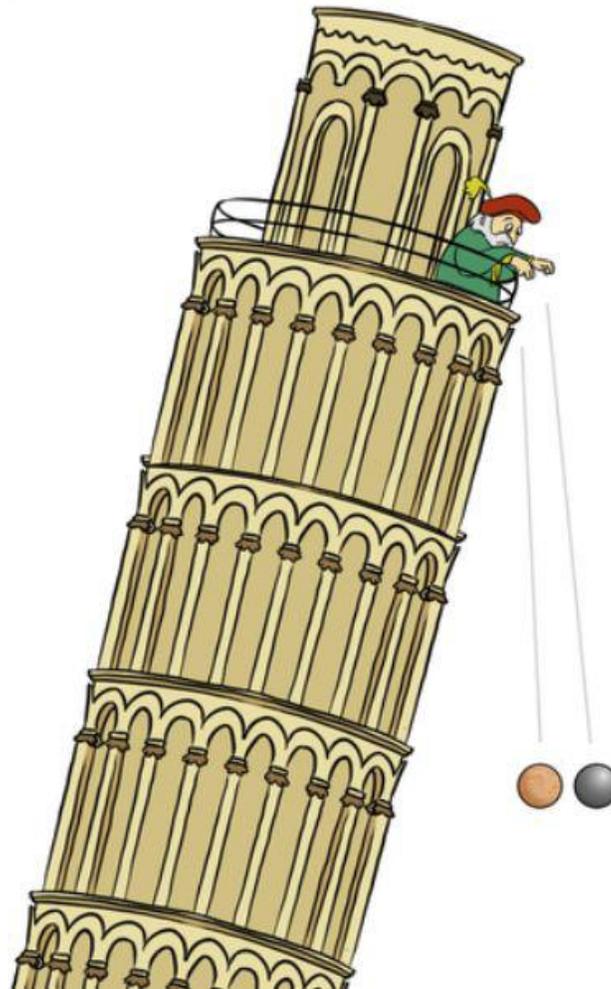


Forces, Momentum and Equilibria



Material Covered

Equilibrium

1. Principle of Moments.
2. Newton's Laws.
3. Equilibria of Systems.

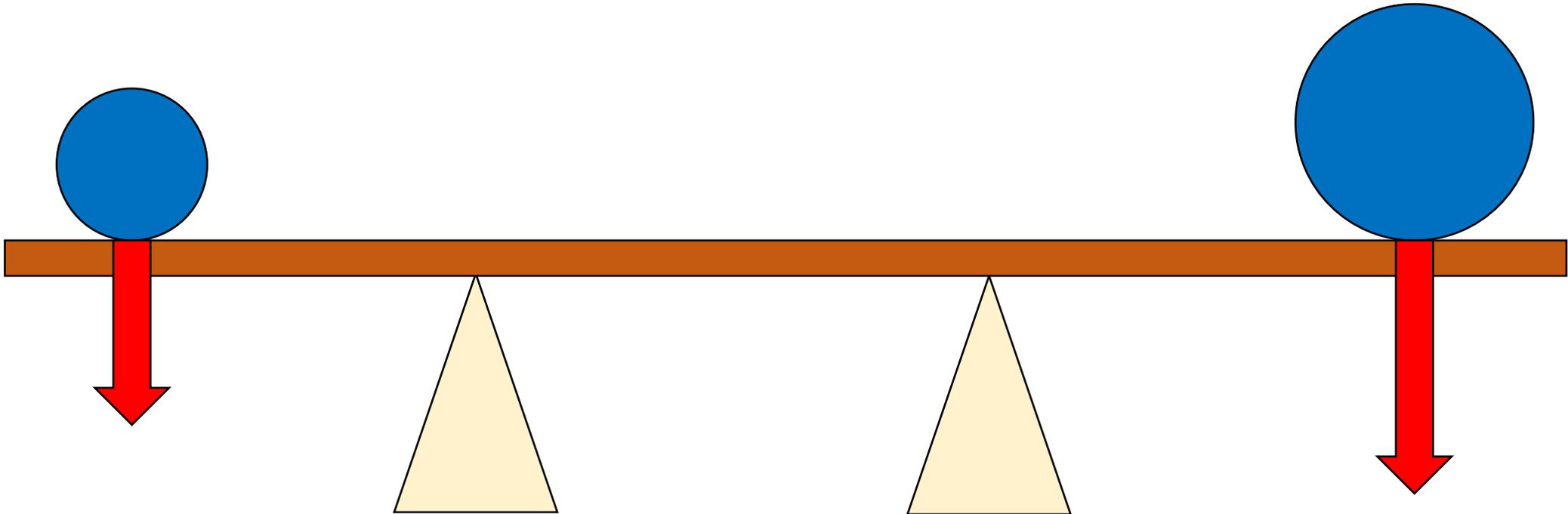
Free Fall and Terminal Velocity

1. Acceleration due to Gravity.
2. Drag Force and Terminal Velocity.

Momentum and Collisions

1. Impulse and Force-Time Graphs.
2. Conservation of Momentum.

Equilibrium



Specification Points - AQA

3.4.1.2 Moments

Content
Moment of a force about a point.
Moment defined as <i>force</i> \times <i>perpendicular distance from the point to the line of action of the force</i> .
Couple as a pair of equal and opposite coplanar forces.
Moment of couple defined as <i>force</i> \times <i>perpendicular distance between the lines of action of the forces</i> .
Principle of moments.
Centre of mass.
Knowledge that the position of the centre of mass of uniform regular solid is at its centre.
Conditions for equilibrium for two or three coplanar forces acting at a point. Appreciation of the meaning of equilibrium in the context of an object at rest or moving with constant velocity.

3.4.1.5 Newton's laws of motion

Content	Opportunities for skills development
<p>Knowledge and application of the three laws of motion in appropriate situations.</p> <p>$F = ma$ for situations where the mass is constant.</p>	<p>PS 4.1 / MS 0.5, 3.2 / AT a, b, d</p> <p>Students can verify Newton's second law of motion.</p> <p>MS 4.1, 4.2</p> <p>Students can use free-body diagrams.</p>

Specification Points – OCR A

3.2.1 Dynamics

Learning outcomes	Additional guidance
<i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i>	
(a) net force = mass \times acceleration; $F = ma$	Learners will also be expected to recall this equation. <i>M1.1</i>
(b) the newton as the unit of force	
(c) weight of an object; $W = mg$	Learners will also be expected to recall this equation.
(d) the terms tension, normal contact force, upthrust and friction	
(e) free-body diagrams	
(f) one- and two-dimensional motion under constant force.	

3.2.3 Equilibrium

Learning outcomes
<i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i>
(a) moment of force
(b) couple; torque of a couple
(c) the principle of moments
(d) centre of mass; centre of gravity; experimental determination of centre of gravity
(e) equilibrium of an object under the action of forces and torques
(f) condition for equilibrium of three coplanar forces; triangle of forces.

Specification Points – OCR B

Learning outcomes

(a) *Describe and explain:*

(iii) the independent effect of perpendicular components of a force

(viii) Newton's laws of motion

(b) *Make appropriate use of:*

(i) the terms: displacement, speed, velocity, acceleration, force, mass, vector, scalar, work, energy, power, momentum, impulse

(c) *Make calculations and estimates involving:*

(i) the resolution of a vector into two components at right angles to each other

(ii) the addition of two vectors, graphically and algebraically

Specification Points - Edexcel

16. be able to draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body

17. be able to use the equation $\sum F = ma$, and understand how to use this equation in situations where m is constant (Newton's second law of motion), including Newton's first law of motion where $a = 0$, objects at rest or travelling at constant velocity

Use of the term terminal velocity is expected

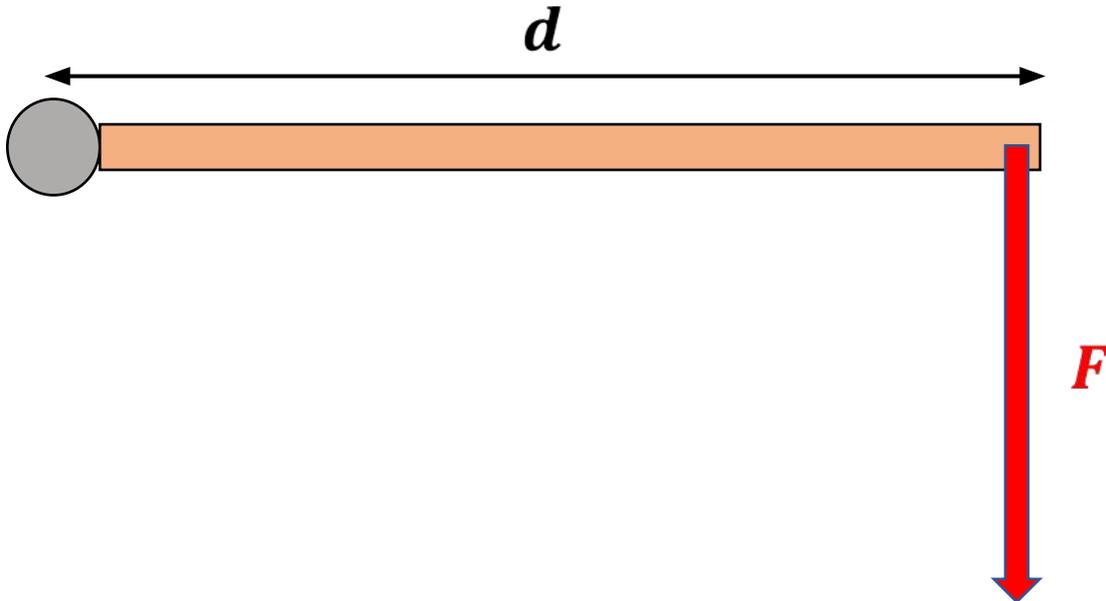
20. know and understand Newton's third law of motion and know the properties of pairs of forces in an interaction between two bodies

23. be able to use the equation for the moment of a force, moment of force = Fx where x is the perpendicular distance between the line of action of the force and the axis of rotation

24. be able to use the concept of centre of gravity of an extended body and apply the principle of moments to an extended body in equilibrium

Principle of Moments

The **moment** of a **force** about a **point** is **equal** to the **product** of the **force** and the **perpendicular distance** from the **line of action** of the **force** to the **point**.

