

Free Body Diagrams

Mark Scheme



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- Free body diagrams simplify complex situations by using arrows to show the exact size and direction of every force acting on a single object.

For each of the following questions **circle** the letter of the correct answer.

- The free body diagram shows the horizontal forces acting on a car.
What is the resultant force acting on the car?

C – is the only correct answer.	1 mark
	Total: 1 mark

- Look at the free body diagram of a book resting on a horizontal desk.

What do the forces represented by arrows X and Y represent?

B – is the only correct answer.	1 mark
	Total: 1 mark

- A rocket has just launched from the launchpad and is accelerating vertically upwards through the sky.
Look at the free body diagram showing the forces acting on the rocket.

Which of the following statements about the arrows is correct?

A – is the only correct answer.	1 mark
	Total: 1 mark

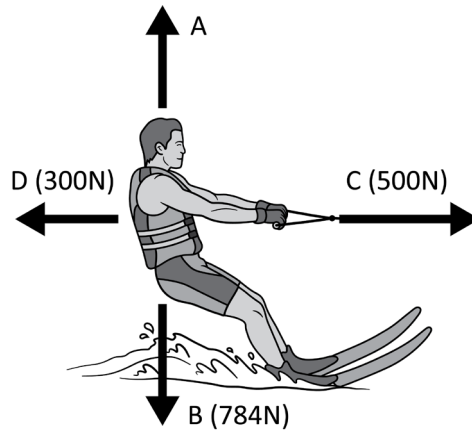
- The free body diagram shows the forces acting on a skydiver falling through the air.
The upward and downward arrows are exactly the same length.

Which statement correctly describes the skydiver's motion?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. A boat is pulling a water skier across a lake.
The diagram shows the free body diagram for the water skier.



- a) Use the detailed picture to help you identify the specific forces labelled A and C on the free body diagram.

Force A = upthrust / normal contact force / reaction force.	1 mark
Force C = tension / pull.	1 mark
	Total: 2 marks

- b) Forces A and B are balanced.
Calculate the magnitude and direction of the resultant force acting on the water skier.

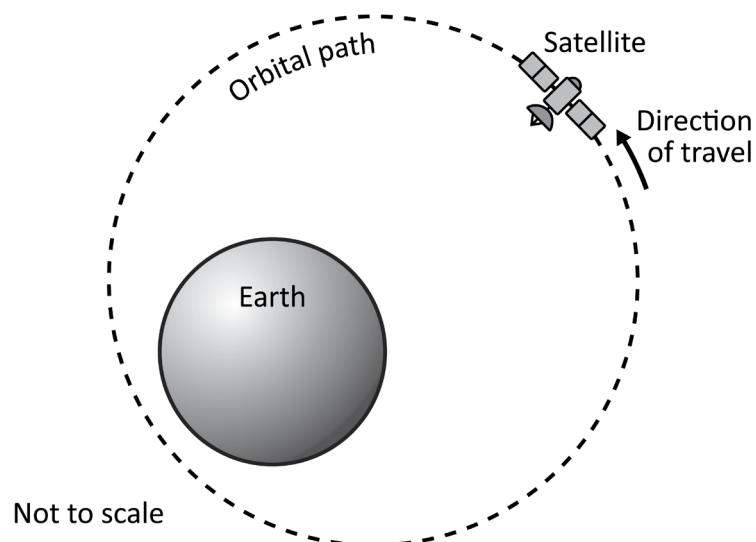
Magnitude = 200	1 mark
Direction = right / forwards	1 mark
	Total: 2 marks

- c) The water skier has a mass of 80 kg.
Calculate the acceleration of the water skier. State the unit of acceleration in your answer.

