Newton's Laws, Free-Body Diagrams & Friction

Force & Dynamics · 8 questions · step-by-step answers at the end

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USEFUL EQUATIONS

$\Sigma F = ma$ $F_g = mg$ $f_s \le \mu_s N$ $f_k = \mu_k N$ $a = g(\sin\theta - \mu_k \cos\theta)$

Questions

Show your working in the space under each question.

1. A block rests on a ramp with $\mu_s = 0.60$. At what angle does it just start to slide?

2. A 5.0 kg block slides down a 30° incline with $\mu_k = 0.20$. Find the normal force, the friction force and the acceleration.

3. An 800 N person stands on a scale in an elevator accelerating upward at 2.5 m/s². What does the scale read?

4. A 60 kg person stands on a scale in an elevator accelerating downward at 2.0 m/s². What does the scale read?

5. A box rests on a 25° ramp with $\mu_s = 0.60$. Does it slide? If not, how big is the friction force compared with its weight?

6. A 10 kg crate is pulled with 50 N at 30° above horizontal across a floor with $\mu_k = 0.20$. Find a.

7. A horse pulls a cart. By the 3rd law the cart pulls back on the horse equally. So how does anything move?

8. In an Atwood machine, what happens to a and T as $m_2 \gg m_1$?

Step-by-step answers

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1. It slips when $mg \sin\theta = \mu_s mg \cos\theta$, so $\tan\theta = 0.60$ and $\theta \approx$ **31°**. The mass doesn't matter.

2. 1. Perpendicular to the slope: $N = mg \cos 30° = (5.0)(9.8)(0.866) =$ **42.4 N**.
2. Kinetic friction: $f = \mu_k N = (0.20)(42.4) =$ **8.5 N**, pointing up the slope.
3. Along the slope: $mg \sin 30° = (5.0)(9.8)(0.5) = 24.5$ N, pointing down.
4. $\Sigma F = ma \rightarrow 24.5 - 8.5 = 5.0a \rightarrow a =$ **3.2 m/s²** down the slope.

Answer: N = 42 N, f = 8.5 N, a = 3.2 m/s²

3. $N = m(g + a) = (800/9.8)(12.3) \approx$ **1000 N**.

4. $N = m(g - a) = 60(7.8) =$ **468 N**.

5. $\tan 25° = 0.47 < 0.60$, so it **stays put**. $f = mg \sin 25° \approx$ **0.42 mg**, not $\mu_s N$.

6. $N = 98 - 50 \sin 30° = 73$ N; friction = 14.6 N; $a = (43.3 - 14.6)/10 \approx$ **2.9 m/s²**.

7. The two forces act on **different objects**. The horse accelerates because the **ground** pushes it forward harder than the cart pulls back.

8. $a \rightarrow$ **g**, and $T \rightarrow$ **$2m_1 g$**.