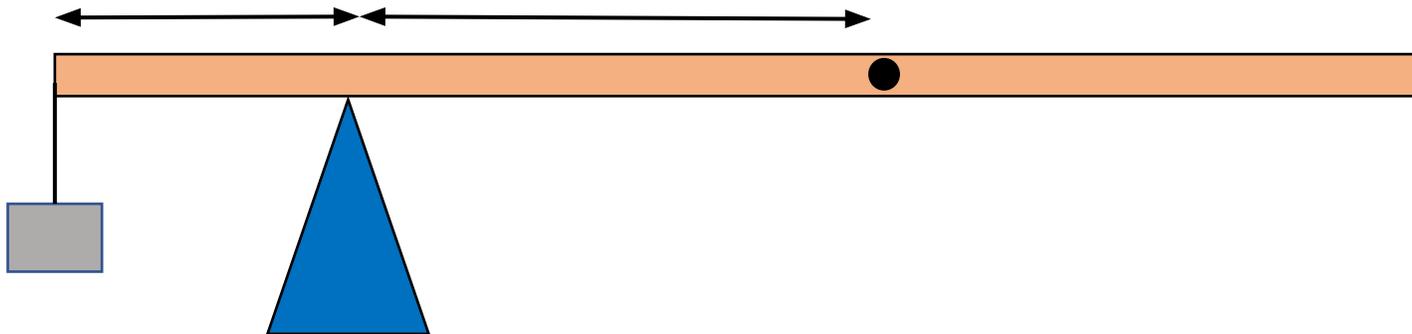


$$\text{Moment} = Fd(\times \sin \theta)$$

Principle of Moments

The **principle of moments** states that for a **body in equilibrium**, the **sum of the clockwise moments** about any **point** is **equal** to the **sum of the anticlockwise moments** about the **same point**.

- The **centre of mass** of an object is the **point** around which its **weight** is **assumed to act from**



Exemplar Calculation Exam Question

Key numerical values of variables which may be **required** for the **calculation**.

Calculation Question: Mathematical question – we need to show our working.

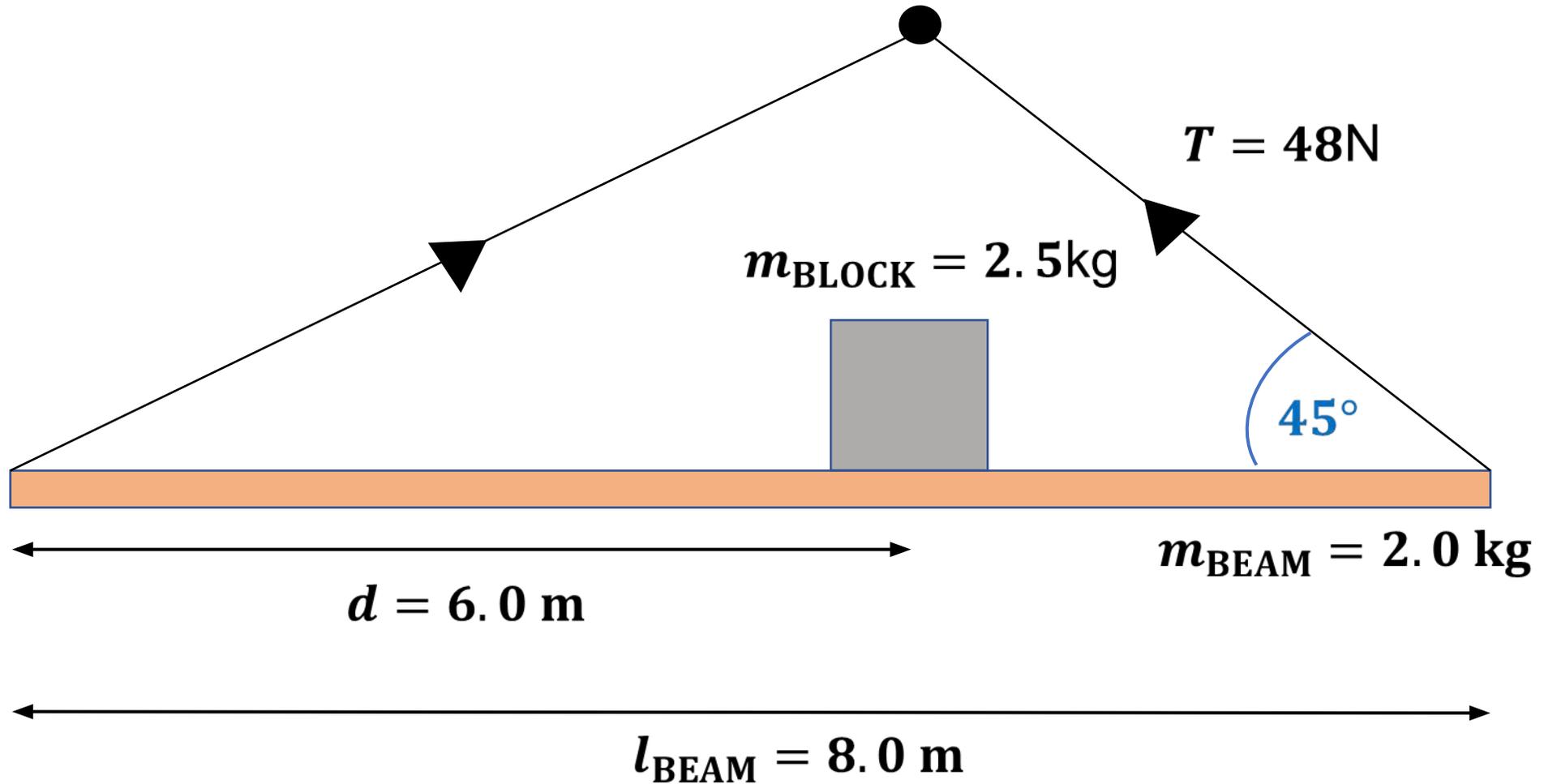
- 1) Consider the following diagram showing an **8.0 m** long **2.0 kg** irregular beam, supporting a **2.5 kg** block, suspended by two taut strings from a support. The tension in the righthand string is **48 N**. The system is in equilibrium. Determine the position of the centre of mass of the beam in the diagram.

[3 marks]

Answer should be a distance from some reference point with **units of metres (m)**.

Context: System in **equilibrium**. Apply the **principle of moments**.

Indicates that there will be about **3 steps** to our **calculation**. Any less and we may have missed something.



Exemplar Calculation Question Answer

Select point about which to take moments

Take moments around left edge of beam.

Sum clockwise moments around left edge.

$$\begin{aligned}\cup \text{Moments} &= m_{\text{BEAM}}g \times \text{CoM}_{\text{BEAM}} + m_{\text{BLOCK}}g \times d \\ &= 2.0 \times 9.81 \times \text{CoM}_{\text{BEAM}} + 2.5 \times 9.81 \times 6.0 \\ &= 19.62 \times \text{CoM}_{\text{BEAM}} + 147.15 \quad \quad \quad [1 \text{ Mark}]\end{aligned}$$

Exemplar Calculation Question Answer

Sum anticlockwise moments around left edge.

$$\cup \text{Moments} = T \times l_{\text{BEAM}} \times \sin 45^\circ = 48 \times 8.0 \times \sin 45^\circ = 271.5 \text{ N}$$

Apply the principle of moments.

[1 Mark]

$$\cup \text{Moments} = \cup \text{Moments} \Rightarrow 19.62 \times \text{CoM}_{\text{BEAM}} + 147.15 = 271.5$$

Solve for answer.

$$\text{CoM}_{\text{BEAM}} = 6.3 \text{ m from left edge}$$

Remember the units.

Give answer to 2 s.f.

[1 Mark]

Newton's Laws

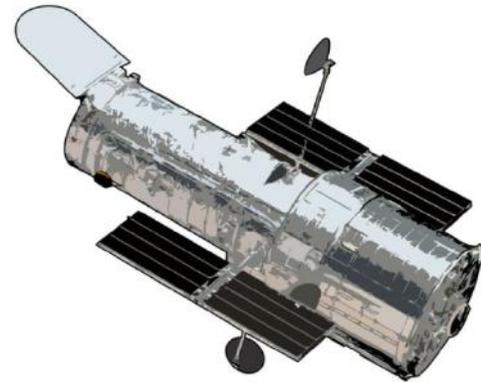
Newton's 1st Law:

An **object** at rest or moving at constant velocity will remain so unless acted upon by a **resultant force**.

Newton's 2nd Law:

The **resultant force** on an **object** is equal to the **product** of its **mass** and **acceleration**.

$$F = ma$$



Newton's Laws

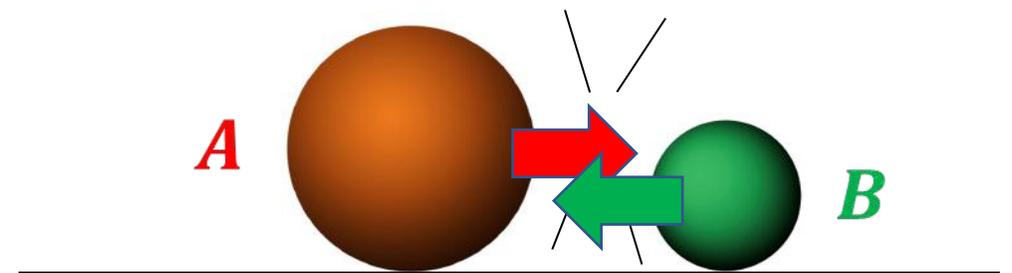
Newton's 3rd Law:

Consider two objects, *A* and *B*. If *A* exerts a force on *B*, *B* will exert a force of the same type of equal magnitude in the opposite direction on *A*.



