inkMaths

ANSWER BOOK

Friction and inclined planes

Mechanics · Year 12–13

6 questions · 20 marks

NAVY EDITION

SECTION A · Warm-up

A1 Friction matches whatever force tries to slide the surfaces, up to the ceiling μR. Equality holds only at that ceiling: in limiting equilibrium, on the point of slipping, or while actually sliding. Below it, friction is exactly as big as it needs to be, no more. [2]

A2 $R = mg = 58.8$ N, so friction can supply up to $\mu R = 23.52$ N. The push of 20 N is below the ceiling, so the box stays put, and friction is exactly 20 N: enough to balance, not the maximum. Quoting 23.52 N as the acting friction is the standard error. [3]

SECTION B · Standard

B1 30 N beats the ceiling of 23.52 N, so the box slides and friction locks at its maximum. Resultant: $30 - 23.52 = 6.48$ N, so $a = 6.48/6 = 1.08 \text{ m s}^{-2}$. Once moving, $F = \mu R$ exactly, and the problem becomes ordinary Newton's second law. [4]

B2 Along the slope, the only force component is $mg \sin 30°$, so $ma = mg \sin 30°$ and $a = g \sin 30° = 4.9 \text{ m s}^{-2}$. The mass multiplies both the driving force and the inertia, and cancels: every block slides a smooth 30° slope identically. [4]

B3 Down-slope pull: $mg \sin 20° = 10.1$ N. Normal reaction: $R = mg \cos 20° = 27.6$ N, so friction can supply up to $\mu R = 13.8$ N. The ceiling beats the pull, so equilibrium is possible and the block stays, with friction actually providing 10.1 N up the slope. On a slope, R is $mg \cos \theta$, never mg: that substitution is the question's whole point. [4]

SECTION C · Stretch

C1 On the point of sliding, $mg \sin \theta = \mu mg \cos \theta$, and dividing by $mg \cos \theta$ gives $\tan \theta = \mu$: mass and g both vanish. For $\mu = 0.5$ the critical angle is $\tan^{-1} 0.5 = 26.6°$. Tilting a surface until things slip is, in effect, measuring μ with a protractor. [2]