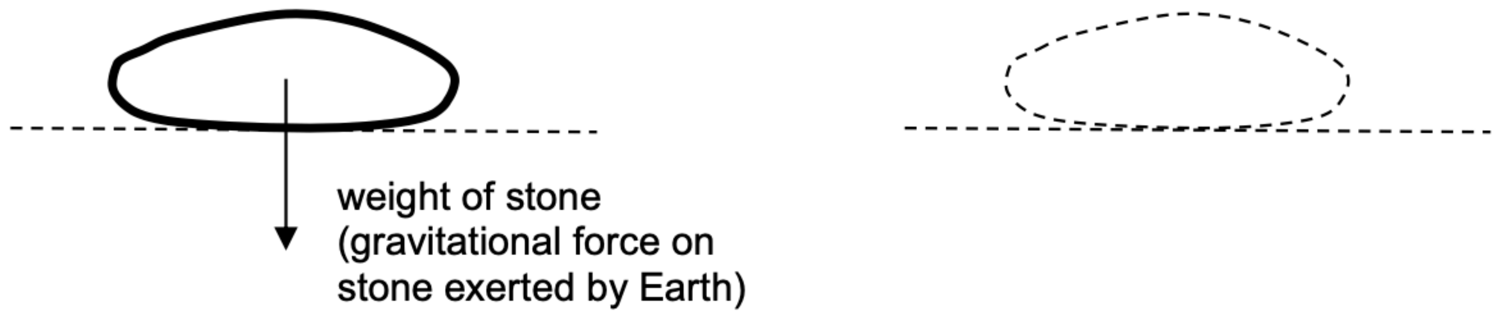
Note: A force only exists if you can answer the question "What body exerts this force?".

Example 6.6.1
A stone is resting on the table as shown.

A force has been identified in each diagram below.
(i) Draw another force that forms an action-reaction pair with the given force.
(ii) Label this force in this manner:
force on __________ (which body) exerted by ____________ (which body)

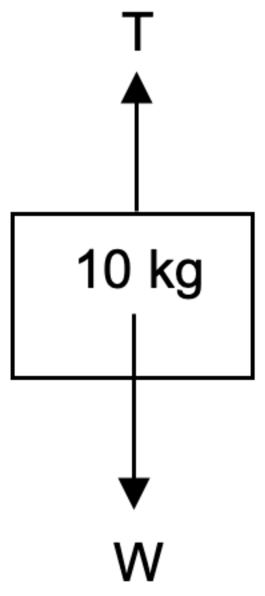
(a)

(b)



- (b) is Similar to Assignment AS6.3 Q4 & Chapter 6 Notes p18

2. The diagram shows a body of mass 10 kg attached to a vertical string. Find the tension T in the string in each of the following situations.



(a) The string raises the body with an acceleration of 5.0 m s^{-2} upwards.

(b) The string lowers the body with an acceleration of 5.0 m s^{-2} downwards.

(c) The string raises the body at a constant velocity of 5.0 m s^{-1}.

4. A man of mass 60 kg enters a lift of mass 800 kg. He steps onto a weighing scale as shown in Fig. 4.1.

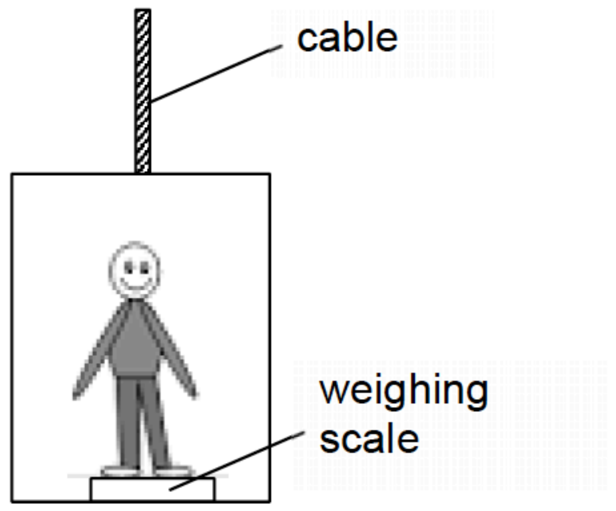


Fig. 4.1

Fig. 4.2

(a) Sketch a free-body diagram for the man in Fig. 4.2.

(b) What will be the reading on the weighing scale if:

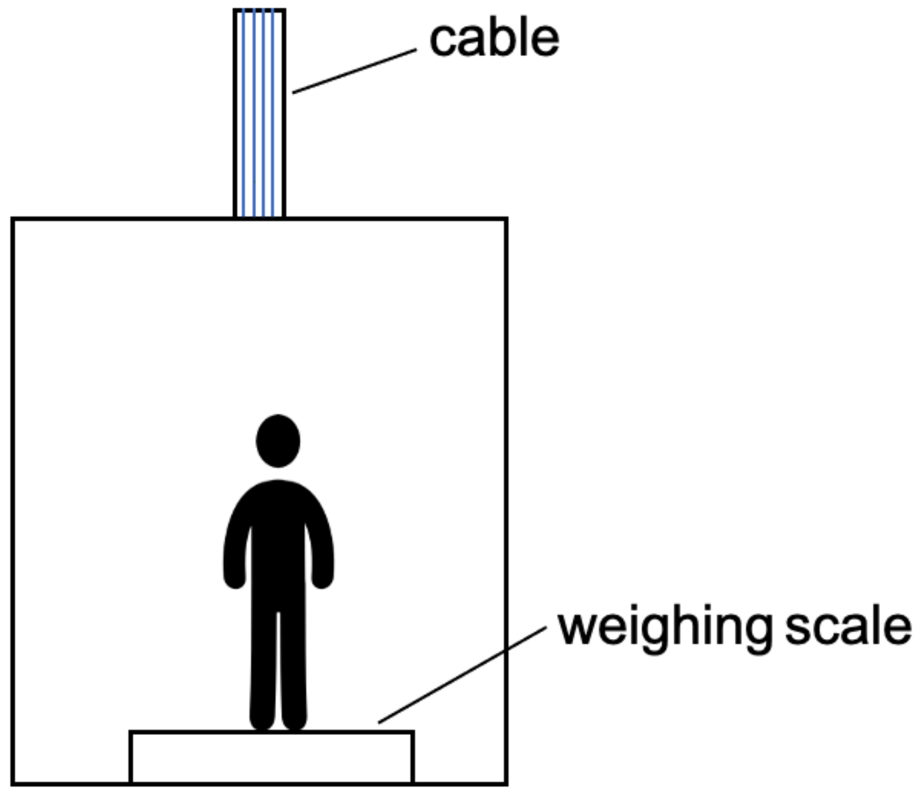
(i) the lift accelerates upwards at 2.0 m s^{-2},

reading on weighing scale = ...

(ii) the lift decelerates upwards at 2.0 m s^{-2}?

reading on weighing scale = ...

3 A man of mass 80 kg is standing on a weighing scale inside an elevator, as shown in Fig. 3.1. The mass of the elevator is 600 kg.