An apple
gravitationally
attracts the
Earth.

In a **collision** the same
force acts on each **object**.



Exemplar Explanation Exam Question

Explanation Question: Bullet-point format.

- 1) A space probe is travelling to Mars at a constant velocity. Upon approaching its destination, the probe ejects its fuel tank backwards. Describe and explain, with reference to Newton's Laws, how the probe's motion is affected by ejecting the fuel tank.

[2 marks]

Context: Newton's Laws (Forces). Identify which of the **laws** applies.

Indicates that we will need to mention about **2 points**.

Need to reference **forces** with each **point**.

-
- On ejection, by Newton's Third Law, fuel tank exerts a force on the probe equal and opposite to the force that the probe exerts on the fuel tank. **[1 Mark]**
-

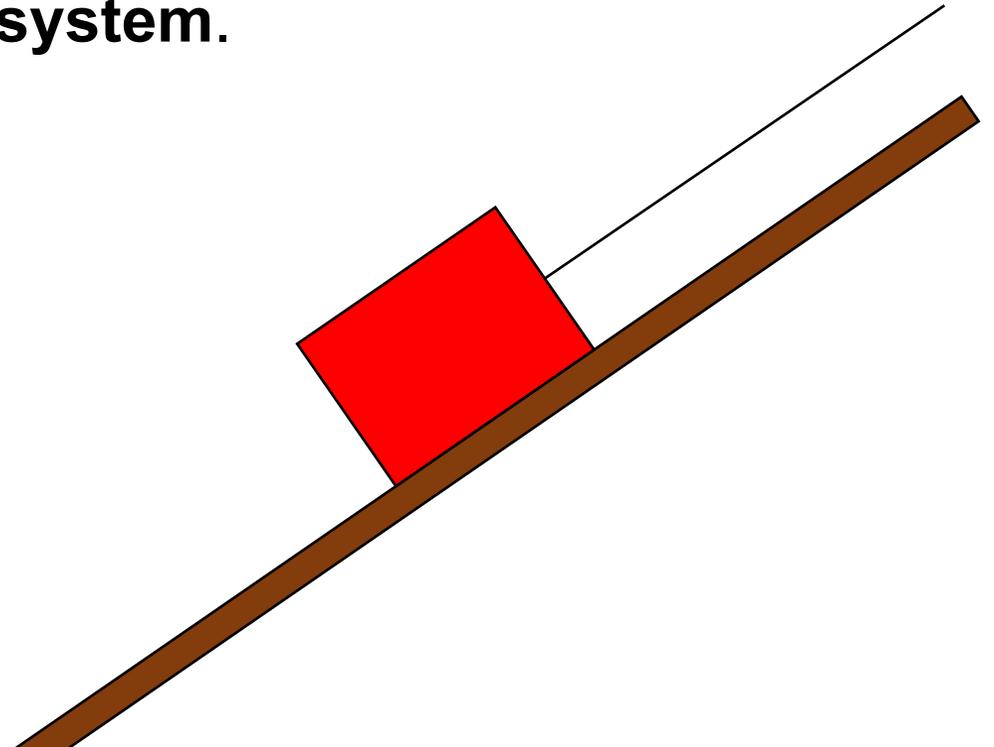
-
- By Newton's Second Law, the probe accelerates forwards as the engine is ejected at a rate proportional to the resultant force. **[1 Mark]**
-
-
-

Equilibria of Systems

A **system** is said to be in **equilibrium** if:

- There is no **resultant force** acting on the **system**.
- There is no **resultant moment** acting on the **system**.

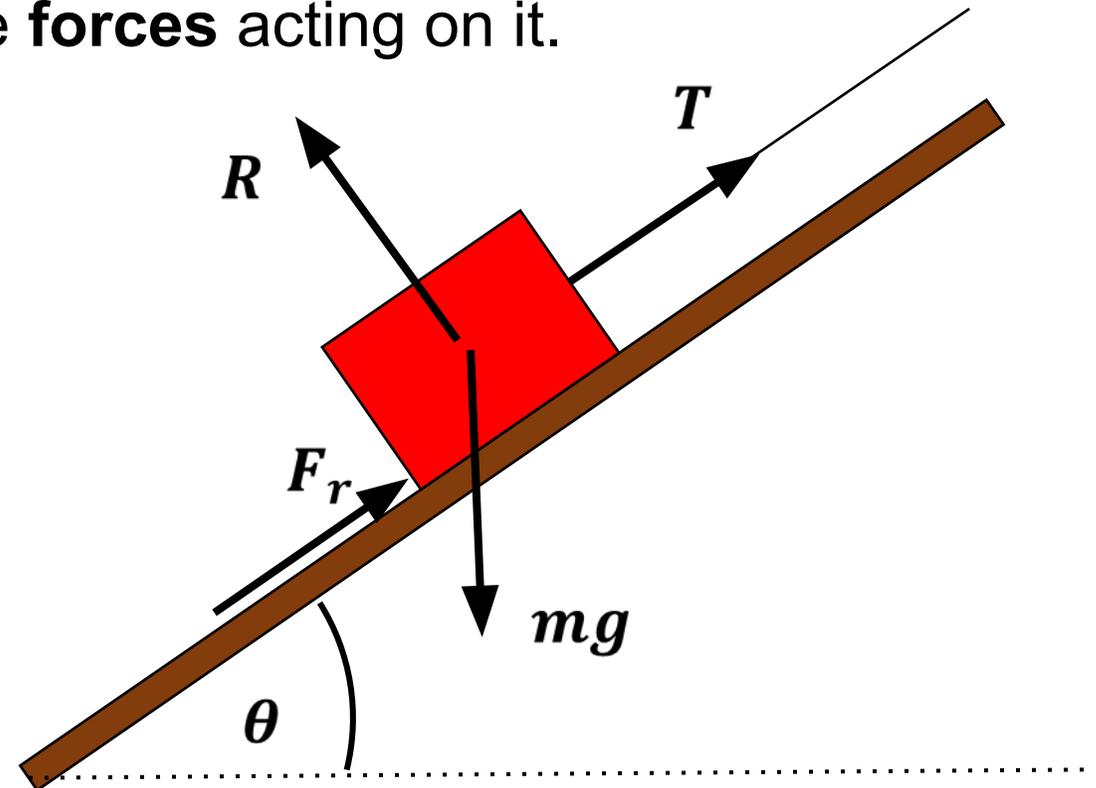
We can use the fact that a **system** is in **equilibrium** to determine the **forces** acting by **balancing forces** in each **direction** and applying the **principle of moments** around different **points**.



Equilibria of Systems

For an object **at rest** on a **slope** we can **resolve forces parallel** to and **perpendicular** to the **slope** to **determine the forces** acting on it.

- **Parallel to slope:**
- **Perpendicular to slope:**



Exemplar Calculation Exam Question

Context: Resolving forces.

Key values we will need.

- 1) A uniform shelf of mass **4 kg** is attached to a wall by a hinge at the point of contact and by a supporting cord of length **1 m** at its far end, which makes an angle of **60°** to the horizontal. There is a normal contact force at the hinge which has an unknown vertical and horizontal component. The shelf is in equilibrium. Calculate the total magnitude of the contact force in the hinge.

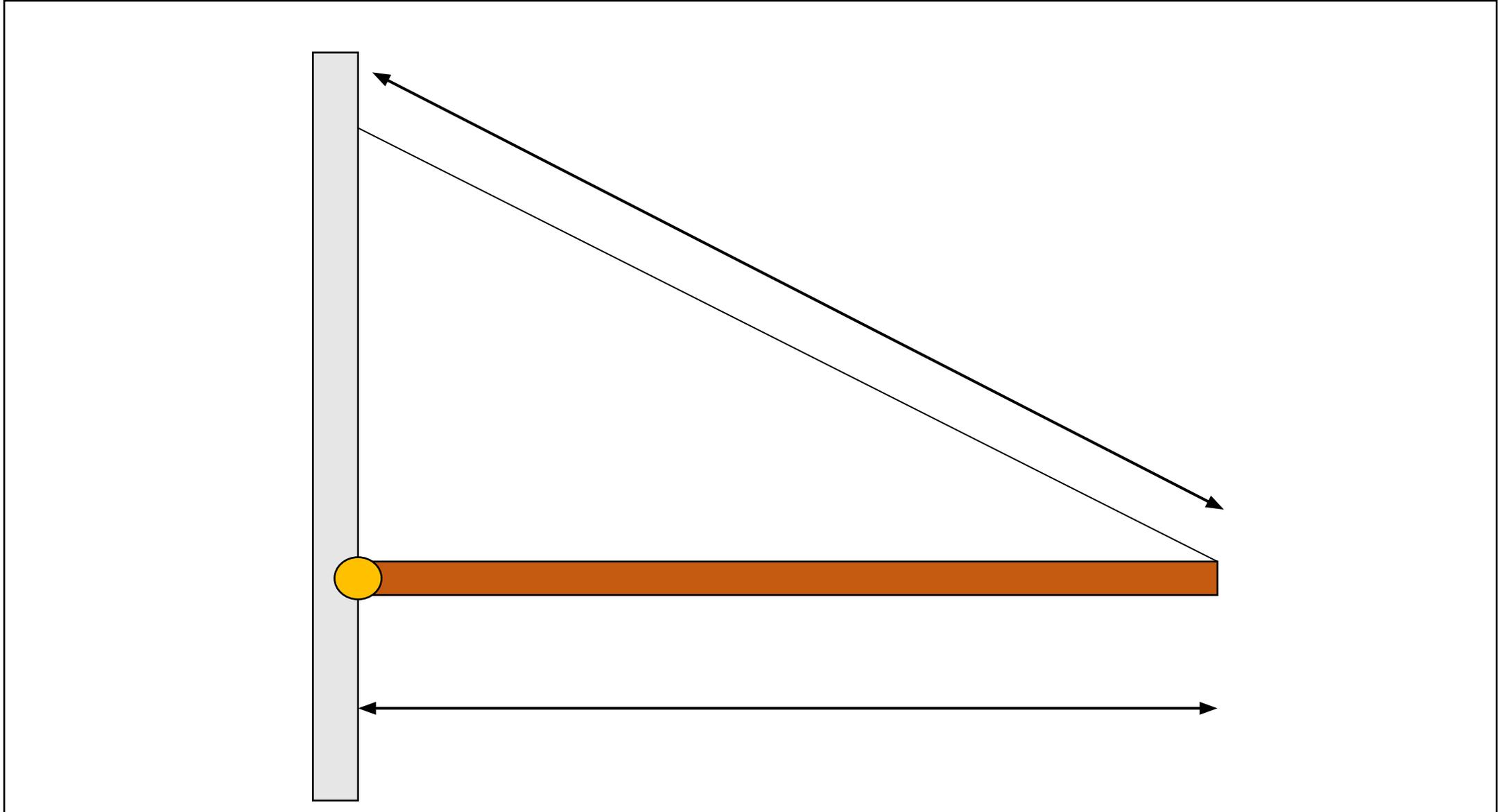
[4 marks]

