Topic 5: Forces

AQA GCSE Physics 8463 · spec 4.5 · sheets 5.1–5.9

Forces: interactions, motion and momentum

- describe forces as vectors, calculate weight and resultant forces, and calculate work done;
- investigate the extension of a spring and the effect of force and mass on **acceleration**;
- describe motion with equations and graphs, and apply Newton's three laws;

Forces: interactions, motion and momentum (2)

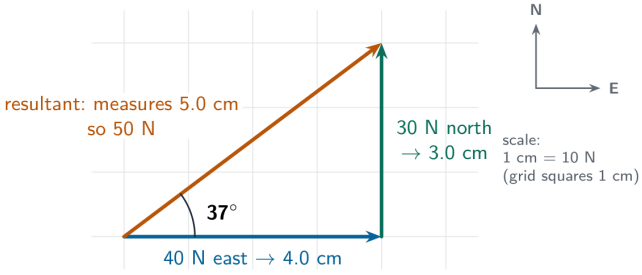
- explain stopping distances and (HT) **momentum**;
- (physics only) use moments, levers and gears, and pressure in fluids.

Scalars, vectors and resultant forces

- **Contact** forces need the objects to touch: friction, air resistance, tension and the normal **contact** force.
- **Non-contact** forces act at a distance: gravitational, magnetic and electrostatic forces.

$$W = mg$$

Figure: Scalars, vectors and resultant forces



answer: 50 N at 37° north of east

- Scale drawing with 1 cm for 10 N: 40 N east and 30 N north give a resultant of 50 N.
- Match each part of the diagram to the text.

Work done and energy transfer

- When a force moves an object, the force does work and energy is transferred:
- W is work done in joules (J), F is force in N, and s is the distance moved along the line of the force, in m.
- One joule is the work done when a force of one newton moves an object one metre, so 1 J = 1 N m.
- Work done against friction transfers energy to thermal stores and makes the object warmer.

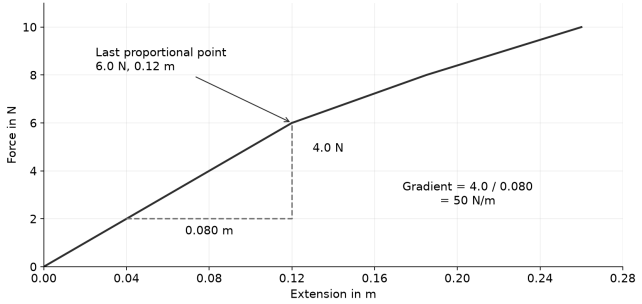
$$W = Fs$$

Forces and elasticity

- To stretch, bend or squash an object that is not moving, you need more than one force; one force alone would just move it. **Elastic** deformation means the object returns to its original shape when the forces are removed. **Inelastic** deformation means it does not.
- For a spring, up to its limit of proportionality:
- F is force in N, k is the spring constant in N/m and e is the extension in m.
- A stiff spring has a large spring constant.

$$F = ke$$

Figure: Forces and elasticity



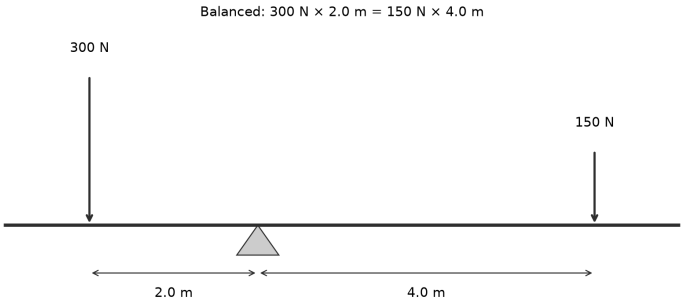
- Required practical 6: force against extension is a straight line, then curves beyond the limit of proportionality.
- Read the axes and units first.

Moments, levers and gears (physics only)

- A force can make an object turn about a pivot.
- The turning effect is called the **moment** :
- M is the **moment** in newton-metres (N m), F is the force in N, and d is the perpendicular distance from the pivot to the line of action of the force, in m.
- If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment.

$$M = Fd$$

Figure: Moments, levers and gears (physics only)



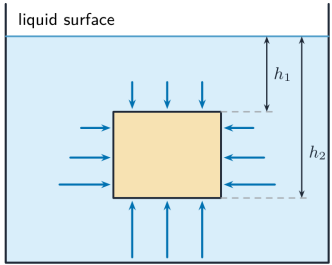
- A balanced beam: 300 N at 2.0 m balances 150 N at 4.0 m.
- Match each part of the diagram to the text.