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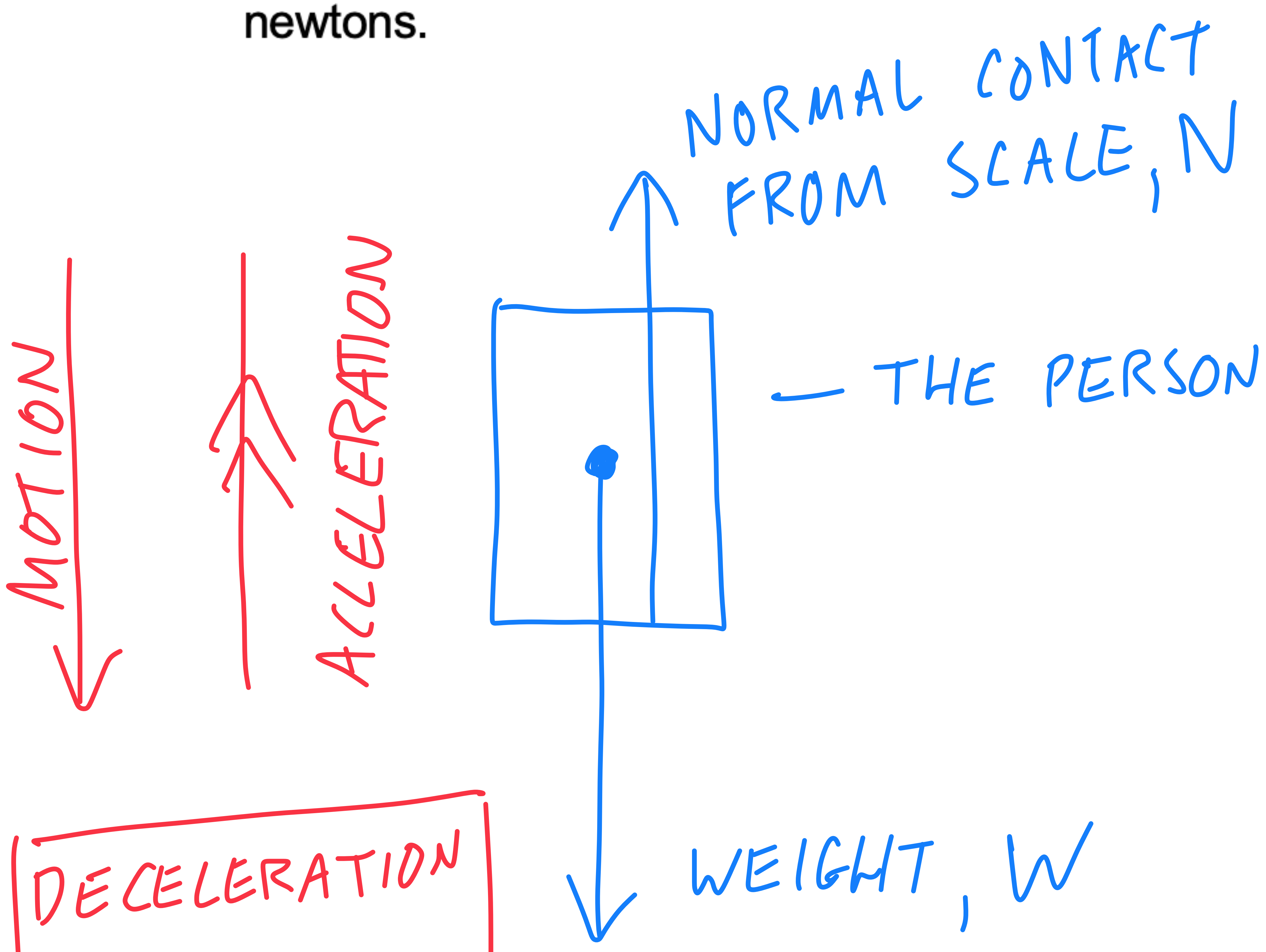
Student B claims these two forces are *not* an action-reaction pair.

State 2 reasons why Student B is correct.

- THE TWO FORCES ARE NOT OF THE SAME NATURE

- THE TWO FORCES ACT ON THE SAME OBJECT (THE MAN)

(b) Now consider the scenario where the elevator is moving downwards and decelerating at a rate of 1.5 m s^{-2}. Determine the reading on the weighing scale in newtons.



DECELERATION
$\Rightarrow$ v & a HAVE OPPOSITE SIGNS

$$F = ma$$

$$N - W = ma$$

$$N - 800 = 80 \times 1.5$$

$$N = 920 \text{ N}$$

Question 4

4 Fig. 4.1 shows an object of mass 4.0 kg hung by two ropes from a horizontal ceiling.

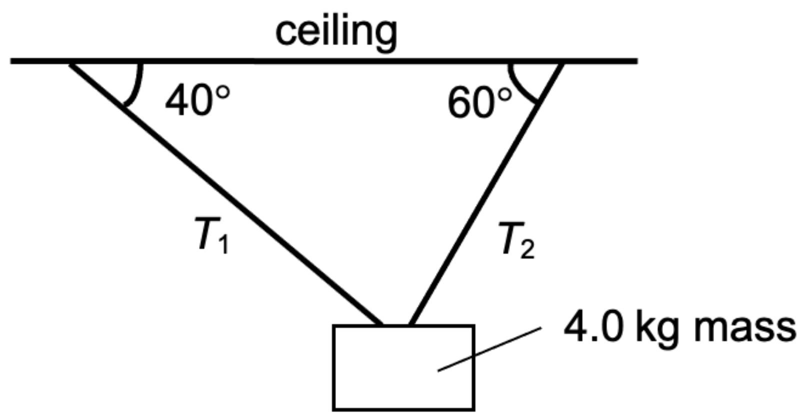


Fig. 4.1

Draw a scaled diagram in the space below to determine the magnitude of the tension of each rope.
State the scale used. [4]

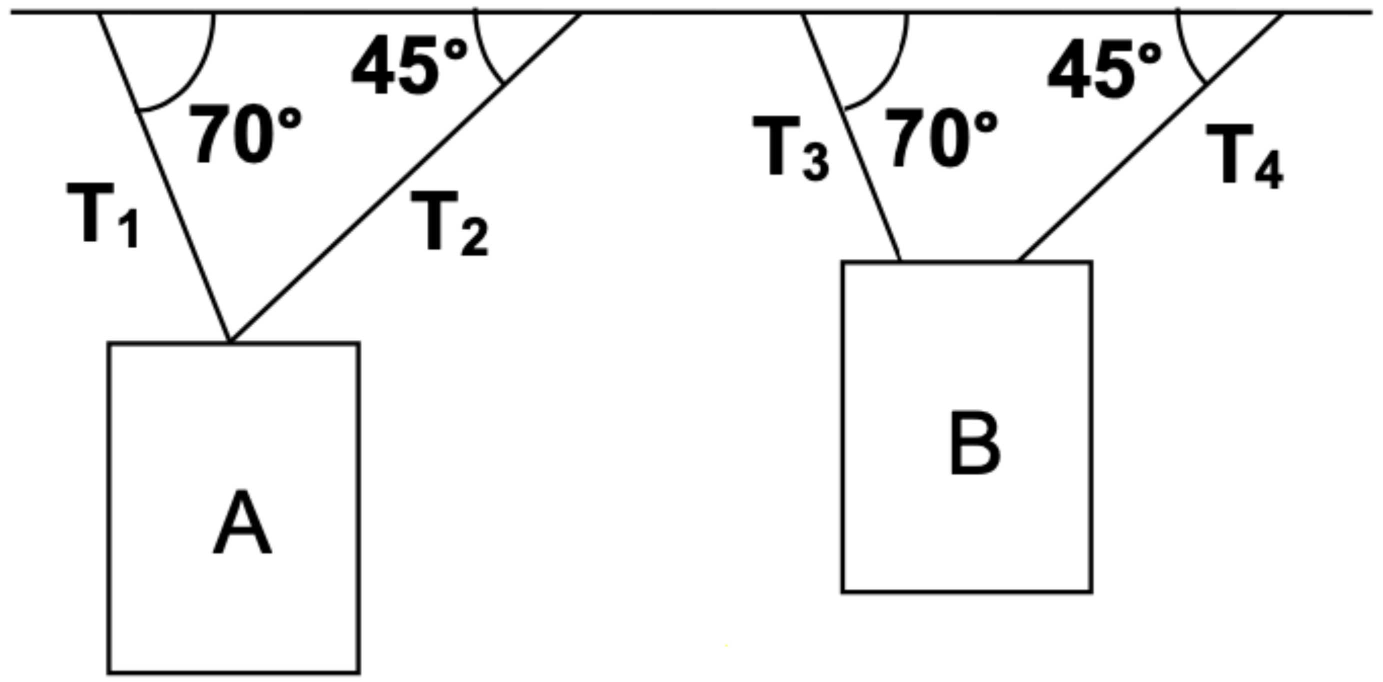
Scale: 1.0 cm represents ……………………

T_1 = ……………………

T_2 = ……………………

- Similar to Chapter 6 Notes p27 Q4

4. In the following diagram, two identical blocks, A and B, are hung from the ceiling by strings inclined at angles **70°** and **45°** as shown.