Calculation Question:

Mathematical question – we need to show our working.

Require **answer** in **Newtons**.

Indicates that there will be about **4 steps** to our **calculation**. Any less and we may have missed something.



Exemplar Calculation Question Answer

Take moments around hinge

System in equilibrium, so clockwise and counter-clockwise moments from hinge are equal

$$\frac{L}{2}mg = LT \sin 60$$

$$T = \frac{Lmg}{2L \sin 60} = \frac{mg}{2 \sin 60} = \frac{4 \times 9.81}{2 \times \frac{\sqrt{3}}{2}} = 22.66 \dots \text{ N}$$

[1 Mark]

Exemplar Calculation Question Answer

Balance horizontal forces

$$R_H = T \cos 60$$

$$R_H = 22.66 \dots \times 0.5 = 11.33 \dots \text{ N}$$

[1 Mark]

Balance vertical forces

$$R_V + T \sin 60 = mg$$

$$R_V = 4 \times 9.81 - 22.66 \dots \times \sin 60$$

$$R_V = 19.62 \dots \text{ N}$$

[1 Mark]

Exemplar Calculation Question Answer

Find magnitude of force

Using Pythagoras

$$R = \sqrt{R_H^2 + R_V^2}$$

$$R = \sqrt{11.33\dots^2 + 19.62\dots^2}$$

$$R = 22.7 \text{ N}$$

[1 Mark]

Free Fall and Terminal Velocity



Specification Points - AQA

3.4.1.4 Projectile motion

Content	Opportunities for skills development
<p>Independent effect of motion in horizontal and vertical directions of a uniform gravitational field. Problems will be solvable using the equations of uniform acceleration.</p> <p>Qualitative treatment of friction.</p> <p>Distinctions between static and dynamic friction will not be tested.</p> <p>Qualitative treatment of lift and drag forces.</p> <p>Terminal speed.</p> <p>Knowledge that air resistance increases with speed.</p> <p>Qualitative understanding of the effect of air resistance on the trajectory of a projectile and on the factors that affect the maximum speed of a vehicle.</p>	<p>PS 2.2, 3.1</p> <p>Investigation of the factors that determine the motion of an object through a fluid.</p>

Specification Points – OCR A

3.2.2 Motion with non-uniform acceleration

Learning outcomes	Additional guidance
<p><i>Learners should be able to demonstrate and apply their knowledge and understanding of:</i></p>	
<p>(a) drag as the frictional force experienced by an object travelling through a fluid</p>	
<p>(b) factors affecting drag for an object travelling through air</p>	<p>HSW6</p>
<p>(c) motion of objects falling in a uniform gravitational field in the presence of drag</p>	<p>HSW9</p>
<p>(d) (i) terminal velocity</p>	<p>HSW1, 5</p>
<p>(ii) techniques and procedures used to determine terminal velocity in fluids.</p>	<p>PAG1 e.g. ball-bearing in a viscous liquid or cones in air. HSW4 Investigating factors affecting terminal velocity.</p>

Specification Points – OCR B

(b) *Make appropriate use of:*

- (i)** the terms: displacement, speed, velocity, acceleration, force, mass, vector, scalar, work, energy, power, momentum, impulse

(c) *Make calculations and estimates involving:*

(viii) kinetic energy = $\frac{1}{2}mv^2$

(ix) gravitational potential energy = mgh

(d) *Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*

- (ii)** determining the acceleration of free fall, using trapdoor and electromagnet arrangement, lightgates or video technique
- (iii)** investigating terminal velocity with experiments such as dropping a ball-bearing in a viscous liquid or dropping paper cones in air.

Specification Points - Edexcel

17. be able to use the equation $\sum F = ma$, and understand how to use this equation in situations where m is constant (Newton's second law of motion), including Newton's first law of motion where $a = 0$, objects at rest or travelling at constant velocity

Use of the term terminal velocity is expected

18. be able to use the equations for gravitational field strength $g = \frac{F}{m}$ and weight

$$W = mg$$

19. **CORE PRACTICAL 1: Determine the acceleration of a freely-falling object.**

Acceleration due to Gravity

- All **objects** (neglecting air resistance) **fall** at a **constant rate** in a **gravitational field** regardless of their **mass**.
- **Galileo** showed that this was true by **timing** the **descent** of **cannonballs** rolling down **ramps**.
- This **constant rate** is the **acceleration due to gravity** (g) which on the surface of **Earth** is taken to be:

$$g = 9.81\text{ms}^{-2}$$

Acceleration due to Gravity

We can **demonstrate** the **principle of constant acceleration** due to **gravity** for all **objects** regardless of **mass** by **resolving a force diagram** for a **falling object** using **Newton's 2nd Law**.



Exemplar Experimental Analysis Exam Question

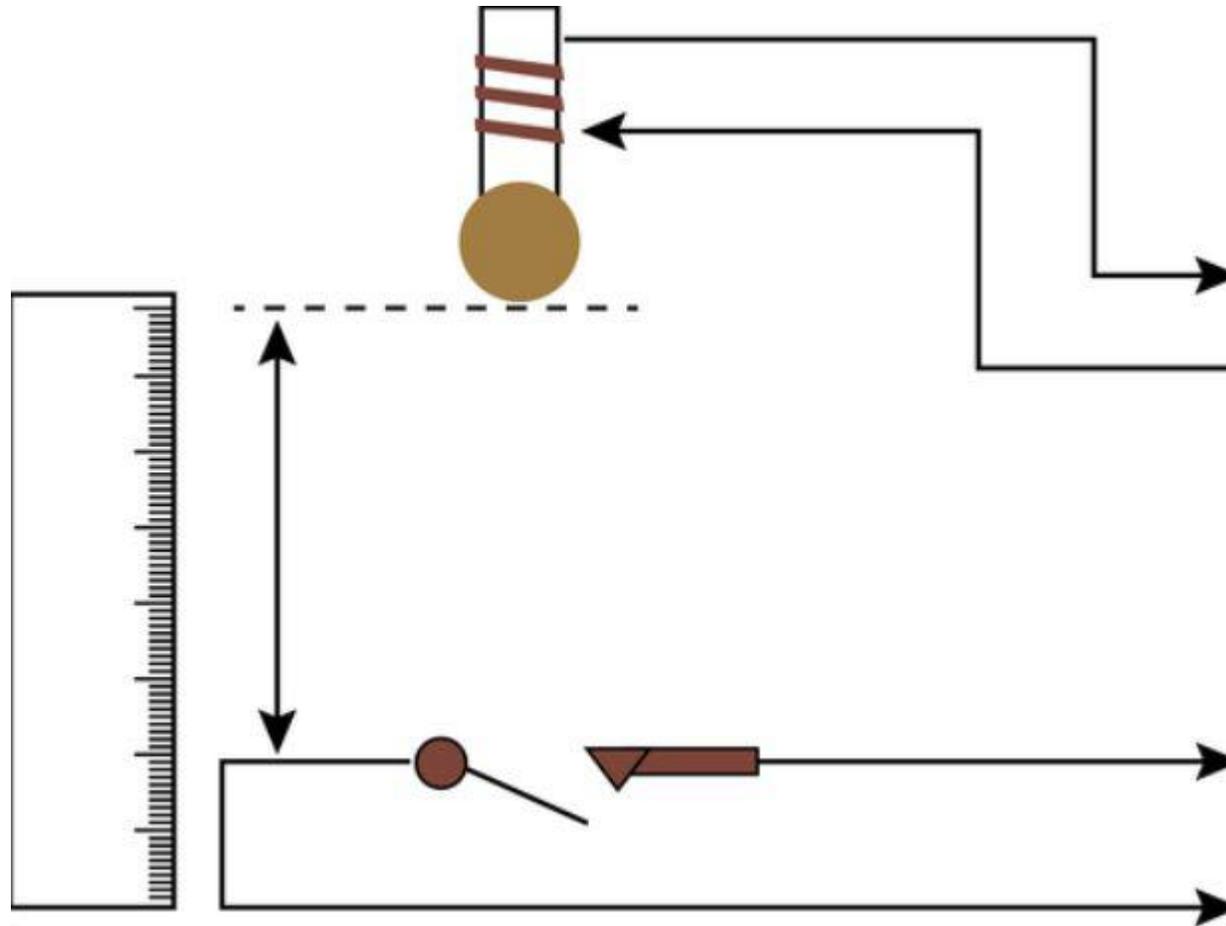
Experimental Analysis Question: Draw a diagram
which is **neat** and **easy** for the examiner to interpret.