Pressure in fluids (physics only)

- A fluid is a liquid or a gas.
- A fluid exerts a force at right angles to any surface in **contact** with it.
- p is pressure in pascals (Pa), F is the force normal to the surface in N, and A is the area in m^2.
- **(HT) Pressure in a liquid.** Pressure increases with depth, because there is more liquid above pushing down, and with the density of the liquid:

$$p = \frac{F}{A}$$

Figure: Pressure in fluids (physics only)



top face: smaller pressure
$p_1 = h_1 \rho g$

upthrust

side forces cancel

bottom face: larger pressure
$p_2 = h_2 \rho g$

pressure rises with depth: a bigger push up than down gives upthrust

- The pressure on the bottom of the object is greater than on the top, which gives an upward **resultant force**: **upthrust**.
- Match each part of the diagram to the text.

Describing motion along a line

- **Distance** is how far an object moves; it is a **scalar**.
- **Displacement** is the distance in a straight line from the start to the end, with a direction; it is a **vector**.
- **Speed** is a scalar. Typical speeds: walking 1.5 m/s, running 3 m/s, cycling 6 m/s, sound in air 330 m/s.

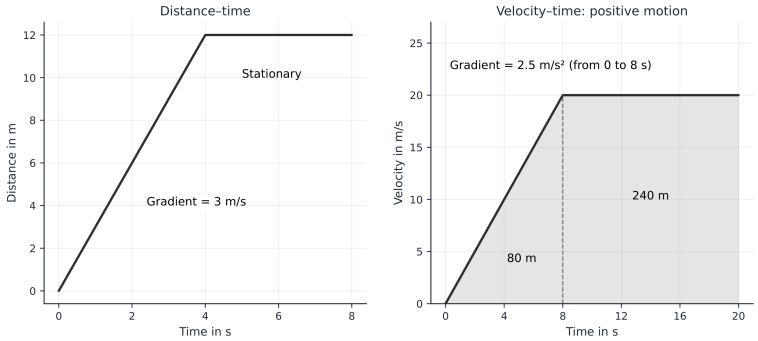
$$a = \frac{\Delta v}{t}$$

Describing motion along a line (2)

- **Velocity** is **speed** in a given direction; it is a **vector**. An object moving in a circle at constant speed has a changing velocity, because its direction changes.
- On a distance–time graph, the gradient is the speed. (HT) For an accelerating object, draw a tangent and find its gradient to get the speed at that **moment**.
- On a velocity–time graph, the gradient is the acceleration, and (HT) the area under the graph is the distance travelled.

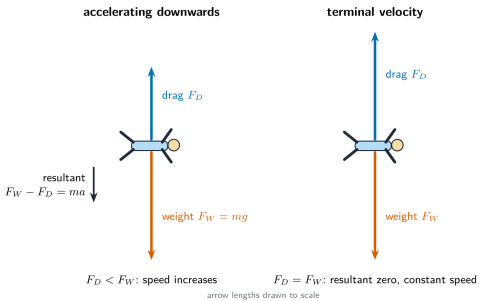
$$v^2 - u^2 = 2as$$

Figure: Describing motion along a line



- The gradient of a distance–time graph is **speed**; the gradient of a velocity–time graph is **acceleration** and the area under it is distance.
- Read the axes and units first.

Figure: Describing motion along a line (2)



- Forces on a skydiver: **drag** is smaller than weight while accelerating, and equal to it at **terminal velocity**.
- Match each part of the diagram to the text.

Newton's laws

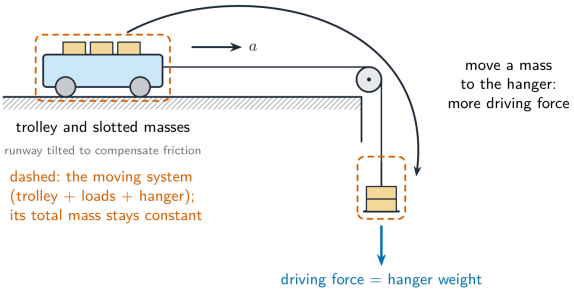
- **Newton's first law.** If the **resultant force** on an object is zero, a stationary object stays still, and a moving object keeps moving at the same **speed** in the same direction.
- A car moving at a steady speed has a driving force equal to the resistive forces. (HT) The tendency of an object to stay at rest or keep moving steadily is called **inertia** .

$$F = ma$$

Newton's laws (2)

- **Newton's second law.** The **acceleration** of an object is proportional to the **resultant force** on it, and inversely proportional to its mass:
- (HT) Inertial mass measures how hard it is to change the velocity of an object; it is the ratio of force to acceleration.

