Topic 1: Forces and motion

Edexcel International GCSE Physics 4PH1 · Section 1 · statements 1.1–1.33P · sheets 1.1–1.3

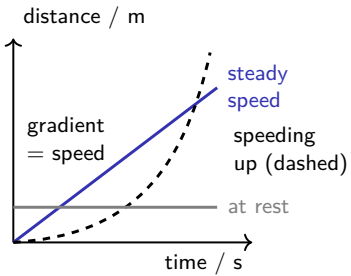
What this topic builds

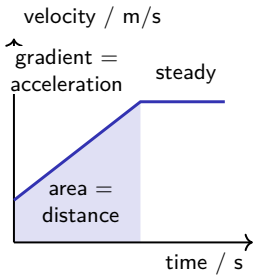
Sheet	What you learn
1.1	Speed, acceleration, distance–time and velocity–time graphs
1.2	**Resultant force**, $F = ma$, weight, stopping distance, **terminal velocity**, Hooke's law
1.3 (P)	Momentum, safety features, Newton's third law, moments

Use the evidence

P-suffixed statements are the separate-science extension, assessed on Paper 2P.

Two graphs, two meanings of gradient





Read the axes first: the same straight line means different motion on each graph.

- Distance–time gradient is speed.
- Velocity–time gradient is acceleration; area is distance.

Speed and acceleration equations

$$v_{\text{av}} = \frac{\text{distance moved}}{\text{time taken}} \qquad a = \frac{v-u}{t} \qquad v^2 = u^2 + 2as$$

u initial velocity, v final velocity, a in m/s^2, s distance in m

1. **Known** A car goes from $u = 4$ m/s to $v = 16$ m/s in $t = 6$ s.
2. **Equation** Acceleration is change of velocity per second: $a = (v-u)/t$.
3. **Substitute** $a = (16\ \text{m/s} - 4\ \text{m/s})/6\ \text{s} = 2\ \text{m/s}^2$.
4. **Distance** Area under the v–t line: $s = \frac{1}{2}(4+16) \times 6 = 60$ m.

Braking: use $v^2 = u^2 + 2as$

1. **Known** $u = 20$ m/s, $v = 0$, $a = -5.0\ \mathrm{m/s^2}$ (slowing down); find s.
2. **Equation** No time is given, so use $v^2 = u^2 + 2as$.
3. **Rearrange** $s = (v^2 - u^2)/(2a)$.
4. **Substitute** $s = (0 - 20^2)/(2 \times (-5.0)) = -400/(-10) = 40$ m.

Decision

At 40 m/s the same brakes need 160 m, four times as far, because the speed is squared.

Your turn: the lift journey

Your turn

A lift starts from rest, speeds up steadily to 3.0 m/s in 2.0 s, moves at 3.0 m/s for 6.0 s, then slows steadily to rest in 2.0 s.

A. Sketch the velocity–time graph.

B. Calculate the acceleration at the start.

C. Calculate the total distance travelled.

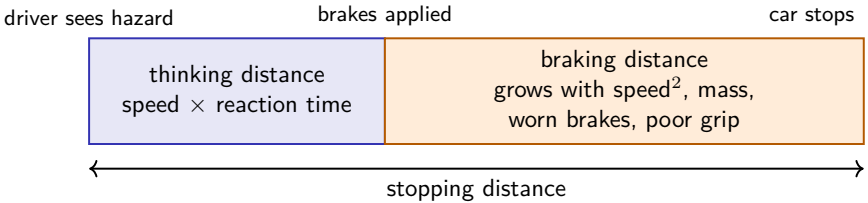
Resultant force and F = ma

$$F = m \times a \qquad W = m \times g$$

F **resultant force** in N, m in kg, g = 10 N/kg on Earth

1. **Known** 1200 kg car, driving force 3600 N forwards, drag 1200 N backwards.
2. **Resultant** Forces along a line add with signs: $F = 3600 - 1200 = 2400$ N forwards.
3. **Equation** $F = ma$, so $a = F/m = 2400\ \text{N}/1200\ \text{kg} = 2\ \text{m/s}^2$.
4. **Weight** $W = mg = 1200\ \text{kg} \times 10\ \text{N/kg} = 12\,000$ N.

Stopping distance has two parts



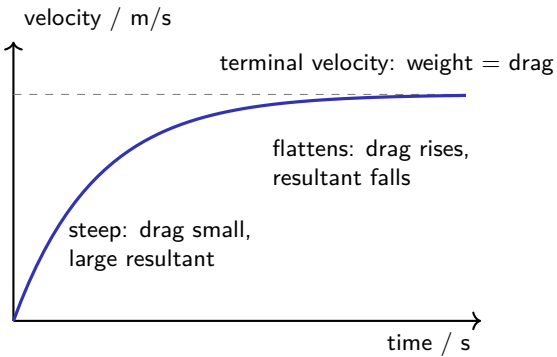
> Stopping distance = thinking distance + braking distance.