(a) Label on the diagram above, the direction of all the tensions that act on the blocks.

(b) Sketch vector diagrams to show the addition of all the forces acing on block A and on block B respectively.

(c) Given that $\mathbf{T_1}$ and $\mathbf{T_2}$ are 50 N and 30 N respectively, comment on how the length of the string affects the magnitude of tension.

(d) Compare the magnitudes of $\mathbf{T_1}$ & $\mathbf{T_3}$. Similarly, compare the magnitudes of $\mathbf{T_2}$ & $\mathbf{T_4}$.

(e) Explain whether we can use the existing triangle above A to show addition of forces acting on A.

4 Fig. 4.1 shows an object of mass 4.0 kg hung by two ropes from a horizontal ceiling.

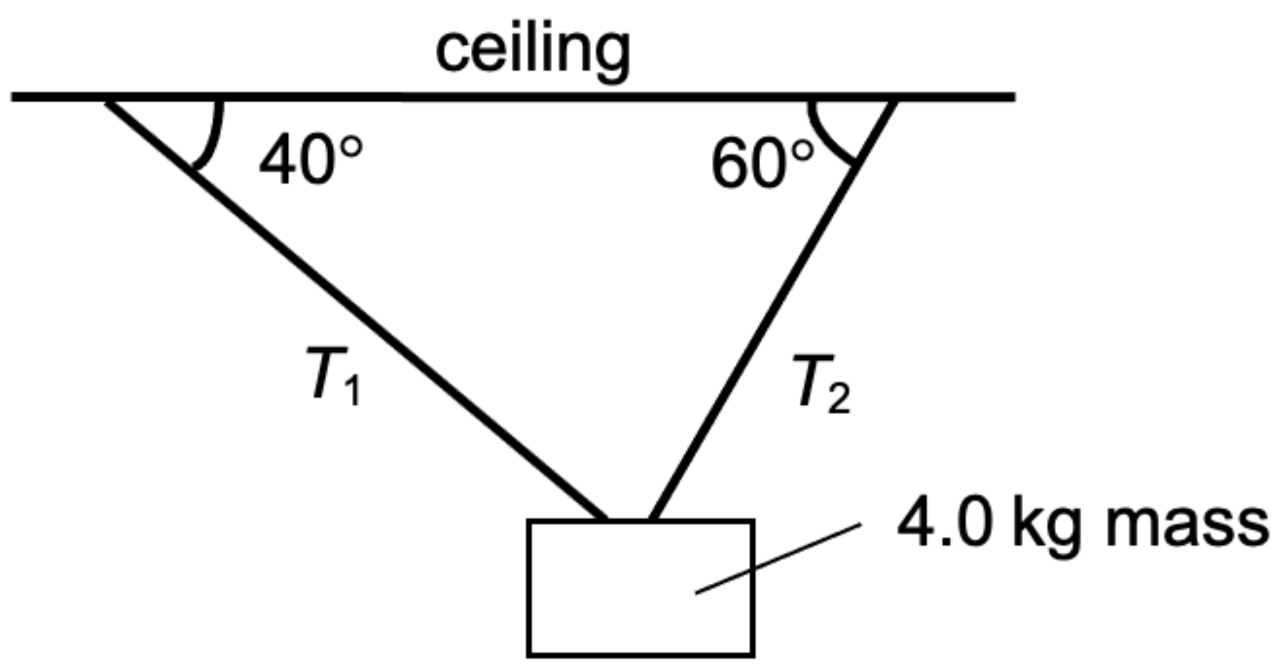


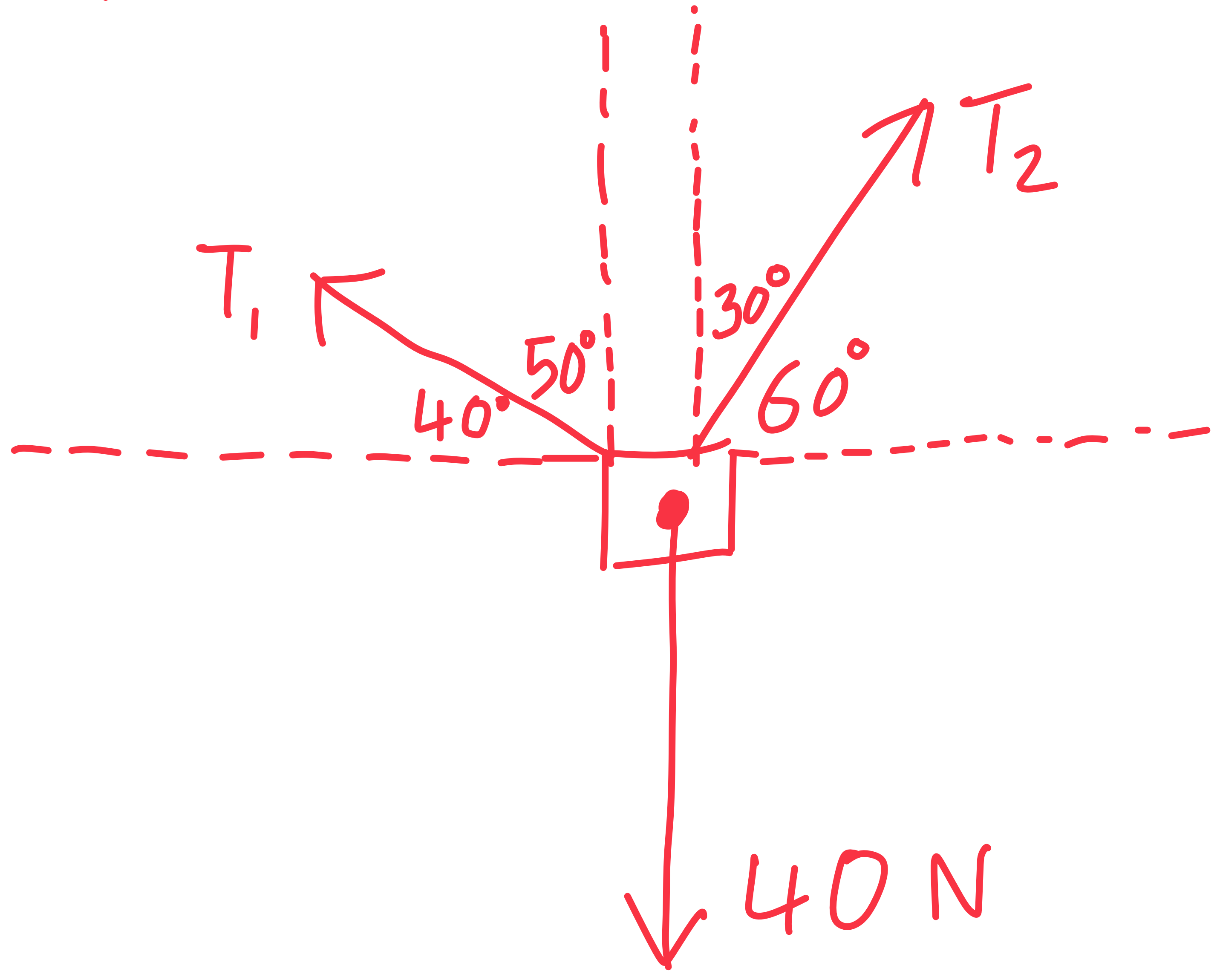
Fig. 4.1

Draw a scaled diagram in the space below to determine the magnitude of the tension of each rope.
State the scale used. [4]

