SI units and modelling assumptions

M6.1 · Mechanics · revision notes

Mechanics is built on three SI base quantities (length, mass and time) and on quantities derived from them: velocity, acceleration, force, weight and moment. Every question also uses modelling words (particle, light, inextensible, smooth, uniform) that tell you what to ignore, and Paper 3 often asks you to state, explain or criticise these assumptions for 1 or 2 marks.

Key facts

- Base SI units: length m, mass kg, time s
- Force and weight in newtons: 1 N = 1 kg m s^{-2}
- km h^{-1} ÷ 3.6 = m s^{-1}
- Light: mass ignored. Inextensible: does not stretch. Smooth: no friction
- Velocity m s^{-1}, acceleration m s^{-2}
- Moment in N m
- Particle: size ignored, no rotation, forces act at one point
- Uniform rod: weight acts at the midpoint

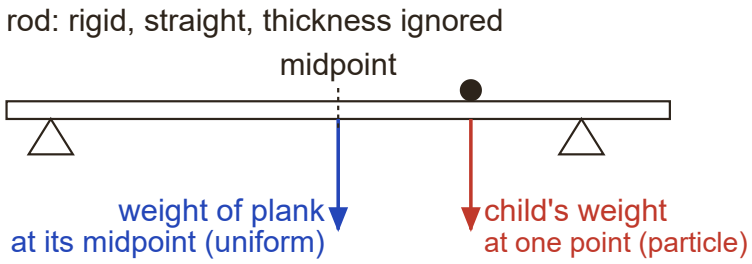
Notes

SI units

- The SI base quantities you need are **length** (metre, m), **mass** (kilogram, kg) and **time** (second, s).
- Derived quantities combine these: velocity and speed in m s^{-1}; acceleration in m s^{-2}.
- **Force** and **weight** are measured in newtons (N). 1 N is the force that gives a mass of 1 kg an acceleration of 1 m s^{-2}, so 1 N = 1 kg m s^{-2}.
- A **moment** (turning effect) is force × perpendicular distance, so it is measured in newton metres (N m).
- Mass and weight are different: mass is measured in kg and does not change; weight is a force, $W = mg$, measured in N.
- Convert to SI units before you substitute: 1 km = 1000 m, 1 hour = 3600 s, 1 g = 0.001 kg, 1 tonne = 1000 kg. To change km h^{-1} to m s^{-1}, divide by 3.6.

Modelling words

- **Particle**: the object's size is ignored, so its mass is at a single point, all the forces act through that point and it cannot rotate.
- **Rod**: a rigid body with length but negligible thickness. It does not bend, and forces on it can make it turn (used in moments questions).
- **Uniform**: the mass is spread evenly, so the weight of a uniform rod acts at its midpoint. **Non-uniform**: the weight acts at the centre of mass, which need not be the midpoint.



Uniform rod: weight at the midpoint. Particle: weight at a single point

- **Light**: the mass is negligible, so the object's weight is ignored. A light string has the same tension throughout, provided any pulley or peg it passes over is smooth.
- **Inextensible**: the string does not stretch, so objects joined by a taut string have the same speed and the same magnitude of acceleration.
- **Smooth**: there is no friction. **Rough**: friction acts. A **peg** is a fixed support that a string or rod can rest on.
- On a rough surface, friction is modelled by $F \leqslant \mu R$

Other assumptions and criticising a model

- Other common assumptions: air resistance is ignored; g is constant (9.8 m s^{-2}); a road is straight and level, or a slope is a flat plane.
- Each assumption makes the maths possible but the answer less realistic. To criticise a model, name a specific effect that it ignores.
- For a refinement, say what you would include (air resistance, the size of the object, a string that stretches) and, if asked, whether the answer would get bigger or smaller.

How to answer each type of question

M = method mark, A = answer mark, B = a mark on its own.

Convert units, then calculate 2 to 3 marks **Grade E**

1. Spot any quantity not in SI units (km, hours, grams, minutes).
2. Convert it first: km h^{-1} ÷ 3.6 gives m s^{-1}.
3. Then substitute into the formula and give the SI unit with your answer.

Example. A train travelling at 90 km h^{-1} brakes with constant deceleration and comes to rest in 50 s. Find the deceleration of the train, giving your answer in m s^{-2}.