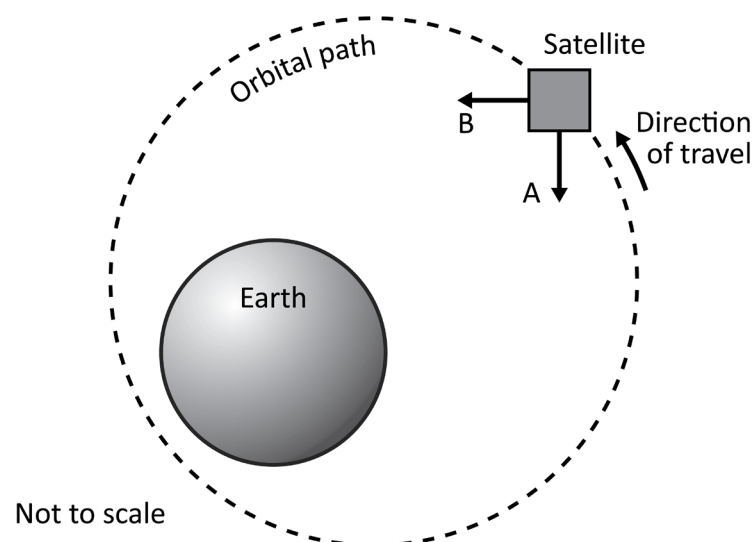
Equation: Resultant force = mass $\times$ acceleration or $F = m \times a$	1 mark
Substitute values: $200 = 80 \times a$	1 mark
Calculate acceleration: $a = 200 \div 80$ $a = 2.5$	1 mark
Unit: m/s^2	1 mark
	Total: 4 marks

(Total for Question 2 is 8 marks)

3. A satellite is moving at a constant speed in a circular orbit around the Earth. Its engines are switched off. The figure below shows the satellite orbiting Earth.



A student is asked to draw a free body diagram for the satellite. Their attempt is shown in the figure below.



- a) State the name of the non-contact force represented by Arrow A.

Gravity / weight / gravitational pull.	1 mark
	Total: 1 mark

- b) The student's free body diagram is **incorrect**. Arrow B should not be there. Explain why there is no forward force acting on the satellite.

An explanation to include:	1 mark
The engines are off, so there is no thrust / driving force.	1 mark
Allow: 1 mark for stating there is no thrust (or no engine force).	
Space is a vacuum (there is no air resistance), so no forward force is needed to keep it moving / to balance friction.	1 mark
Allow: 1 mark for explaining that because there is no drag/friction to overcome, it will keep moving (Newton's first law)	
	Total: 2 marks

- c) The satellite is moving at a constant speed in its circular orbit.

Explain why the satellite is **accelerating**, even though it is moving at a constant speed.

An explanation to include:	
The satellite is constantly changing direction.	1 mark
Allow: 1 mark for mentioning the change in direction.	
Therefore, its velocity is constantly changing (because velocity is a vector / has direction).	1 mark
Allow: 1 mark for linking changing direction to changing velocity.	
(And acceleration is the rate of change of velocity).	1 mark
	Total: 2 marks

- d) The satellite has a mass of 1200 kg. At this high altitude, the gravitational field strength (g) is 8.5 N/kg. Calculate the resultant force acting on the satellite.

Weight = mass $\times$ gravitational field strength $W = m \times g$	1 mark
Calculation: $W = 1200 \times 8.5$ $W = 10,200 \text{ (N)}$	1 mark
	Total: 2 marks

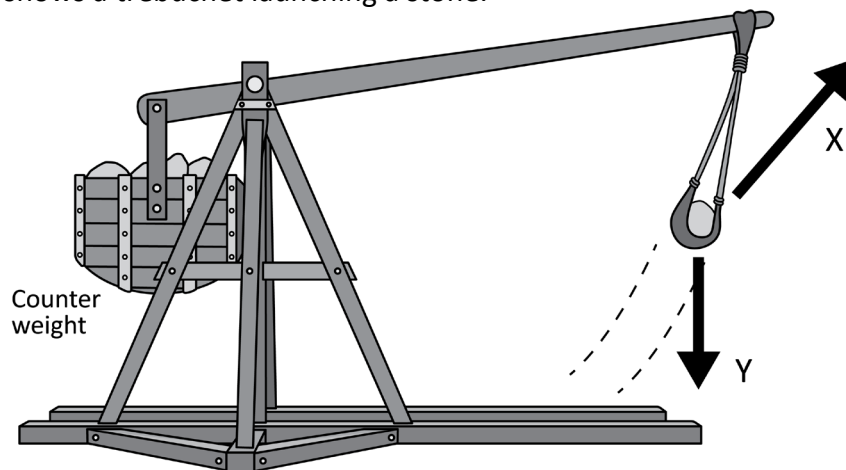
- e) Over many years, the satellite slowly loses altitude and enters the top of the Earth's atmosphere. Describe how the free body diagram of the satellite will change, and explain how this will affect its motion.

