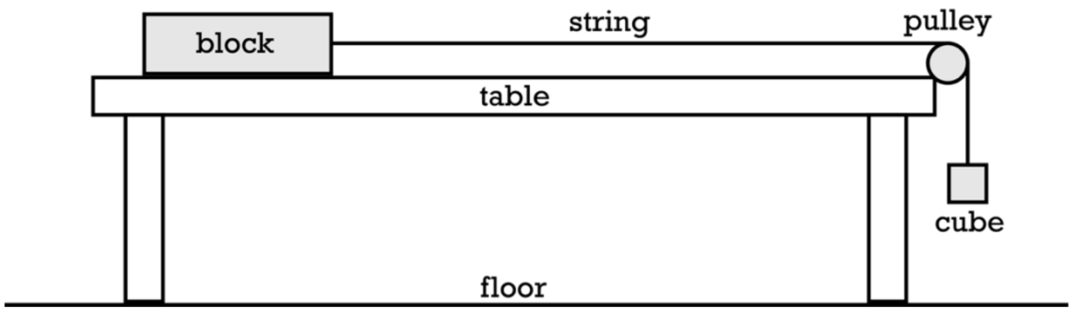
Flipping Physics Lecture Notes:
Friction - AP Physics 1: Dynamics Review Supplement
http://www.flippingphysics.com/ap1-dynamics-friction.html

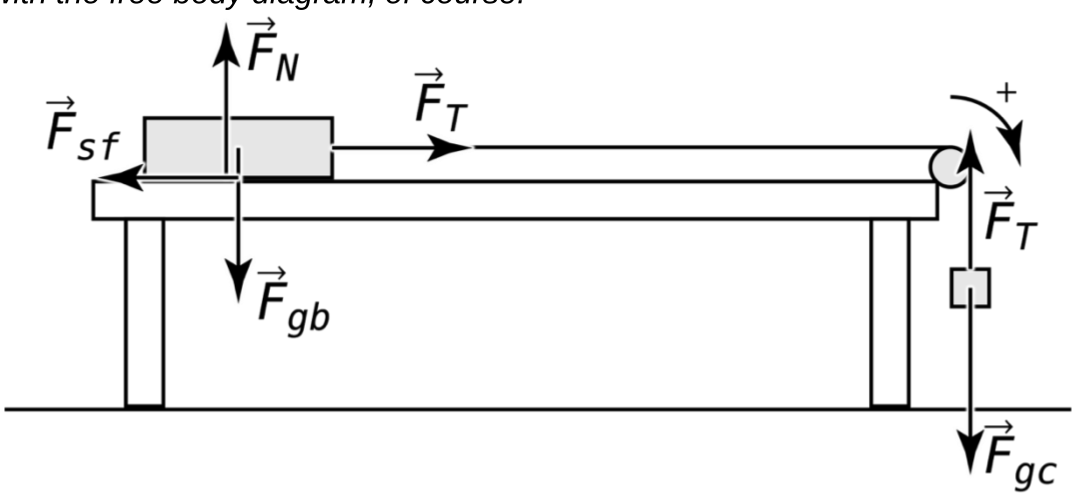
This lesson is a part of my AP Physics 1 Ultimate Review Packet. Please consider signing up for access to the whole Review Packet at www.UltimateReviewpPacket.com!

1) As shown, a block of mass m_b on a table is attached to a string which goes over an ideal pulley and is attached to a cube of mass m_c. The block and cube are currently at rest. If the coefficient of static friction between the block and the table is μ_s, the magnitude of the force preventing the block from accelerating is best described by:



(A) $\mu_s m_b g$ (B) $\mu_s m_c g$ (C) $(m_c + m_b)g$ (D) $m_c g$

Start with the free body diagram, of course!



You can see it is the force of static friction between the block and the table which prevents the block from accelerating. We need to solve for the magnitude of that force of static friction. Defining the positive direction as down and to the right, we can sum the forces on the entire block-cube system in that positive direction:

$$\sum F_+ = F_{gc} - F_T + F_T - F_{sf} = ma_+ = m(0) = 0 \Rightarrow F_{sf} = F_{gc} = m_c g$$

The correct answer is D.

Many of you may want to solve this problem this way…
Sum the forces on the block in the y-direction:

$$\sum F_y = F_N - F_{gb} = m_b a_y = m_b(0) = 0 \Rightarrow F_N = F_{gb} = m_b g$$

and then solve for the force of static friction like this:

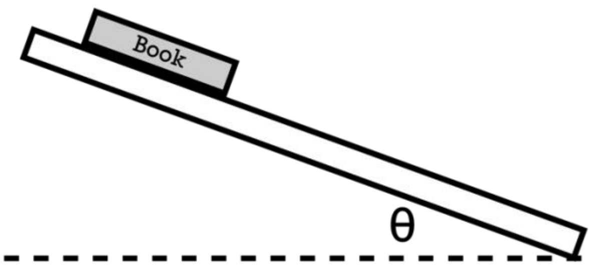
$$F_{sf} = \mu_s F_N = \mu_s m_b g$$

Which would make you think that choice A is correct. However, the equation for the force of static friction you used is not correct. The correct equation for the force of static friction is:

$$F_{sf} \le \mu_s F_N$$

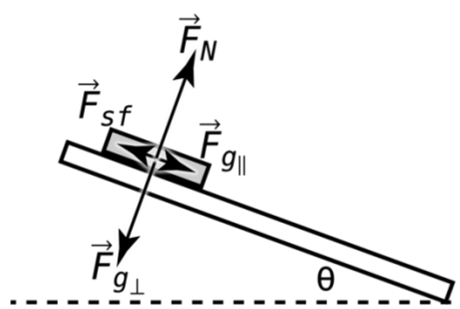
In other words, the force of static friction likely is not at its maximum value, which means you have to solve for the force of static friction the way I did in this problem.