- 1) Plan an experiment to measure the acceleration due to gravity.
[4 marks]

Context: Acceleration due to **gravity** (free fall).

Detail **measurements** to take and **apparatus**.

Marks for diagram, setup and analysis.



- Drop small ball for which we can neglect air resistance from height. **[1 Mark]**

- Measure height using metre rule and measure time using stopwatch/timer. **[1 Mark]**

- Use stroboscope which flashes periodically and camera to measure position of ball against metre rule background.

OR **[1 Mark]**

- Have ball fall from electromagnet onto trapdoor which breaks timer switch. **[1 Mark]**

-
- Plot graph of distance against time squared and measure acceleration due to gravity from gradient of graph.
-

OR

[1 Mark]

-
- Use equation $s = \frac{1}{2}gt^2$ to determine g .
-

[1 Mark]

Drag Force and Terminal Velocity

Often we **cannot neglect** the **effect** of **air resistance** on a **falling object**.

- **Drag** is a **resistive force** acting on an **object moving** through a **fluid**.

The **magnitude** of the **drag force** (D) depends on:

- The **object's cross-sectional area** and **shape**.
- The **object's speed**.
- The **fluid's viscosity**.



- As an object **accelerates** under a **driving force** its **velocity increases**.
- Therefore the **drag force** on the object also **increases**.
- Eventually the **drag force balances** the **driving force**. The object is now in **equilibrium**.
- According to **Newton's first law** the object stops **accelerating**. It has reached its **terminal velocity**.



An **object at rest** or **moving at constant velocity** will remain so unless acted upon by a **resultant force**.

Exemplar Explanation Exam Question

Context: Terminal velocity.

Explanation Question: Bullet-point format.

- 1) A parachutist jumps from an airplane. After they have reached terminal velocity, the parachutist pulls their parachute. Describe and explain, with reference to the forces acting on the parachutist, the motion of the parachutist falling under gravity before and after they deploy their parachute.

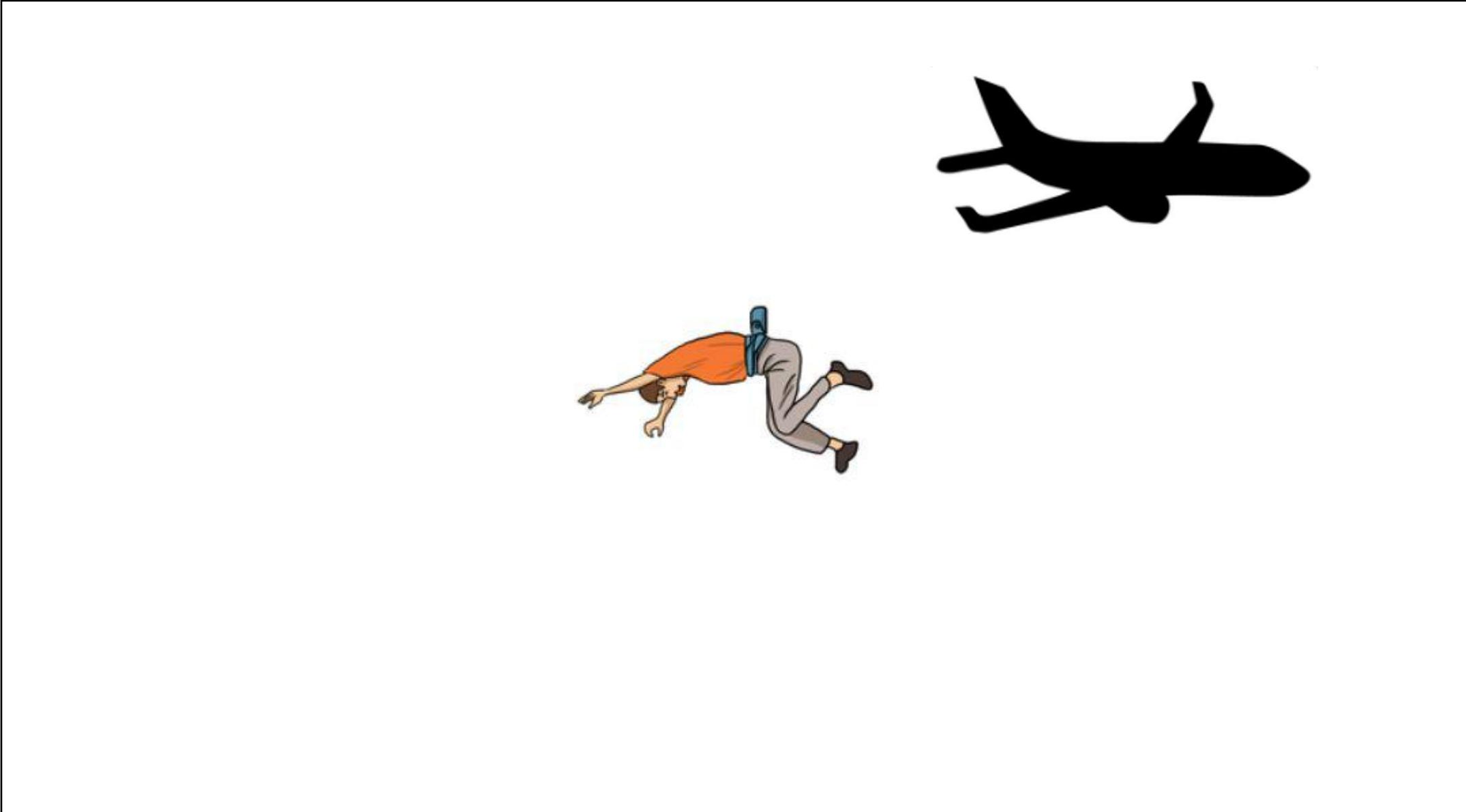
[5

Each **point** should **reference** a **change** in **motion**. **marks]**

Need to reference **forces** (e.g: **weight**, **drag**) with each **point**.

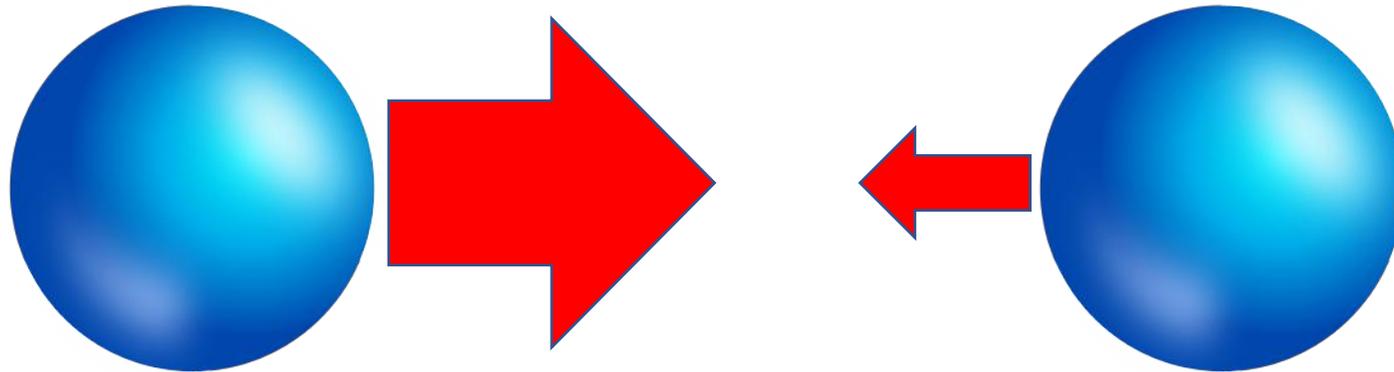
Indicates that we will need to mention about **5 points**.

Include both for full marks!



- The parachutist jumps out of the plane and begins to accelerate under gravity. **[1 Mark]**
- As the parachutist accelerates, the magnitude of the drag force opposing their weight increases ($D \propto v^2$). **[1 Mark]**
- The acceleration decreases until the drag force is balanced by their weight, reaching terminal velocity (v_1^T). **[1 Mark]**
- The parachute is deployed. The cross-sectional area has increased and therefore the drag force also increases. **[1 Mark]**
- The parachutist decelerates until they reach a new slower terminal velocity (v_2^T where $v_2^T < v_1^T$). **[1 Mark]**

Momentum and Collisions



Specification Points - AQA

3.4.1.6 Momentum

Content	Opportunities for skills development
<p><i>momentum = mass × velocity</i></p> <p>Conservation of linear momentum.</p> <p>Principle applied quantitatively to problems in one dimension.</p> <p>Force as the rate of change of momentum, $F = \frac{\Delta(mv)}{\Delta t}$</p> <p>Impulse = change in momentum</p> <p>$F\Delta t = \Delta(mv)$, where F is constant.</p> <p>Significance of the area under a force–time graph.</p> <p>Quantitative questions may be set on forces that vary with time. Impact forces are related to contact times (eg kicking a football, crumple zones, packaging).</p>	<p>MS 2.2, 2.3</p> <p>Students can apply conservation of momentum and rate of change of momentum to a range of examples.</p>

Specification Points – OCR A

3.5.1 Newton's laws of motion

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

- (a) Newton's three laws of motion
- (b) linear momentum; $p = mv$; vector nature of momentum
- (c) net force = rate of change of momentum;
$$F = \frac{\Delta p}{\Delta t}$$
- (d) impulse of a force; impulse = $F\Delta t$
- (e) impulse is equal to the area under a force–time graph.