Figure: Newton's laws



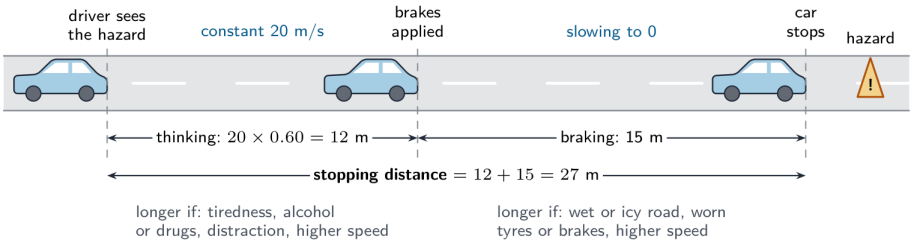
- Required practical 7: the moving mass is the trolley, the hanger and all the masses they carry.
- Match each part of the diagram to the text.

Stopping distances

- **Thinking distance** is how far the vehicle travels during the driver's reaction time: thinking distance = **speed** $\times$ reaction time. Reaction times are usually 0.2 to 0.9 s. They are longer if the driver is tired, has taken drugs or alcohol, or is distracted.
- **Braking distance** is how far the vehicle travels after the brakes are applied. It is longer at higher speeds, on wet or icy roads, and with worn brakes or tyres.

$$a = \frac{v^2 - u^2}{2s} = \frac{0 - 18^2}{2 \times 24} = -6.75 \text{ m/s}^2$$

Figure: Stopping distances



- Thinking distance plus braking distance gives the stopping distance.
- Match each part of the diagram to the text.

Momentum (HT)

- **Momentum** is mass multiplied by velocity:
- p is **momentum** in kg m/s, m is mass in kg and v is velocity in m/s.
- Momentum is a **vector**.
- In a closed system, the total momentum before an event, such as a collision or an explosion, equals the total momentum after it.

$$p = mv$$

Sources for this lesson

- AQA, *GCSE Physics (8463) specification*, section 4.5 Forces, and the *Required practical handbook* (practicals 6 and 7).
- NASA, *Apollo 15 Lunar Surface Journal*, "The hammer and the feather", 2 August 1971.
- AQA, *GCSE Physics* Paper 2 Higher, June 2024 and June 2025 (spring, rocket, braking, air bag and **acceleration** questions, adapted).

Common errors

- Giving weight in kilograms; weight is a force, in newtons.
- Using the length of the spring instead of the extension in $F = ke$.
- Using a distance that is not perpendicular to the force when calculating a **moment**.

Common errors (2)

- Saying zero **resultant force** means the object is not moving; it may be moving at a constant velocity.
- Putting both forces of a third-law pair on the same object.
- Reading the wrong part of a graph: gradient of distance–time is **speed**, gradient of velocity–time is **acceleration**, area under velocity–time is distance.

Common errors (3)

- Mixing up the factors: tiredness, drugs and distraction affect thinking distance; road and vehicle conditions affect braking distance.
- Ignoring direction in **momentum** calculations.

Key terms

- **Vector**: a quantity with magnitude and direction.
- **Resultant force**: the single force that has the same effect as all the forces acting.
- **Weight**: the force on an object due to gravity.

Key terms (2)

- **Moment**: the turning effect of a force.
- **Terminal velocity**: the steady **speed** reached when the **drag** equals the weight.
- **Inertia**: the tendency of an object to keep its state of motion.

Key terms (3)

- **Stopping distance**: thinking distance plus braking distance.
- **Momentum**: mass multiplied by velocity.

Check yourself

- 1.
- Name two **contact** forces and two **non-contact** forces. 2.
- A 5.0 kg bag is lifted 1.2 m.
- Calculate its weight ($g = 9.8$ N/kg) and the work done. 3.