SCALE : 1cm REPRESENTS 4N / 5N

(10N - TOO SMALL)

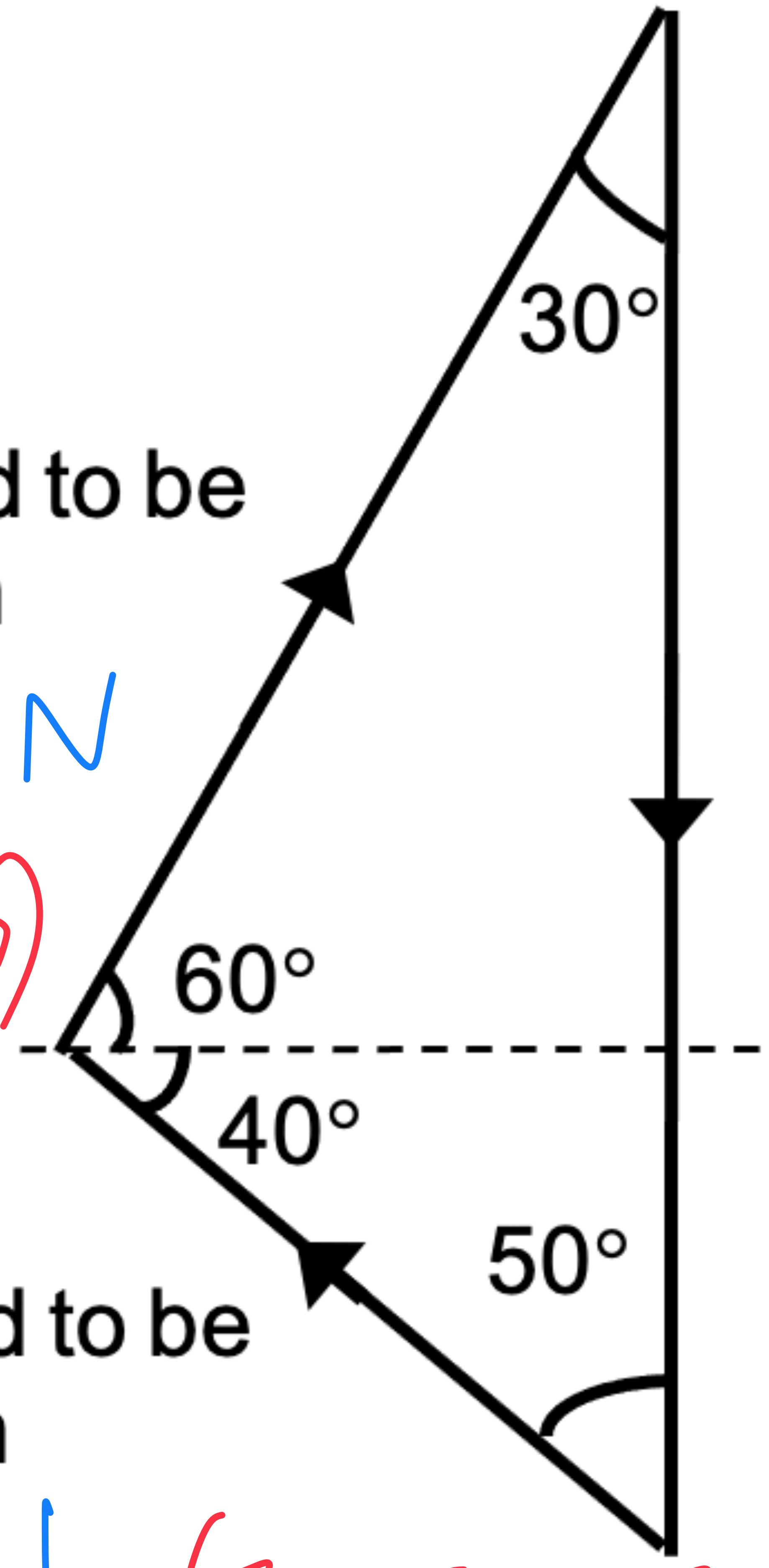
FREE BODY DIAGRAM



T_2 measured to be 7.8 cm

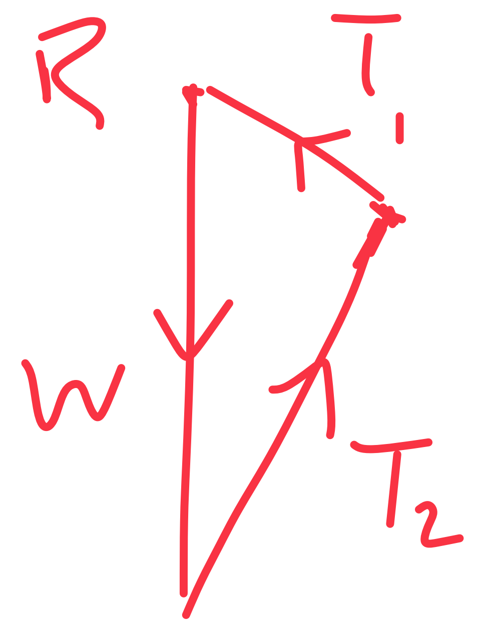
20.4 N

(20.0 – 21.0)



W of 40 N represented by 10.0 cm

OR



T_1 measured to be 5.1 cm

31.2 N (30.5 – 31.6)

Question 5

5 **(a)** State the *Principle of Moments*.

....

....

.... [1]

A toy is designed with a heavy hemispherical lower section joined to a taller, lighter upper section such that it will balance in the position shown in Fig. 5.1 and will return to this position after being pushed to the side as shown in Fig. 5.2.

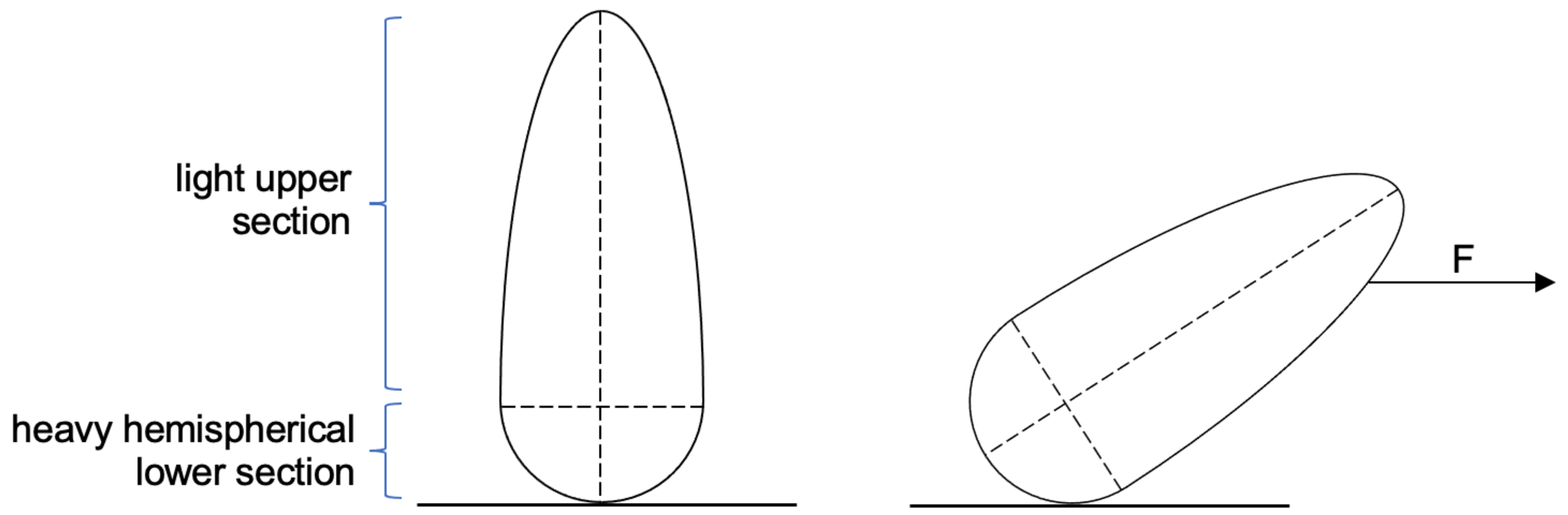


Fig. 5.1 **Fig. 5.2**

(b) Indicate on Fig. 5.1 the position of the centre of gravity of the toy with an "X". [1]

(c) The toy is now pulled to one side by a force F as shown in Fig. 5.2.