3.5.2 Collisions

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

- (a) the principle of conservation of momentum
- (b) collisions and interaction of bodies in one dimension and in two dimensions

Specification Points – OCR B

(a) *Describe and explain:*

(viii) Newton's laws of motion

(ix) The principle of conservation of momentum; Newton's Third Law as a consequence.

(b) *Make appropriate use of:*

(i) the terms: displacement, speed, velocity, acceleration, force, mass, vector, scalar, work, energy, power, momentum, impulse

(c) *Make calculations and estimates involving:*

(iv) momentum $p = mv$

(v) the equation $F = ma = \frac{\Delta(mv)}{\Delta t}$ where the mass is constant

(vi) the principle of conservation of momentum

(d) *Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):*

(i) investigating the motion and collisions of objects using trolleys, air-track gliders etc. with data obtained from ticker timers, light gates, data-loggers and video techniques

Specification Points - Edexcel

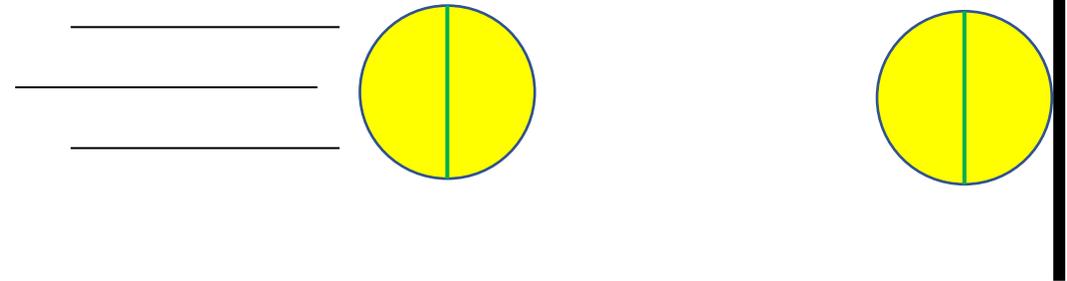
21. understand that momentum is defined as $p = mv$

22. know the principle of conservation of linear momentum, understand how to relate this to Newton's laws of motion and understand how to apply this to problems in one dimension

Impulse

Change in momentum (Δp) is closely linked to force (F). We can show this by writing **Newton's second law in terms of **momentum**.**

$$F = ma$$



$$F = \frac{\Delta p}{\Delta t}$$

Impulse

The **change in momentum** (Δp) of an **object** during a **collision** is also known as the **impulse**.

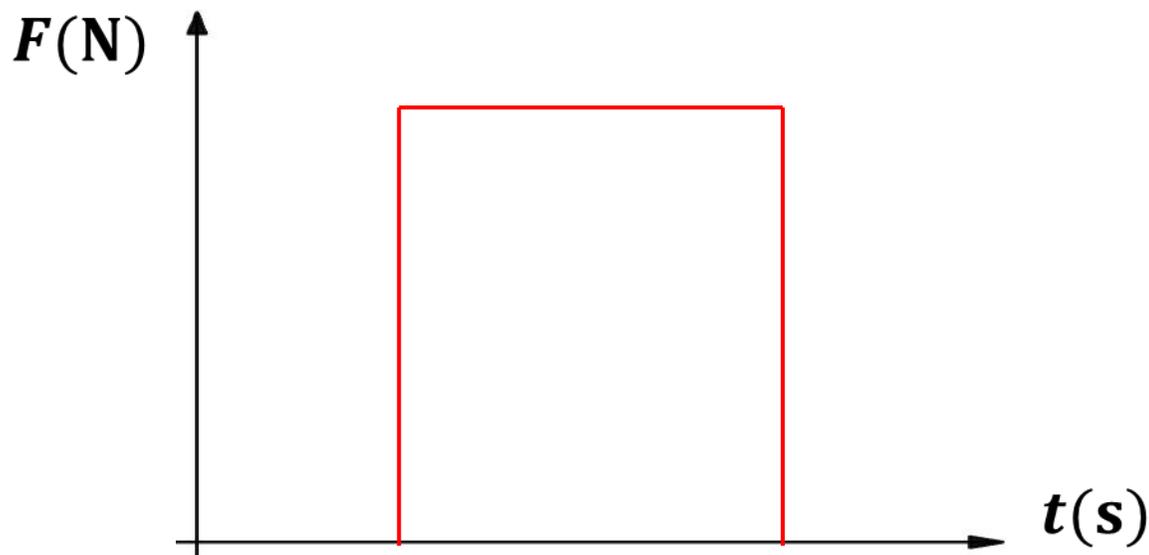
$$\text{Impulse} = F\Delta t = \Delta p$$

- **Increasing the time of a collision for fixed impact force increases the resulting momentum change.**
- **Increasing the time of a collision for fixed momentum change decreases the impact force.**

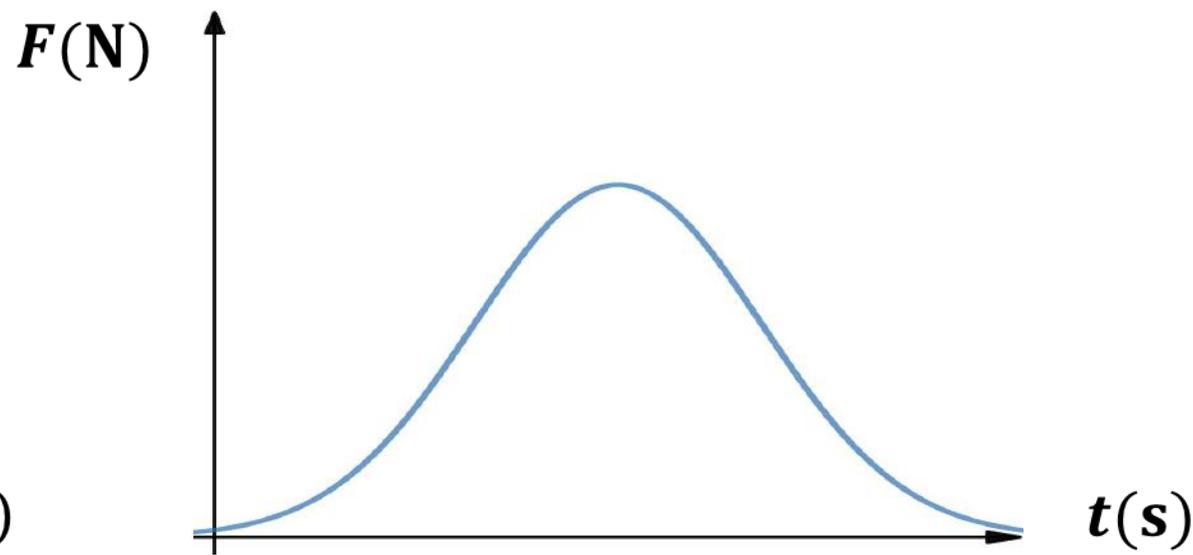
Impulse and Force-Time Graphs

Force-time graphs show the **impact forces** which **act** during **collisions**.

Constant force:



Varying force:



- The **impulse** of a **collision** is equal to the **area** under the **force-time** graph.

Exemplar Explanation Exam Question

Explanation Question:
Bullet-point format.

Context: Impact force. We should reference **impulse** and **momentum**.

- 1) Explain how crumple zones reduce the impact force to a driver during a vehicle collision.

[3 marks]

Answer in terms of **forces acting** on the **driver**.

3 marks means at least 3 points are required.

-
- During a collision the crumple zones give way and collapse.
-

[1 Mark]

-
- This increases the impact time (Δt) for the collision compared to if the car were completely rigid.
-

[1 Mark]

-
- Therefore the average impact force on the car (F) is reduced according to the impulse equation:
-

$$F = \frac{\Delta p}{\Delta t}$$

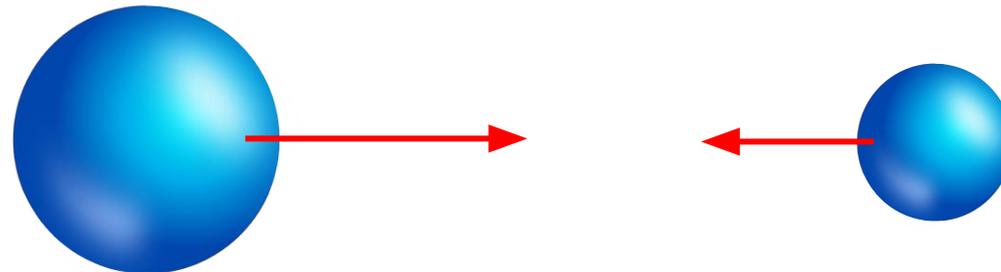
[1 Mark]

Conservation of Momentum

Momentum is equal to mass times velocity:

$$p = mv$$

- During **collisions** between **objects**, **momentum** can be **transferred**.
- However, **total momentum** in any **specific direction** is always **conserved** if no **external force** acts.



- As **momentum** is a **vector quantity** with **direction**, when considering a **problem** we must select a **direction** to be **positive** (usually **direction** with largest **momentum**).