Model answer.

90 km h^{-1} = 90 ÷ 3.6 = 25 m s^{-1} (B1)

$0 = 25 + 50a$ (M1), so $a = -0.5$ and the deceleration is 0.5 m s^{-2} (A1)

State what an assumption means, or how it was used 1 mark each **Grade C**

1. Give the meaning in context, not just a definition, e.g. 'the weight of the plank acts at its midpoint'.
2. If asked how you used it, point to the step in your working that it allowed.
3. Use the key phrases: negligible mass, same tension, same acceleration, no friction, acts at a single point.

Example. A plank rests horizontally on two supports and a child sits on it. The plank is modelled as a uniform rod and the child as a particle.
(a) Explain what is meant by 'uniform' in this model.
(b) Explain how the modelling assumption that the child is a particle is used when taking moments.
(c) State one other assumption made by modelling the plank as a rod.

Model answer.

(a) The mass of the plank is evenly distributed, so its weight acts at its midpoint (B1)

(b) The child's weight acts at a single point on the plank, so it has one definite distance from the point you take moments about (B1)

(c) The plank is rigid (it does not bend), or its width and thickness can be ignored (B1)

Criticise a model or suggest a refinement 1 to 2 marks **Grade A**

1. Name a specific effect the model ignores: air resistance, the size or spin of the object, stretching of a string, friction that varies.
2. Say how you would include it (the refinement).
3. If asked, say whether the answer would increase or decrease, with a reason.

Example. A ball is thrown vertically upwards. It is modelled as a particle moving freely under gravity, and the model predicts that the greatest height reached is 7.2 m.
(a) Suggest one refinement that would make the model more realistic.
(b) State how this refinement would affect the predicted greatest height.

Model answer.

(a) Include air resistance acting on the ball (B1)

(b) Air resistance acts downwards while the ball rises, so its deceleration is greater than g and the greatest height would be less than 7.2 m (B1)

Don't lose marks

- Substituting km h^{-1}, grams or minutes straight into a formula.
- Mixing up mass and weight: weight is mg newtons, never kilograms.
- Vague criticisms such as 'the model is not accurate' or 'human error' score nothing. Name the effect that is ignored.
- Mixing up light and inextensible: light gives the same tension (and no weight), inextensible gives the same acceleration.
- Suggesting 'use a more accurate value of g' as a refinement: this is not usually accepted.

More tips

Memory tricks

- km h^{-1} to m s^{-1}: divide by 3.6. Useful facts: 36 km h^{-1} = 10 m s^{-1}, 72 km h^{-1} = 20 m s^{-1}, 90 km h^{-1} = 25 m s^{-1}.
- Pair each word with its effect: light → ignore its weight, same tension; inextensible → same acceleration; smooth → no friction; particle → no rotation; uniform → weight at the midpoint.
- Unit check: an acceleration must come out in m s^{-2} and a force in N. If the units don't match, you have probably used the wrong formula.

Exam technique

- For 'explain how you have used…', refer to a particular step in your working, e.g. 'the tension is the same in both parts of the string'.
- Give answers found using $g = 9.8$ to 2 or 3 significant figures.
- Always give units with a final answer: m, m s^{-1}, m s^{-2}, N, N m.
- Read the assumptions from the question: words like light, smooth and uniform each tell you something you must use.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade E

State the SI units of basic quantities

Length is measured in metres (m), mass in kilograms (kg) and time in seconds (s).

Grade E

Convert units before substituting

Divide km h^{-1} by 3.6 to get m s^{-1}, divide grams by 1000 to get kilograms, and multiply minutes by 60 to get seconds.

Grade D

Give the units of derived quantities

Velocity m s^{-1}, acceleration m s^{-2}, force and weight N (1 N = 1 kg m s^{-2}), moment N m.

Grade C

State what each modelling term means

For example, light means the mass is ignored and inextensible means the string does not stretch.

Grade B

Explain how an assumption was used

Link the assumption to a step in your working, e.g. a smooth pulley means the tension is the same on both sides.

Grade A

Criticise a model and suggest a refinement

Name one specific effect the model ignores, such as air resistance, and say how including it would change the answer.

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