(i) Indicate on Fig. 5.2 the position of the centre of gravity of the toy when it is in this position. [1]

(ii) Explain why the toy is able to return to its original position when the force F is removed from the toy.

....

....

.... [2]

- Similar to Assignment AS7.2 Q2

2. Fig. 2.1 shows a cross-section of a child's toy called Tumbling Kelly. The toy consists of a thin plastic egg-shaped shell with a layer of lead fixed at the bottom. The toy is tilted as shown in Fig. 2.2.

Fig. 2.1

Fig. 2.2

(a) Mark the centre of gravity of the toy in Fig. 2.1 and 2.2 with a cross (X)

(b) **(i)** When the toy is released from this tilted position, it rotates. State the direction of its rotation and explain your answer.

....

....

....

(ii) Subsequently, the toy oscillates with decreasing amplitude and finally comes to rest. State the final position of the toy and explain your answer.

....

....

....

....

5 **(a)** State the *Principle of Moments*.

For an object in equilibrium, the sum of the clockwise moments about a point are equal to the sum of the anticlockwise moments about the same point.

POINT CAN BE ANY POINT.

DOESN'T HAVE TO BE A PIVOT!

A toy is designed with a heavy hemispherical lower section joined to a taller, lighter upper section such that it will balance in the position shown in Fig. 5.1 and will return to this position after being pushed to the side as shown in Fig. 5.2.

