inkMaths

ANSWER BOOK

Friction and inclined planes

Mechanics · Year 12–13

6 questions · 23 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Friction matches whatever force is trying to slide the surfaces past each other, up to a ceiling of μR. Equality holds only at that ceiling, which happens in limiting equilibrium, on the point of slipping, or while the object is actually sliding. Below the ceiling friction is exactly as large as it needs to be and no larger. B1 for the inequality, B1 for the conditions giving equality. [2]

A2 Vertically, $R = mg = 58.8$ N, so friction can supply up to $\mu R = 0.4 \times 58.8 = 23.52$ N. The applied 20 N is below that ceiling, so the box stays put and friction takes the value 20 N, exactly enough to balance. Quoting 23.52 N as the acting friction is the error the question is set to catch. A 'show that' demands the comparison in writing, so state that $20 < 23.52$ before concluding. M1 for $R = mg$, A1 for $\mu R = 23.52$ N, M1 for the comparison, A1 for the friction being 20 N. [4]

SECTION B · Standard

B1 30 N beats the ceiling of 23.52 N, so the box slides and friction locks at its maximum value. The resultant is $30 - 23.52 = 6.48$ N, so $a = 6.48/6 = 1.08$ m s^{-2}. Once the box is moving, $F = \mu R$ exactly, and the problem reduces to ordinary Newton's second law. M1 for the resultant, A1 for 6.48 N, A1 for the acceleration. [3]

B2 Resolving along the slope, the only force component is $mg \sin 30°$, so $ma = mg \sin 30°$ and $a = g \sin 30° = 4.9$ m s^{-2}. The mass multiplies both the driving force and the inertia, so it cancels. Every block slides a smooth 30° slope in the same way, whatever it weighs. M1 for resolving along the slope, A1 for the acceleration, B1 for the mass cancelling. [3]

B3 Down the slope the pull is $mg \sin 20° = 3 \times 9.8 \times \sin 20° = 10.1$ N. Perpendicular to the slope, $R = mg \cos 20° = 27.6$ N, so friction can supply up to $\mu R = 0.5 \times 27.6 = 13.8$ N. The ceiling of 13.8 N beats the pull of 10.1 N, so equilibrium is possible and the block stays at rest with friction actually providing 10.1 N up the slope. On a slope R is $mg \cos \theta$ and never mg. That substitution is the whole point of the question, and writing $R = 29.4$ N throws away every mark after it. M1 for $mg \sin 20°$, A1 for the friction ceiling of 13.8 N, M1 for the comparison, A1 for the conclusion. [4]

SECTION C · Stretch

C1 Going up, gravity and friction both act down the slope, so $ma = mg \sin 25° + \mu mg \cos 25°$ and $a = 9.8(\sin 25° + 0.3 \cos 25°) = 6.81$ m s^{-2} of deceleration. The mass cancels. Then $0 = 6^2 - 2 \times 6.81 \times s$ gives $s = 2.64$ m. At the top the block is at rest, so ask whether the down-slope pull can beat the friction ceiling: $mg \sin 25° = 8.28$ N against $\mu mg \cos 25° = 5.33$ N. It can, so the block slides back. The same test written as an angle is $\tan 25° = 0.466 > 0.3 = \mu$, which is the standard criterion for slipping on a rough slope. Coming down, friction reverses and acts up the slope, so the return acceleration is $9.8(\sin 25° - 0.3 \cos 25°) = 1.48$ m s^{-2}, much gentler than the climb. M1 A1 for the deceleration up the slope, M1 A1 for the distance, M1 A1 for the comparison that settles the slide-back, B1 for the return acceleration. [7]