2) A book with mass m is at rest on an incline of angle θ as shown. If the coefficient of static friction between the book and the incline is μ_s, and the coefficient of kinetic friction between the book and the incline is μ_k, which expression best represents the force of friction currently acting on the book?



(A) $\mu_s mg\cos\theta$ (B) $\mu_k mg\cos\theta$ (C) $mg\cos\theta$ (D) $mg\sin\theta$

Start with the free body diagram, of course!



$$\sum F_\parallel = F_{g_\parallel} - F_{sf} = ma_\parallel = m(0) = 0$$

$$F_{sf} = F_{g_\parallel} = mg\sin\theta$$

The correct answer is D.

Many of you may want to solve this problem this way…
Sum the forces on the book in the perpendicular direction:

$$\sum F_\perp = F_N - F_{g_\perp} = ma_\perp = m(0) = 0 \Rightarrow F_N = F_{g_\perp} = mg\cos\theta$$

and then solve for the force of static friction like this:

$$F_{sf} = \mu_s F_N = \mu_s mg\cos\theta$$

Which would make you think that choice A is correct. However, the equation for the force of static friction you used is not correct. The correct equation for the force of static friction is:

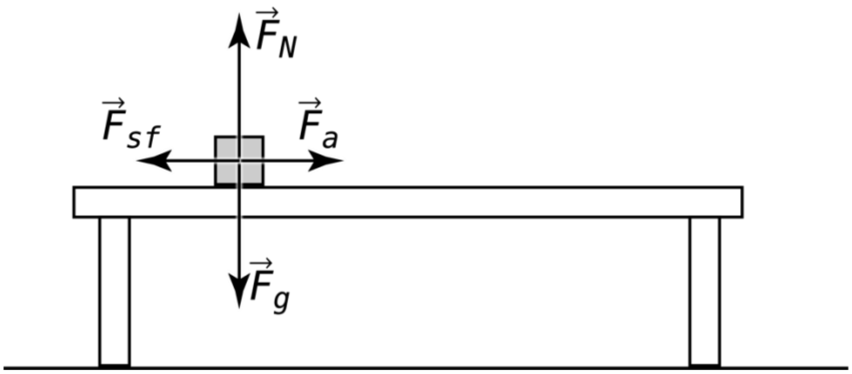
$$F_{sf} \le \mu_s F_N$$

In other words, the force of static friction likely is not at its maximum value, which means you have to solve for the force of static friction the way I did in this problem.
This should seem eerily familiar to you.

3) A 20 kg mass is at rest on a table. A horizontal force of 140 N is applied to a block, however, it is not enough to move the block. Which of the following best describes what we know about the coefficient of static friction between the block and the table?

(A) $\mu_s \geq 0.7$ (B) $\mu_s \geq 1.4$ (C) $\mu_s = 0.7$ (D) $\mu_s = 1.4$

Start with the free body diagram:



Then use Newton's Second Law, twice:

$$\sum F_y = F_N - F_g = ma_y = m(0) = 0 \Rightarrow F_N = F_g = mg$$

$$\sum F_x = F_a - F_{sf} = ma_x = m(0) = 0 \Rightarrow F_a = F_{sf} = \mu_s F_N = \mu_s mg$$

$$\Rightarrow \mu_s = \frac{F_a}{mg} = \frac{140}{(20)(10)} = 0.7$$

It is important to recognize that, because the force of static friction is less than or equal to the coefficient of static friction times force normal, $F_{sf} \leq \mu_s F_N$*, what we have solved for here is the minimum coefficient of static friction to keep the block from moving. In other words, the coefficient of static friction could be equal to or greater than 0.7. The correct answer is A.*

To better help you understand why the coefficient of static friction is equal to or greater than 0.7, let's solve for the force of static friction and force normal in the problem.

$$F_a = F_{sf} = 140N \;\&\; F_N = F_g = mg = (20)(10) = 200N$$

And then solve for the coefficient of static friction using the equation for the force of static friction:

$$F_{sf} \leq \mu_s F_N \Rightarrow 140 \leq \mu_s (200) \Rightarrow 0.7 \leq \mu_s \Rightarrow \mu_s \geq 0.7$$

And you can see the coefficient of static friction between the block and the table is greater than or equal to 0.7 in this problem.

For those of you who challenge this step: $0.7 \leq \mu_s \Rightarrow \mu_s \geq 0.7$

Here it is in several steps instead:

$$0.7 \leq \mu_s \Rightarrow 0.7 < \mu_s \text{ or } 0.7 = \mu_s \Rightarrow \mu_s > 0.7 \text{ or } \mu_s = 0.7 \Rightarrow \mu_s \geq 0.7$$