inkMaths

ANSWER BOOK

Modelling, quantities and units

Mechanics · Year 12–13

7 questions · 21 marks

NAVY EDITION

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SECTION A · Warm-up

A1 All the mass is treated as concentrated at a single point, so size, shape and rotation are ignored. Every force then acts at that one point, which means there are no turning effects and no moments to take. The whole of Newton's second law becomes available with nothing to resolve about. B1 for the assumption, B1 for a consequence. [2]

A2 Speed: 90 km h^{-1} = 90 × 1000 m per 3600 s = 25 m s^{-1}. Density: 1 g is 10^{-3} kg and 1 cm^3 is 10^{-6} m^3, so 1 g cm^{-3} is 1000 kg m^{-3} and 2.5 g cm^{-3} = 2500 kg m^{-3}. B1 for the speed, B1 for the density. Convert before substituting, never after. A speed left in km h^{-1} inside a suvat equation alongside g in m s^{-2} is wrong by a factor of 3.6. [2]

SECTION B · Standard

B1 Light means the cable's own weight is ignored, so the tension is the same at every point along it. Inextensible means the cable cannot stretch, so the load moves exactly as the top end does, with the same speed and the same acceleration. B1 B1, one for each word, and each has to be tied to its consequence. [2]

B2 A smooth surface or pulley exerts no friction, so it provides only a normal reaction, and a smooth pulley leaves the tension unchanged across it. Rough means friction acts and has to enter the equations. Uniform means the mass is evenly spread, so a uniform rod's weight acts at its midpoint. B1 B1 B1 for the three words. Each word is a licence to leave something out of the working, which is why they are worth reading twice. [3]

B3 Velocity m s^{-1}, acceleration m s^{-2}, force N = kg m s^{-2}. In the equation, ut has units (m s^{-1})(s) = m, and at^2 has (m s^{-2})(s^2) = m. Every term is a length, which is what an equation for displacement demands. B1 for the units of velocity and acceleration, B1 for the newton in base units, M1 for checking the units of each term, A1 for the conclusion. The ½ is a pure number and carries no units. A check like this catches a formula misremembered as $s = ut + \frac{1}{2}at$, where the last term would be a velocity. [4]

B4 Scalars: mass, speed and distance, each a bare size. Vectors: weight, velocity and displacement, each carrying a direction as well. B1 B1 for the two lists. The pairings are the point. Speed is the magnitude of velocity, distance is the path-length companion of displacement, and mass is a scalar in kilograms while weight is a force in newtons pointing down. [2]

SECTION C · Stretch

C1 The model neglects air resistance and treats each object as a particle acted on by its weight alone, so both fall with acceleration g and the masses cancel out of ma = mg. For the stone the assumption holds well over a short drop. It is dense and compact, so the air resistance it meets stays small compared with its weight. For the feather it fails almost immediately, because a large surface area and a tiny weight mean air resistance rises to match the weight within a fraction of a second, after which the feather drifts at near-constant speed. Assumptions are judged object by object, not once per problem. When a prediction misses, the modeller identifies the weakest assumption, replaces it with something more realistic such as a resistance force that grows with speed, solves again and compares again. B1 for identifying the neglect of air resistance, B1 for the masses cancelling, B1 for the stone with a reason, B1 for the feather with a reason, B1 for identifying the weakest assumption, B1 for the refine and compare loop. That loop of model, compare, refine is the whole discipline, and a model is kept when it is simple enough to solve and close enough to be useful, not when it is true. [6]