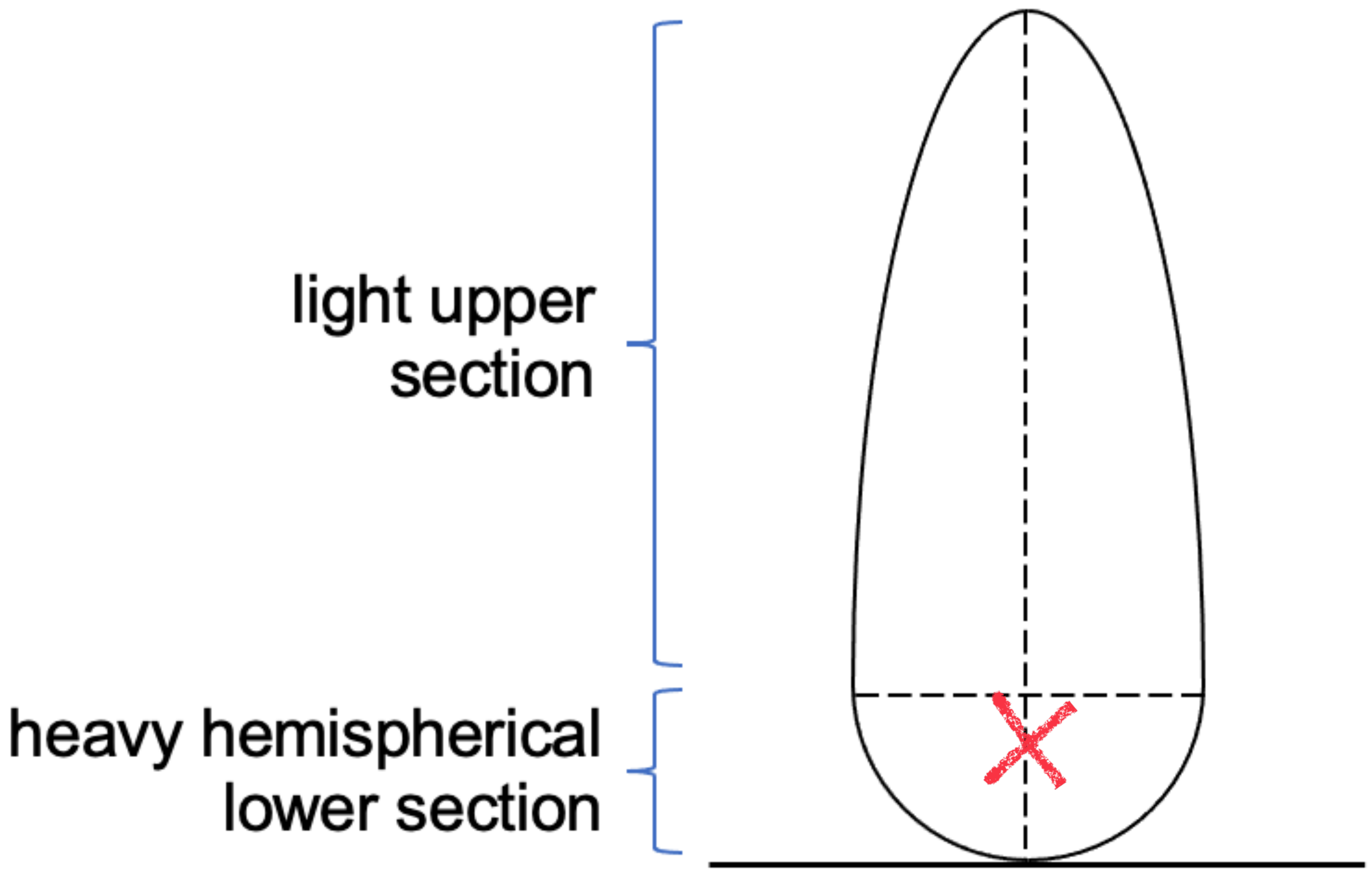


Fig. 5.1

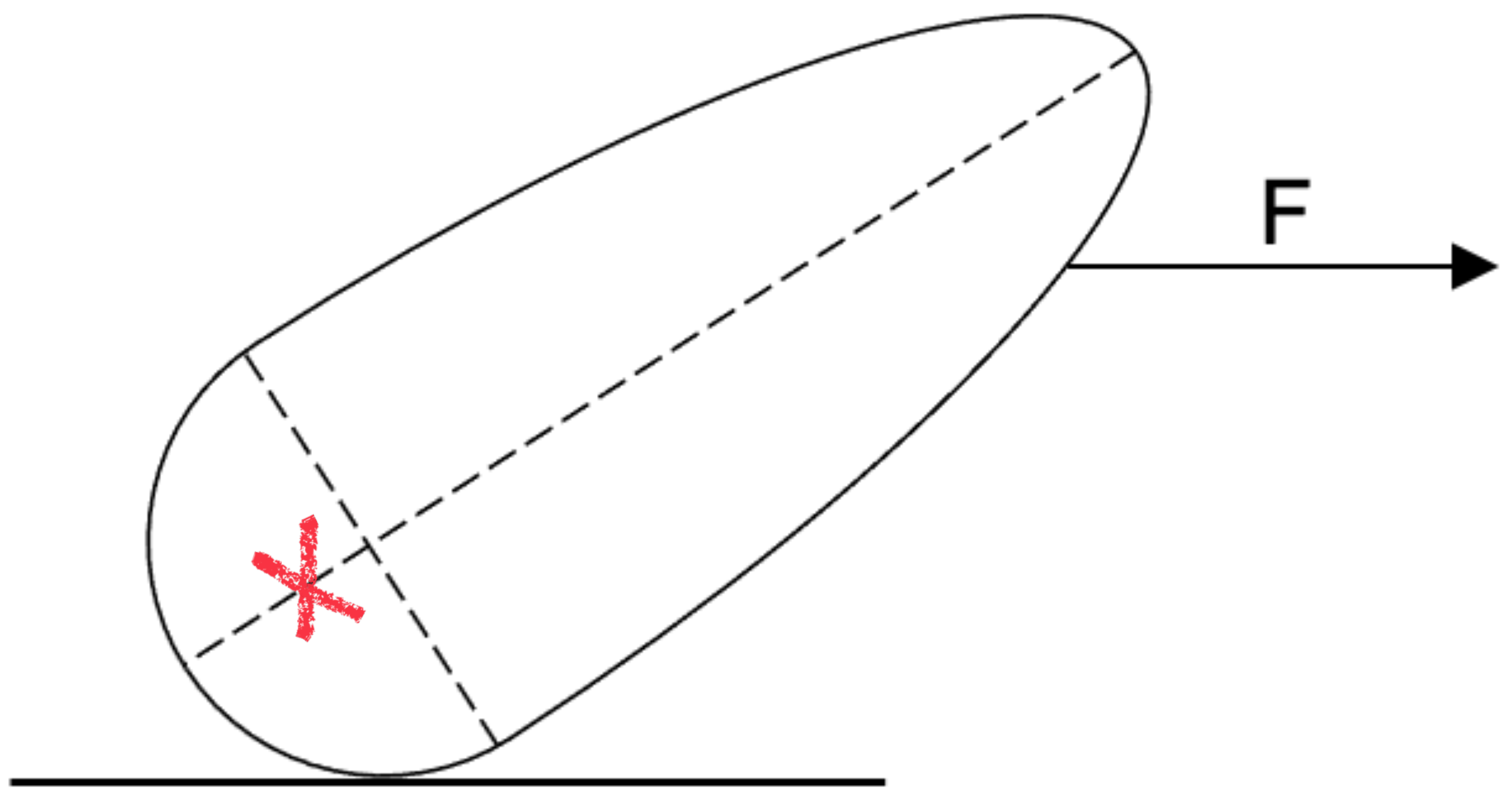


Fig. 5.2

(b) Indicate on Fig. 5.1 the position of the centre of gravity of the toy with an "X". [1]

(c) The toy is now pulled to one side by a force F as shown in Fig. 5.2.

(i) Indicate on Fig. 5.2 the position of the centre of gravity of the toy when it is in this position. [1]

Explain why the toy is able to return to its original position when the force F is removed from the toy.

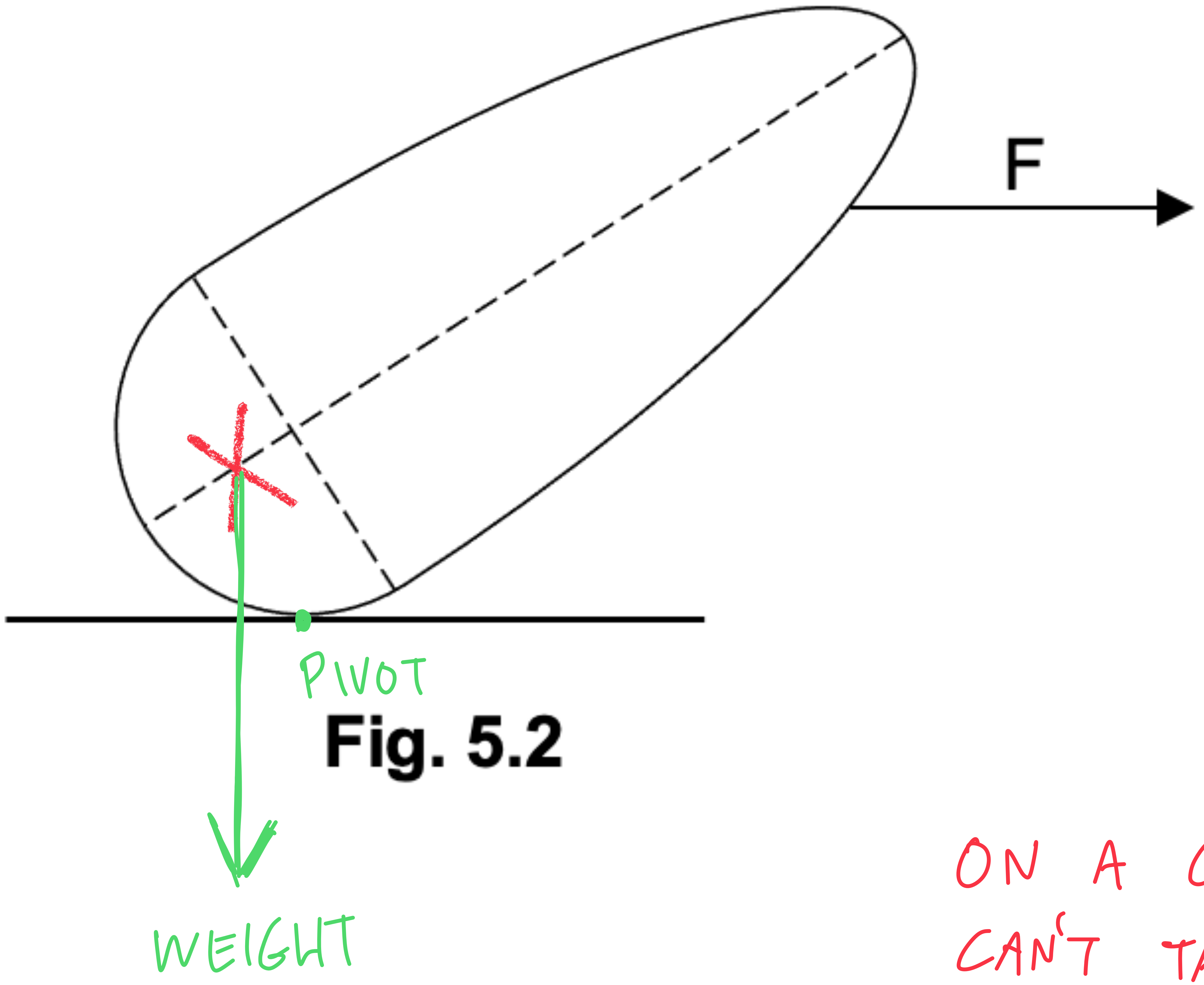


Fig. 5.2

The position of the CoG has moved to the left of the pivot

OR the line of action of the weight force is to the left of the pivot

OR the weight causes a anti-clockwise moment about the pivot

Resulting in a net anticlockwise moment acting on the toy.

ON A CURVED SURFACE WE CAN'T TALK ABOUT THE BASE.
IT IS ONLY IN CONTACT WITH GROUND AT ONE POINT (PIVOT) WHICH CHANGES AS IT ROTATES.

Question 6

6 A uniform ball of radius 50 cm is resting at point P against a step of height 20 cm.
A horizontal force of 25 N is applied to the ball at a height of 80 cm above the ground.

