inkMaths

ANSWER BOOK

Connected particles and pulleys

Mechanics · Year 12–13

6 questions · 24 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Inextensible means the string cannot stretch, so its ends move together and the two accelerations match in magnitude. Light string and smooth pulley mean nothing along the way absorbs force, so the tension is the same at both ends. B1 for the shared acceleration, B1 for the shared tension. A rough pulley would break the second half of that, since friction at the pulley leaves the two sides pulling with different tensions. [2]

A2 Newton's second law applies body by body, to the forces on that body alone. The 7 kg mass feels its own weight and the tension and nothing else. B1 for the law applying to one body at a time, B1 for the forces being those on that body alone. Writing one equation per particle, then combining them, is the method from start to finish. [2]

SECTION B · Standard

B1 Take each mass's own direction of motion as positive. Heavy side: $7g - T = 7a$. Light side: $T - 3g = 3a$. Adding the pair removes T and gives $4g = 10a$, so $a = 2g/5 = 3.92$ m s^{-2}. Substituting back, $T = 3(g + a) = 3 \times 13.72 = 41.2$ N. M1 A1 for the pair of equations, M1 for eliminating T, A1 for $a = 3.92$, A1 for $T = 41.2$. Check it in the other equation as well: $7(9.8 - 3.92) = 41.2$ N, which agrees. The tension also has to sit between $3g = 29.4$ N and $7g = 68.6$ N. If T came out equal to either weight, that mass would not be accelerating at all. [5]

B2 Treat the whole system first, because the towbar tension is internal to it and cancels: $2000 - 500 = 1250a$, so $a = 1.2$ m s^{-2}. Now take the trailer on its own: $T - 100 = 250 \times 1.2$, so $T = 400$ N. M1 A1 for the system equation, A1 for $a = 1.2$, M1 for the trailer equation, A1 for $T = 400$. The car's own equation is a free check, $2000 - 400 - 400 = 1000 \times 1.2$. Choosing the system equation first is what makes a come out so cleanly, and the smaller body then exposes T with the least arithmetic. [5]

B3 Hanging mass: $2g - T = 2a$. Block: $T = 4a$, since the table is smooth and the string is horizontal. Adding gives $2g = 6a$, so $a = g/3 = 3.27$ m s^{-2} and $T = 4a = 13.1$ N. M1 A1 for the two equations, A1 for $a = 3.27$, A1 for $T = 13.1$. Only the hanging weight drives the system, but it has to move all 6 kg, which is why the block's mass appears in the denominator even though gravity never pulls it sideways. [4]

SECTION C · Stretch

C1 While the string is taut the acceleration is 3.92 m s^{-2}, as before. Over the 1.4 m drop, $v^2 = 0 + 2 \times 3.92 \times 1.4 = 10.976$, so $v = 3.31$ m s^{-1}. The 3 kg mass is by then 1.4 m up and moving upwards at the same 3.31 m s^{-1}. The moment the 7 kg mass lands the string goes slack, so the 3 kg mass becomes a free particle under gravity alone. It rises a further $v^2/(2g) = 10.976/19.6 = 0.56$ m, reaching 1.4 + 0.56 = 1.96 m above the floor. M1 A1 for v = 3.31 over the drop, B1 for the string going slack, M1 for the free-flight stage, A1 for the extra 0.56 m, A1 for 1.96 m. The acceleration changes at the instant of landing, from 3.92 m s^{-2} upwards to 9.8 m s^{-2} downwards, so the motion has to be split into two suvat stages. Running a single suvat through the whole thing assumes constant acceleration where there is none, so its numbers are wrong from the landing onward. [6]