**Slide 5: Static Friction**

It's asking about force, probably I need a FBD:

I'm a box with socks

There are four forces:
- I feel: push from person,
- resistance of friction from floor,
- my own weight pushing down,
- and the floor pushing back on me.

I'm not yet sliding

⇒ USE STATIC FRICTION

Remember: you can push harder & harder & still not move something due to STATIC friction. The maximum static friction is:

\[ f_s = M_s N \]

... So to move me this person would have to push harder than \( f_s \) to resist/overcome static friction:

\[ |F_{\text{push}}| \geq f_s \]

So what is \( f_s \)?

First get normal force \( (n) \):

\[ \Sigma F_y = M_a y = 0 \text{ not moving vertically} \]

\[ n - F_g = 0 \]

\[ n = F_g \]

\[ n = mg \]

\[ f_s = M_s N = M_s mg \]

\[ f_s = (0.1)(70)(9.8) \]

\[ f_s = 68.6 N \]

Will start to move if I push harder than this!

Note: Direction of friction is negative here; important if asked for it.
Slide 6: Kinetic Friction

Same set-up as before:

\[ F_k = M_k N = M_k mg \] (got normal force before)

\[ = 0.05(70)(9.8) \]

\[ = 34.3 \text{ N} \]

At least 34.3 N to keep me moving!

If pushed less than this, I'd slide gradually to a stop, and static friction force would apply again once I'm stopped.
will a box accelerate down a ramp?

\[ F_{gx} = ma_x \]

Unless kinetic friction is so strong that it can stop the box on the incline, the \( F_{gx} = ma_x \) (\( x \)-direction acceleration component of gravity facing down the ramp) will accelerate the box down the ramp.

Because \( M_k \) is always smaller than \( M_s \) for a given surface, in this example we know that the box will indeed accelerate down the ramp.
STATIC
FRICITION:
AMAZON
PACKAGE

\[ f_s \leq M_s N \]

\[ f_{s,\text{max}} = M_s N \]

When static friction is overcome, the thing starts to move!
We need gravity force down the ramp to overcome the force of friction.

\[ \sin \theta = \frac{F_{gx}}{F_g} \]
\[ \cos \theta = \frac{F_{gy}}{F_g} \]

\[ F_{gx} = F_g \sin \theta \]
\[ F_{gy} = F_g \cos \theta \]

KNOWNS

\[ m = 2 \text{ kg} \]
\[ M_s = 0.5 \]
\[- F_{gx} = F_g \sin \theta = mg \sin \theta = 2(9.8) \sin \theta = 19.6 \sin \theta \]
\[- F_{gy} = M_s N = M_s F_g \cos \theta = M_s mg \cos \theta = 0.5(2)(9.8) \cos \theta = 9.8 \cos \theta \]

\[ |F_{gx}| = |f_{s,\text{max}}| \]

\[ 19.6 \sin \theta = 9.8 \cos \theta \]
\[ \frac{\sin \theta}{\cos \theta} = \frac{9.8}{19.6} \]
\[ \tan \theta = 0.5 \]
\[ \theta = 26.6^\circ \]

Essentially, you can turn \( F_{gx} \) up & up by raising \( \theta \) until it gets to the critical angle where \( |F_{gx}| = |f_{s,\text{max}}| \)!
Perfectly inelastic:

Two things are attached or stuck after the collision.

Elastic:

No distortion or major losses of energy from dissipation.
(KE is conserved)

Inelastic:

Lots of energy release during collision because of friction, fire, heating, distortion.
Bendy/soft things usually have inelastic collisions
(KE not conserved)
INELASTIC VS ELASTIC VS PERFECTLY ELASTIC