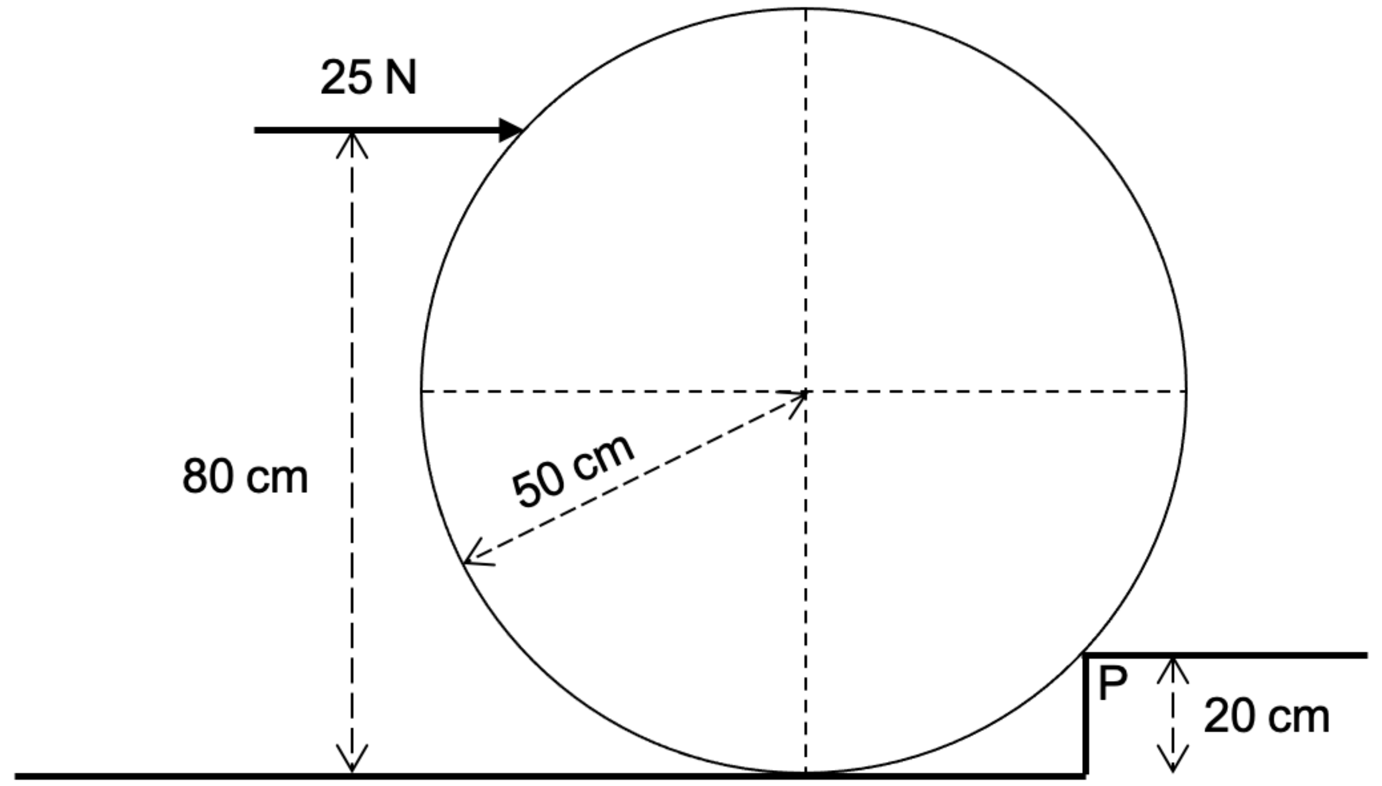


Fig. 6.1

(a) Determine the magnitude and direction of the moment generated by the 25 N force about P.

magnitude = ... [1]

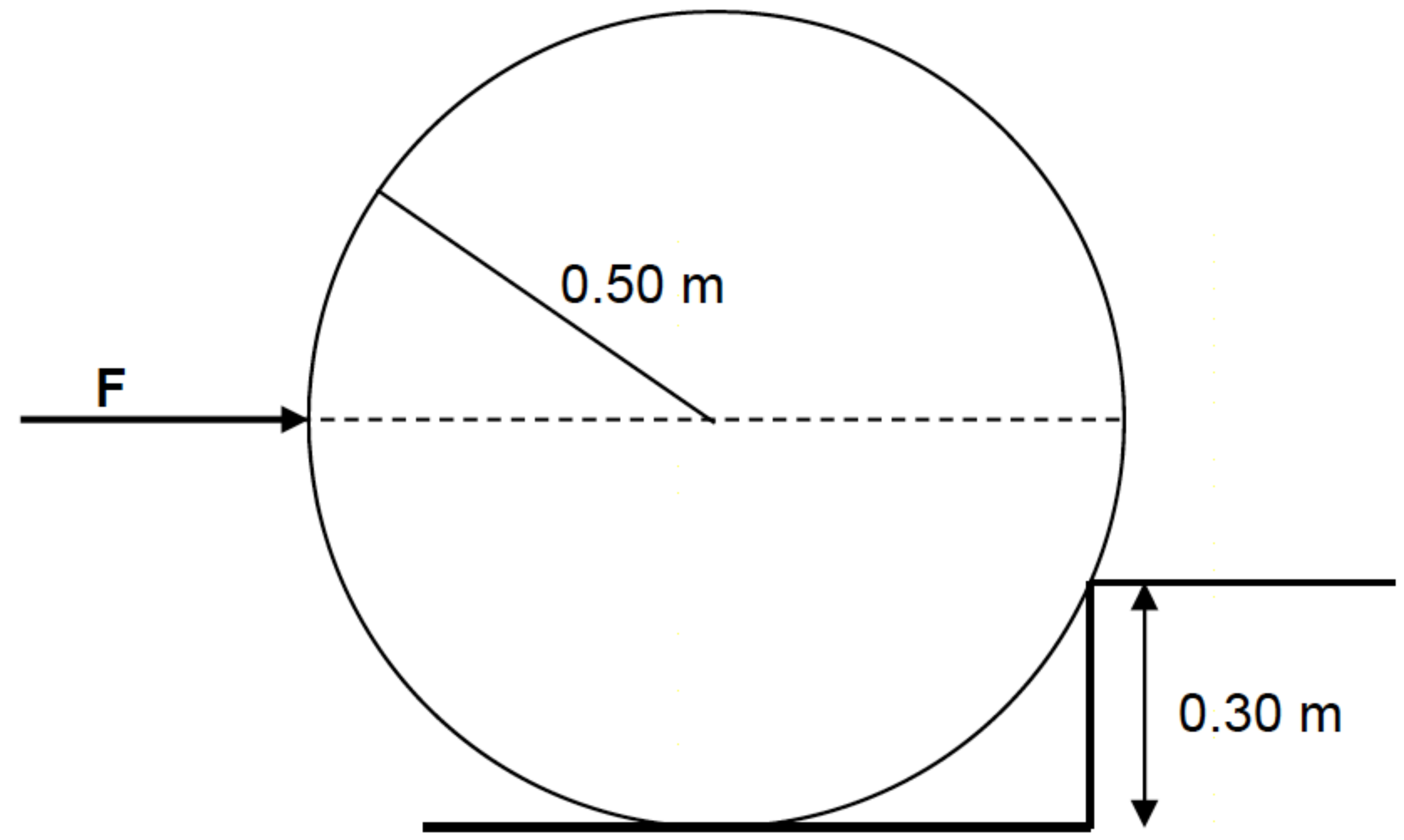
direction = ... [1]

(b) Assuming that the 25 N force is the minimum force required to allow the ball to roll up the step, determine the weight of the ball.

weight = ... [3]

- Similar to Chapter 7 Notes p17

3. A ball, of radius 0.50 m and mass 2.0 kg, is resting against a step of height 0.30 m. A horizontal force, **F**, is applied to the ball at the midpoint as shown below.



(a) Calculate the minimum value of **F** for which the ball will roll up the step?

(b) Explain how it would be possible to get the ball to roll up the step using an initial force less than that calculated in (a).

....

....

....

....

6 A uniform ball of radius 50 cm is resting at point P against a step of height 20 cm.
A horizontal force of 25 N is applied to the ball at a height of 80 cm above the ground.