Conservation of Momentum

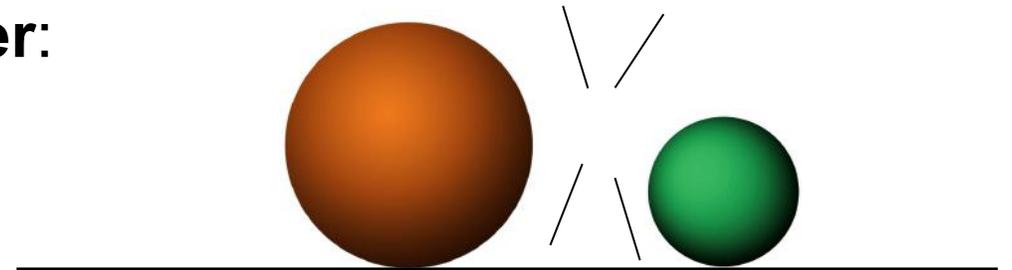
We can use the **conservation of momentum** to **calculate the momenta and velocities** of **objects** after **collisions**.

- It is usually **helpful** to **draw a diagram** to **represent a collision**.

Before:



After:



$$p_1 - p_2 = -p_3 + p_4$$

Exemplar Calculation Exam Question

Use **information** given in **diagram**.

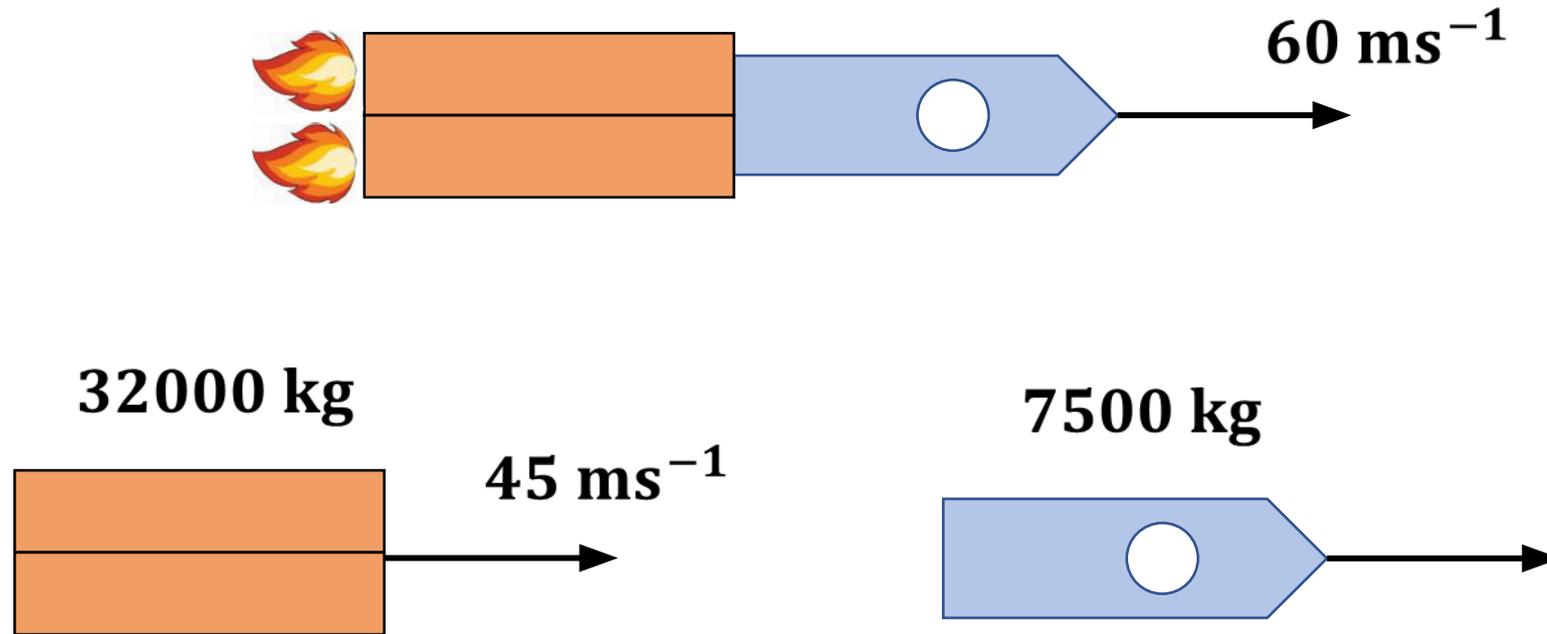
Context: Values of mass and velocity indicate we will have to use conservation of momentum.

- 1) Consider the diagram below showing a rocket of mass **7500 kg** travelling through space at **60 ms^{-1}** with a fuel tank of mass **32000 kg**. The rocket detaches the fuel tank, after which the fuel tank travels in the original direction of motion with velocity **45 ms^{-1}** . Determine the velocity of the rocket after the fuel tank detaches.

Calculation Question: Mathematical question – we need to show our working.

[3 marks]

Indicates that there will be about **3 steps** to our **calculation**. Any less and we may have missed something.



Exemplar Calculation Question Answer

Calculate total momentum before detachment:

$$\begin{aligned} p_i &= (m_{\text{ROCKET}} + m_{\text{TANK}}) \times v_i = (32000 + 7500) \times 60 \\ &= 2370000 \text{ kgms}^{-1} \end{aligned} \quad [1 \text{ Mark}]$$

Calculate total momentum after detachment:

$$\begin{aligned} p_f &= m_{\text{TANK}} \times v_{\text{TANK}} + m_{\text{ROCKET}} \times v_{\text{ROCKET}} \\ &= 32000 \times 45 + 7500 \times v_{\text{ROCKET}} = 1440000 \text{ kgms}^{-1} + 7500v_{\text{ROCKET}} \end{aligned} \quad [1 \text{ Mark}]$$

Exemplar Calculation Question Answer

Apply conservation of momentum to equate p_i and p_f

$$p_i = p_f$$

$$2370000 \text{ kgms}^{-1} = 1440000 \text{ kgms}^{-1} + 7500v_{\text{ROCKET}}$$

$$v_{\text{ROCKET}} = 124 \text{ ms}^{-1}$$

[1 Mark]

MINI MOCK PAPER



- 1) A tennis player is attempting to serve a ball at the highest speed possible. Explain why the tennis player follows through with their racket when striking the ball.

[3 marks]

- Following through with racket increases time of collision of
racket and ball.

[1 Mark]

- According to Newton's Second Law $\Delta p = F\Delta t$, increasing the
time of collision Δt increases the change in momentum Δp for
given impact force F .

[1 Mark]

- As $\Delta p = m\Delta v$ this increases the resulting velocity change
 Δv of the ball.

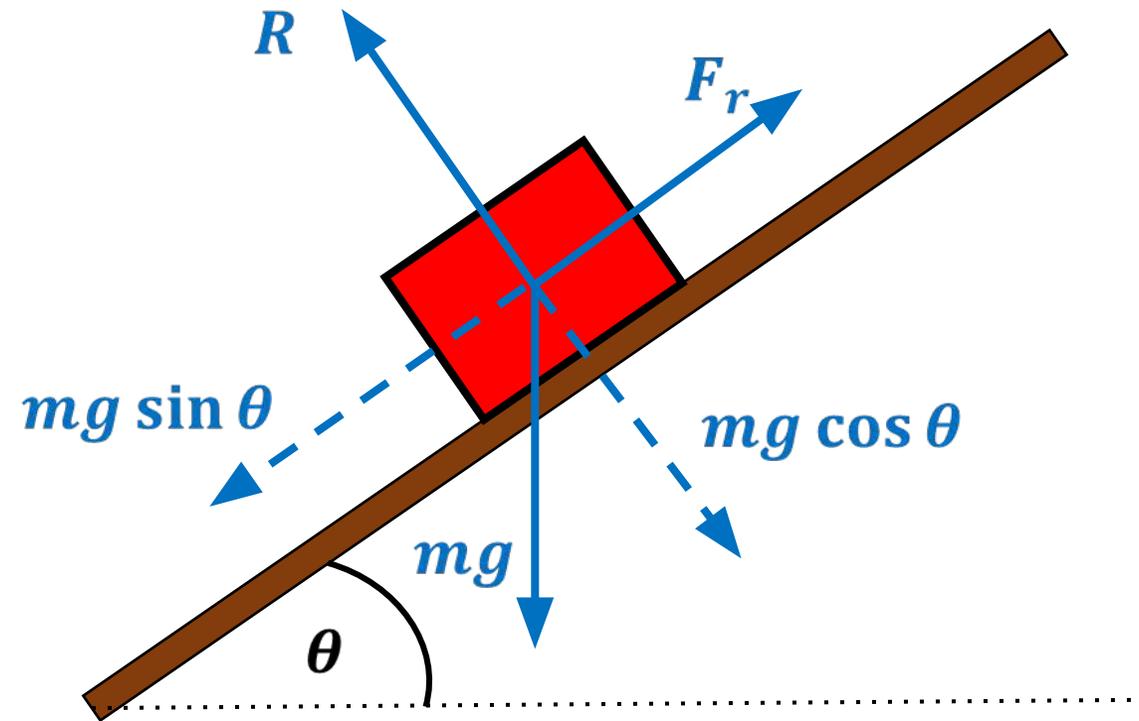
[1 Mark]

2) (i) A box sits upon a slope at rest. The maximum magnitude of the frictional force acting on the box from its contact with the slope is $0.4R$ where R is the normal reaction force the slope enacts on the box. Find the angle of inclination of the slope θ for which the box will be in equilibrium, with the frictional force at its greatest magnitude.