- Thinking distance depends on speed and reaction time.
- Braking distance depends on speed, mass, brakes and grip.

Worked example: thinking distance

1. **Known** Speed 25 m/s, reaction time 0.70 s, braking distance 48 m.
2. **Thinking** distance $=$ speed $\times$ time $= 25\ \mathrm{m/s} \times 0.70\ \mathrm{s} = 17.5$ m.
3. **Stopping** $17.5\ \mathrm{m} + 48\ \mathrm{m} = 65.5$ m, about 66 m.
4. **Tired driver** Reaction time 1.4 s doubles the thinking distance to 35 m; braking is unchanged.

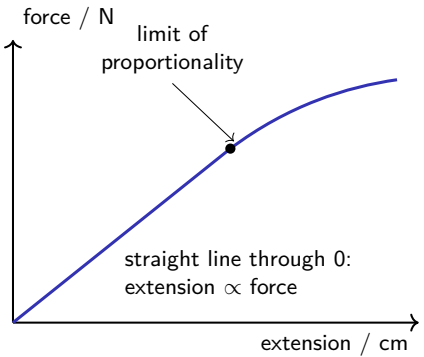
Falling to terminal velocity



Drag grows until it equals weight; the resultant is zero and velocity stays constant.

- Drag rises with speed.
- At **terminal velocity** weight equals drag.

Hooke's law and the force–extension graph



Extension $\propto$ force up to the limit of proportionality; elastic means it returns to its original shape.

- Extension is proportional to force in the linear region.
- Past the limit of proportionality the line curves.

Worked example: extension, not length

1. **Known** Unloaded length 8.0 cm; with 2.0 N the length is 10.5 cm.
2. **Extension** $10.5 - 8.0 = 2.5$ cm for 2.0 N.
3. **Proportion** Hooke's law: 4.0 N is twice the force, so the extension is $2 \times 2.5 = 5.0$ cm.
4. **Length** $8.0 + 5.0 = 13.0$ cm, not $2 \times 10.5 = 21$ cm.

Momentum is conserved in a collision

$$p = m \times v \qquad F = \frac{mv - mu}{t}$$

p in kg m/s; force equals the rate of change of momentum

1. **Before** $1200 \times 15 + 800 \times 0 = 18\,000$ kg m/s.
2. **After** They move together: mass 2000 kg, same total momentum.
3. **Speed** $v = p/m = 18\,000/2000 = 9.0$ m/s.
4. **Force on 800 kg car** $F = (800 \times 9.0 - 0)/0.15\ \text{s} = 48\,000$ N.

Why safety features stretch the time

The passenger must lose the same momentum whatever happens.

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Crumple zones, airbags and seat belts lengthen the collision time.

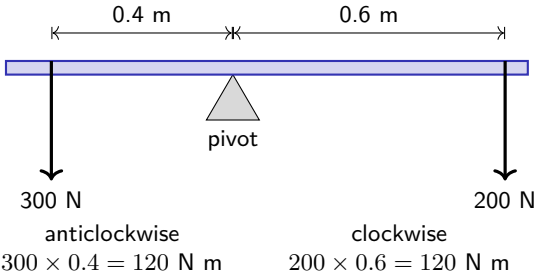
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$F = (mv - mu)/t$: a longer t gives a smaller force.

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Doubling the time from 0.15 s to 0.30 s halves the force.

Balancing moments on a beam



Balanced: clockwise moments = anticlockwise moments.
200 N $\times$ 0.6 m = 300 N $\times$ 0.4 m = 120 N m.

- **Moment** = force $\times$ perpendicular distance from the pivot.
- Weight acts through the **centre of gravity**.

Your turn: a beam on two supports

Your turn

A light 4.0 m beam rests on supports at its ends. A 600 N load sits 1.0 m from the left support.

A. Take moments about the left support to find the right support's force.

B. Use up forces = down forces for the left support.

C. Which support carries more, and why?

Six mistakes that cost marks

Mistake	**Correct idea**
Positive *a* while braking	Slowing down means *a* is negative
Doubling a spring's length	Only the extension is proportional to force
No forces at **terminal velocity**	Weight and drag are equal; resultant zero
Ignoring direction in momentum	Give one velocity a minus sign
Distance along the beam	Use the perpendicular distance
Alcohol lengthens braking	It lengthens reaction, so thinking distance

Check yourself

Your turn

Answer without notes, then check.

A. A cyclist covers 900 m in 3 minutes. Average speed in m/s?

B. Acceleration from 30 m/s to rest in 5 s?

C. Explain, in terms of forces, why a skydiver reaches terminal velocity.

D. (P) A 60 kg runner at 8 m/s. Momentum?

E. (P) The moment of a 50 N force 0.3 m from the pivot?