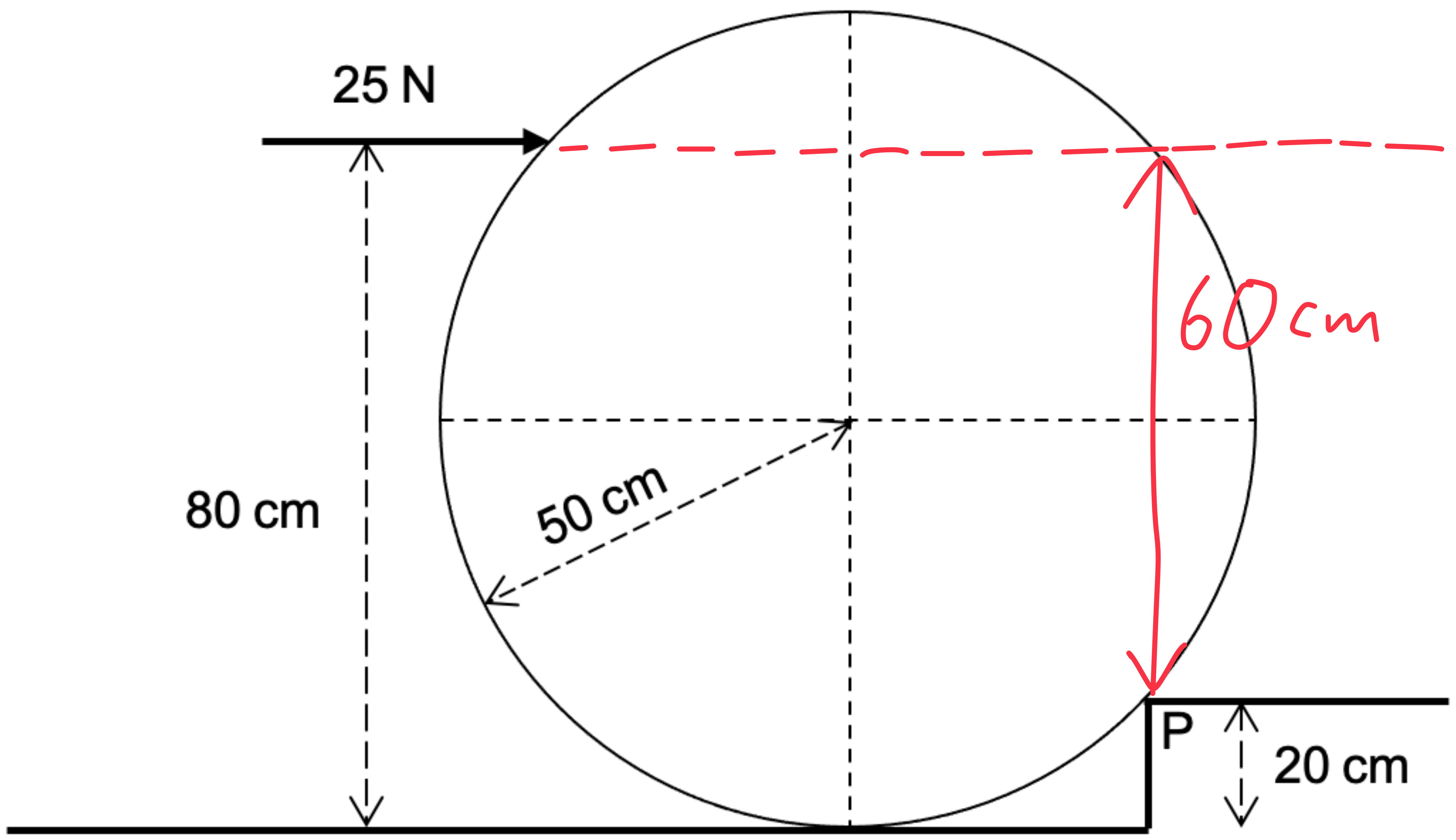


Fig. 6.1

MOMENT ABOUT P

$= F \times d$

$= 25 \times 60$

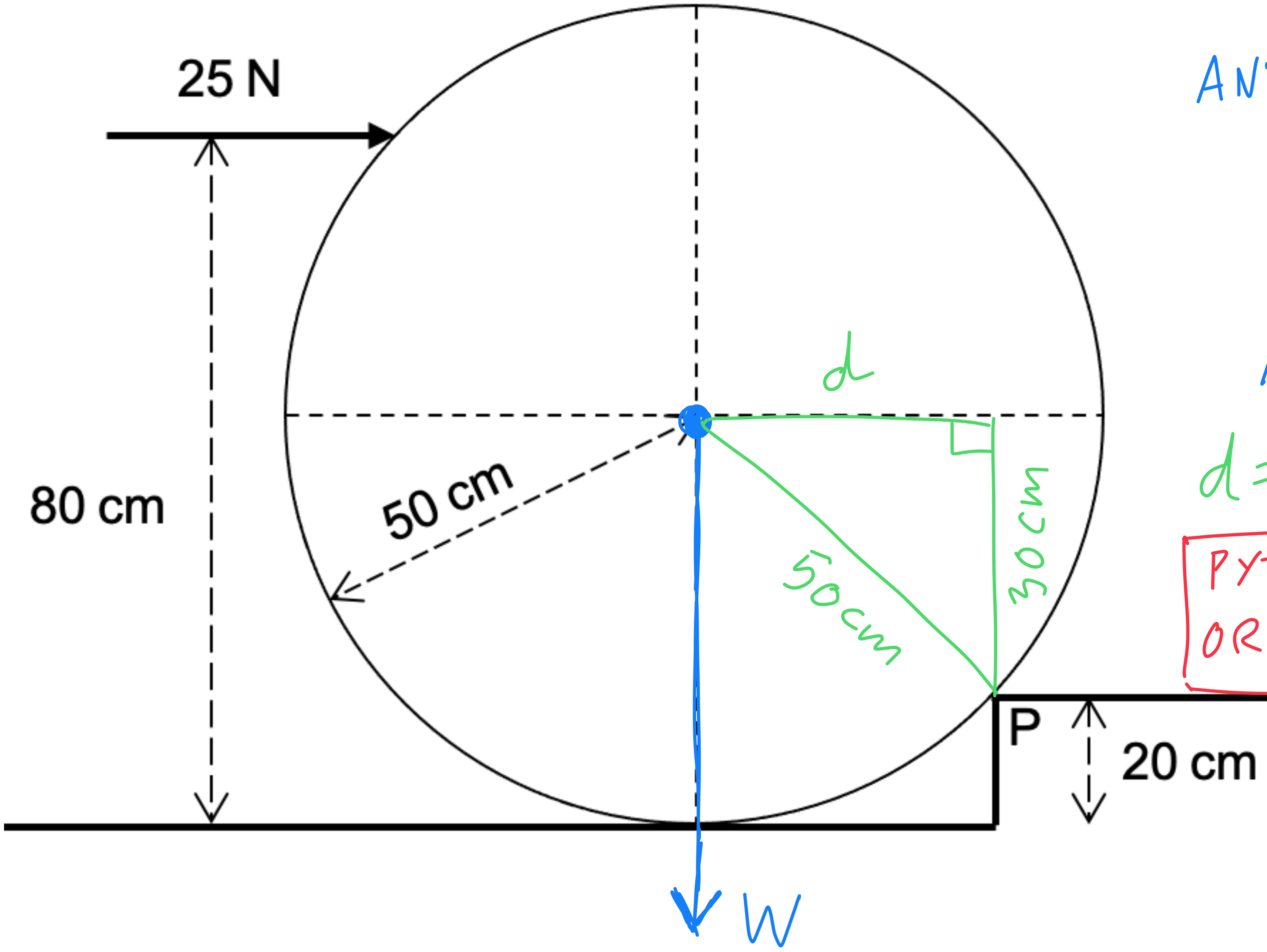
$= 1500$ Ncm

$= 15$ Nm

CLOCKWISE

(a) Determine the magnitude and direction of the moment generated by the 25 N force about P.

(b) Assuming that the 25 N force is the minimum force required to allow the ball to roll up the step, determine the weight of the ball.



TAKING MOMENTS ABOUT P,
LET WEIGHT BE W,
ANTICLOCKWISE MOMENTS

$= F \times d$

$= W \times 40$

APPLYING PRINCIPLE OF MOMENTS

$d = 40\,cm$

PYTHAGORAS Δ OR NOTICING ITS A 3-4-5 Δ

$40W = 1500$

$\Rightarrow W = 37.5\,N$