[3 marks]

(ii) Explain what happens to the box when the angle is larger or smaller than θ

[2 marks]



Exam Question Answer

Resolve forces perpendicular to plane to find R

$$R = mg \cos \theta$$

[1 Mark]

Resolve forces parallel to plane

$$\begin{aligned} mg \sin \theta &= F_r \\ &= 0.4R = 0.4mg \cos \theta \end{aligned}$$

[1 Mark]

Exam Question Answer

Rearrange to find θ

$$mg \sin \theta = 0.4mg \cos \theta$$

$$0.4 = \frac{\sin \theta}{\cos \theta} = \tan \theta$$

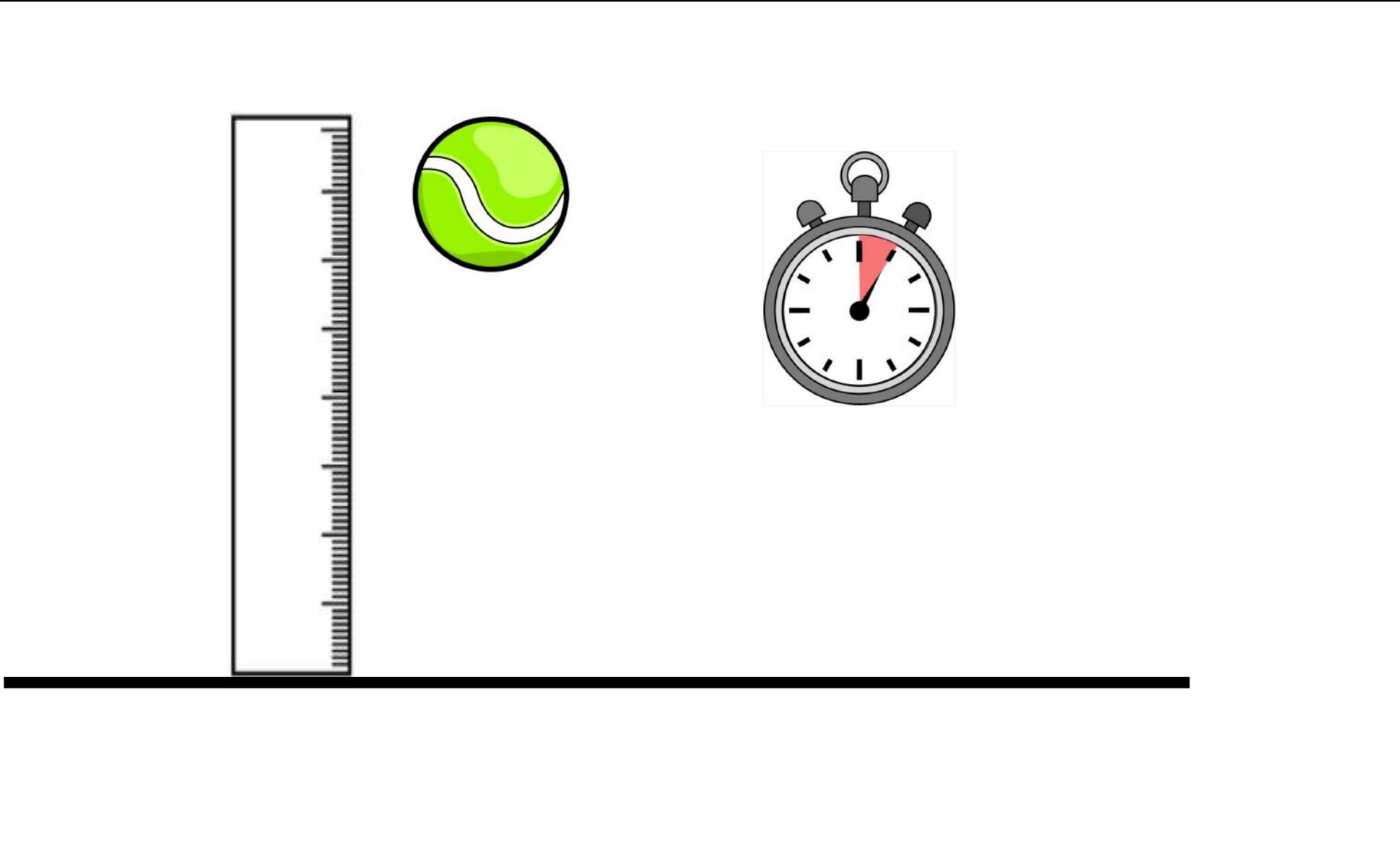
$$\theta = \tan^{-1}(0.4) = 21.8^\circ$$

[1 Mark]

- If angle is greater than θ , then friction is weaker than component of weight down the slope. So box slips down the slope **[1 Mark]**

- If angle is less than θ , then magnitude of friction decreases to match component of weight down the slope. So the box remains in equilibrium. **[1 Mark]**

- 3) A student decides to conduct an experiment to determine the acceleration due to gravity according to the following setup. They use a stopwatch to record the time of a ball's fall from several different heights. Discuss how the student's experiment could be improved to obtain an accurate value for the acceleration due to gravity.
[6 marks]



- Largest source of random error is likely to be human reaction time operating the stopwatch.

[1 Mark]

- This error could be reduced using a trapdoor in combination with a timer and an electromagnet to drop a steel ball.

[1 Mark]

- Use ruler with a higher resolution to improve precision of measurement of height.

[1 Mark]

- Always measure from the bottom of the ball to remove any
-
- systematic error in measurement of height.
-

[1 Mark]

- Air resistance acts on the ball, causing student to measure
-
- smaller value of acceleration acting on the ball.
-

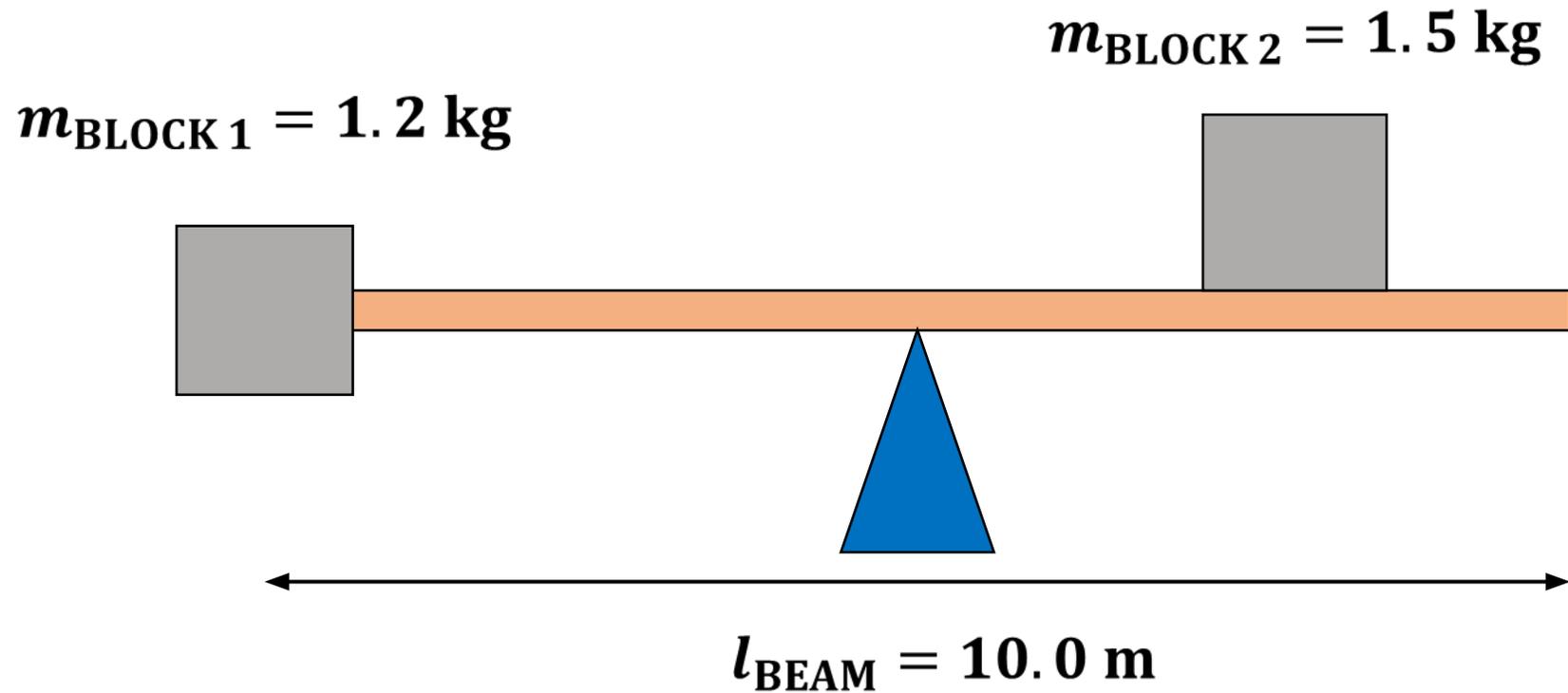
[1 Mark]

- Effect of air resistance could be reduced by using an object
-
- which experiences a smaller drag force (denser object with
-
- smaller cross-sectional area).
-

[1 Mark]

- 4) Consider the following diagram showing an **10.0 m** long, regular beam, balancing on a pivot placed at the centre of mass. A **1.2 kg** block is attached to one end of the beam and a **1.5 kg** block at some unknown distance along the beam. Determine the position of the **1.5 kg** block along the beam

[2 marks]



Exam Question Answer

Select point about which to take moments

Take moments around pivot.

Sum clockwise moments around pivot.

$$\begin{aligned}\cup \text{Moments} &= \frac{l_{\text{BEAM}}}{2} m_{\text{BLOCK}} g \\ &= \frac{10.0}{2} \times 1.2 \times 9.81\end{aligned}$$

Exam Question Answer

Sum anticlockwise moments around pivot.

$$\curvearrowright \text{Moments} = x \times m_{\text{BLOCK 2}}g$$

$$= x \times 1.5 \times 9.81$$

[1 Mark]

Apply the principle of moments.

$$\curvearrowright \text{Moments} = \curvearrowleft \text{Moments} \Rightarrow \frac{10.0}{2} \times 1.2 \times 9.81 = x \times 1.5 \times 9.81$$

$$x = 4 \text{ m to right from pivot}$$

[1 Mark]