A description to include:	
A new force arrow (air resistance / drag / friction) must be added pointing backwards (opposite to the direction of motion).	1 mark
This creates a resultant force acting against the satellite.	1 mark
This causes the satellite to decelerate / slow down.	1 mark
	Total: 3 marks

(Total for Question 3 is 10 marks)

4. Long before the invention of the cannon, the trebuchet was the medieval world's preferred method for aggressively taking down a neighbour's castle.

The figure below shows a trebuchet launching a stone.



- a) Identify the two forces acting on the stone in the figure above.

Force X = tension / pull.	1 mark
Force Y = weight / gravity	1 mark
	Total: 2 marks

- b) The stone has a mass of 90 kg. The gravitational field strength (g) is 9.8 N/kg.

Calculate the size of Force Y.

Recall equation: Weight = mass $\times$ gravitational field strength $W = m \times g$	1 mark
Calculation: $W = 90 \times 9.8$ $W = 882 \text{ (N)}$	1 mark
	Total: 2 marks

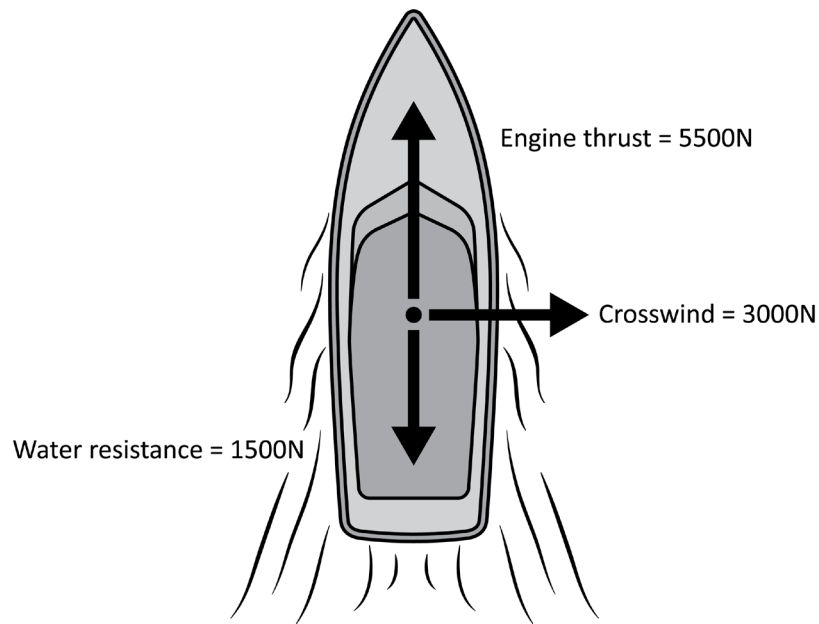
- c) As the stone is moving in the sling the resultant force acting on the stone is 3150 N.

Calculate the acceleration of the stone.

Recall equation: Resultant Force = mass $\times$ acceleration $F = m \times a$	1 mark
Substitute values: $3150 = 90 \times a$	1 mark
Calculate acceleration: $a = 3150 \div 90$ $a = 35$	1 mark
	Total: 3 marks

(Total for Question 4 is 7 marks)

5. The free body diagram shows a plan view of the horizontal forces acting on a speedboat.



The speedboat has a mass of 800 kg.
Calculate the magnitude of the acceleration of the speedboat.

Step 1: Resolve the forces in the vertical/forward direction:	
Resultant forward force = $5500 - 1500 = 4000 \text{ N}$	1 mark
Step 2: Use Pythagoras to find the total resultant force:	
$a^2 + b^2 = c^2$ $4000^2 + 3000^2 = R^2$ $16,000,000 + 9,000,000 = 25,000,000$ $R = \sqrt{25,000,000}$ Total resultant force = 5000 N	1 mark
Step 3: State or use Newton's second law:	
$F = m \times a$	1 mark
Step 4: Substitute the values:	
$5000 = 800 \times a$	1 mark
Calculate the final acceleration:	
$a = 5000 \div 800$ $\text{acceleration} = 6.25 \text{ (m/s}^2\text{)}$	1 mark
	Total: 5 marks

(Total for Question 5 is 5 marks)