Before  $\rightarrow$  After

$m_1 = m$  \hspace{1cm}  $m_2 = m$

\hspace{1cm}  $\circ \rightarrow \circ$

\hspace{1cm}  $v_{1x} = 5 \text{ m/s}$  \hspace{1cm}  $v_{2x} = 0 \text{ m/s}$

\hspace{1cm}  $v_{1f} = 1.0 \text{ m/s}$  \hspace{1cm}  $v_{2f} = ?$

MOMENTUM ALWAYS CONSERVED
\[ \Sigma p_i = \Sigma p_f \]
\[ m_1 v_{1x} + m_2 v_{2x} = m_1 v_{1f} + m_2 v_{2f} \]
\[ 5 + 0 = 1 + v_{2f} \]
\[ v_{2f} = 4 \text{ m/s} \]

Key Q: IS KE CONSERVED?
\[ \Sigma KE_i = \Sigma KE_f \]
\[ KE_{1x} + KE_{2x} = KE_{1f} + KE_{2f} \]
\[ \frac{1}{2} m v_{1x}^2 + \frac{1}{2} m v_{2x}^2 = \frac{1}{2} m v_{1f}^2 + \frac{1}{2} m v_{2f}^2 \]
\[ \frac{5^2}{2} + 0^2 = \frac{1^2}{2} + \frac{4^2}{2} \]
\[ 25 \neq 1 + 16 \]
\[ 25 \neq 17 \text{ J} \]

LOST 8 J of energy.

INELASTIC: ENERGY NOT CONSERVED
**STUNT MAN**

**Knowns:**
- \( m = 80 \text{ kg} \)
- \( v_0 = 2 \text{ m/s} \)
- \( h = 30 \text{ m} \)
- \( \Delta y = -30 \text{ m} \)
- \( a_y = -9.8 \text{ m/s}^2 \)
- \( a_x = 0 \text{ m/s}^2 \)

**Unknown:** 
- \( v = ? \)

\[
\text{PE}_i = mgh_i = (80)(9.8)(30) \text{ J}\\
\text{PE}_f = mgh_f = (80)(9.8)(0) = 0 \text{ J}\\
\text{KE}_i = \frac{1}{2}mv_0^2 = \frac{1}{2}(80)(2)^2 = 160 \text{ J}\\
\text{KE}_f = \frac{1}{2}mv^2 = \frac{1}{2}(80)v^2\\
\text{KE}_i + \text{PE}_i = \text{KE}_f + \text{PE}_f\\
160 + 23520 = 40v^2 + 0\\
\]

\[
v = 24.3 \text{ m/s}\\
\]
Think what's happening:

If I throw an object with mass, I recoil: same as shooting a gun or throwing a big object from a small boat. Can also think of as Newton's 3rd law: I put a force on the ball and it exerts the same force on me! So I start to move backwards, although I don't move much because I'm massive compared to the ball.

Then I catch it...

\[
\begin{align*}
\frac{m_1v_1}{t_1} &= \frac{m_2v_2}{t_2} \\
\text{momentum still conserved} \\
\text{(always in an isolated system)} \\
\text{So I move more fast towards even wall with each throw & catch.}
\end{align*}
\]

Note: ISS still has air & you can still hold two objects together; thanks still friction.

Note 2: If you're anywhere near Earth, gravity vector always points toward Earth, even in orbit (we will cover this in more detail in a few weeks!)
Answer: D

Acceleration vector decreases; consider $a_x$ for different points on the hill!

You'll know speed increases, too, because you're converting more PE to KE (potential to movement)
They Stuck! Sounds **Perfectly inelastic**

_by conservation of momentum._

Momentum always conserved in a collision.

**Before**

\[
\begin{align*}
  m_1 &= 2m \\
  m_2 &= m \\
  v_{1i} &= v_0 \\
  v_{2i} &= 2v_0
\end{align*}
\]

**After**

\[
\begin{align*}
  m_1 v_{1i} + m_2 v_{2i} &= (m_1 + m_2) v_f \\
  (2m)(v_0) + (m)(-2v_0) &= (2m + m) v_f \\
  2mv_0 - 2mv_0 &= 3mv_f \\
  0 &= 3mv_f \\
  v_f &= 0 \text{ m/s}
\end{align*}
\]

**OH! Actually their momenta cancel → they aren’t moving after, so land in center of arena!**
Promise solutions to next two probs by next week!

(email me if you think you'll want them and I'll remember to post)