I : Block Dragging 3

In these problems you are going to consider what happens when you pull on a block that is not yet moving.

Force Number 5. Static Friction

(for forces 1 – 4, consult sections D and F)

Static Friction

A constraint force that prevents items from moving.
- Static friction acts only on objects that are stationary, or on surfaces on slipping against each other.

- It acts only when an object is being pushed or pulled, and is only strong enough to prevent motion. It never creates motion.

-The direction is always whatever direction is necessary to resist motion.

-The magnitude of static friction is given by the following formula:

$$F_{fr} \leq \mu_s F_N$$

- The formula includes a less-than-or-equal sign because static friction is not a set amount but *equals the force it is resisting*. If the resisting force is stronger than the maximum static friction, the object beings moving and kinetic friction takes over.

- Typically, the coefficient of static friction is *greater than* the coefficient of kinetic friction, which is why it is more difficult to *start* an object moving than *keep* it moving.

Symbol	Quantity	SI Unit	Notes
F_{fr}	Magnitude of force of friction	Newtons (N)	
μ_s	Coefficient of static friction	Unitless	A property of the two materials sliding against each other.
F_N	Magnitude of normal force	Newtons (N)	Represents the strength of the connection between two objects.

How to Solve the Following Static Friction Problems:

Preliminary Steps
1. Determine the magnitude of gravity and the normal force

2. Determine the *maximum* magnitude of static friction using the formula $F_{fr} \leq \mu_s F_N$

(maximum force of static friction = coefficient of static friction * normal force)

3. If the applied force is greater than the maximum magnitude of static friction, the box begins moving. [continue to step YES - 4]

If the applied force is less than the maximum magnitude of static friction, the box does not move. [continue to step NO – 4.]

If the box moves:
YES -4. The box experiences *kinetic* friction. Determine the magnitude of kinetic friction using the formula:

$$F_{frK} = \mu_K F_N$$

YES -5. Draw a complete free-body diagram. Determine the net force

YES -6. Determine the acceleration of the box using Newton's Second law.

If the box does not move:
NO -4. The force of static friction will be equal to the applied force acting on the block. This ensures the block does not move.

NO -5. Draw a complete free-body diagram of the block. The net force acting on the block should be equal to zero.

NO -6. Because the net force is zero, the acceleration of the block is equal to zero.

I : Block Dragging 3: Static Friction

I .**1.** [4 points]
A box is at rest on a flat surface with friction. No force is being applied to the box.
Suddenly, a force of 30.0 N is applied to the left.
The mass of the box is 5.00 kg.
The coefficient of static friction between the box and the surface is 0.800.
The coefficient of kinetic friction between the box and the surface is 0.400.

a) Determine the magnitudes of gravity and normal force acting on the block.

b) Determine the *maximum* magnitude of static friction.

c) Determine if the box is moving or not. Explain your reasoning in words.

d) Draw a free-body diagram of the box below. Make sure the forces are properly named and the magnitudes are correct.

e) Explain how you determined the magnitude of the force of friction.

f) If you determined in part (c) that the box *was* moving, determine its acceleration.
For full credit on this question, you must write the formula you are using and properly apply it.
If you determined in part (c) that the box was not moving, write that acceleration is zero and explain why by explicitly referring to one of Newton's Laws.

I : Block Dragging 3: Static Friction

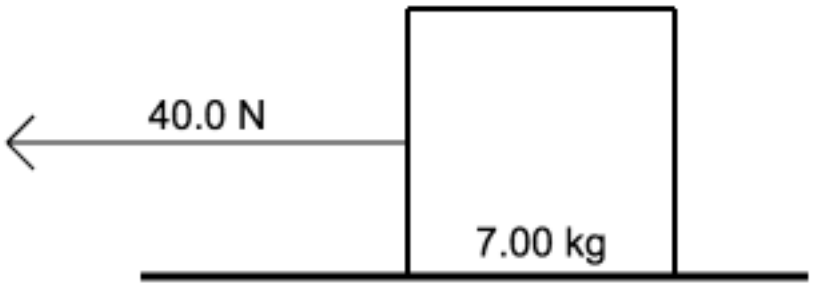
I .**2.** [4 points]
A box is at rest on a flat surface with friction. No force is being applied to the box.
Suddenly, a force of 40.0 N is applied to the left.
The mass of the box is 7.00 kg.
The coefficient of static friction between the box and the surface is 0.750.
The coefficient of kinetic friction between the box and the surface is 0.500.

a) Determine the magnitudes of gravity and normal force acting on the block.

b) Determine the *maximum* magnitude of static friction.

c) Determine if the box is moving or not. Explain your reasoning in words.

d) Draw a free-body diagram of the box below. Make sure the forces are properly named and the magnitudes are correct.



e) Explain how you determined the magnitude of the force of friction.

f) If you determined in part (c) that the box *was* moving, determine its acceleration.
For full credit on this question, you must write the formula you are using and properly apply it.
If you determined in part (c) that the box was not moving, write that acceleration is zero and explain why by explicitly referring to one of Newton's Laws.

Block Dragging 3: Static Friction

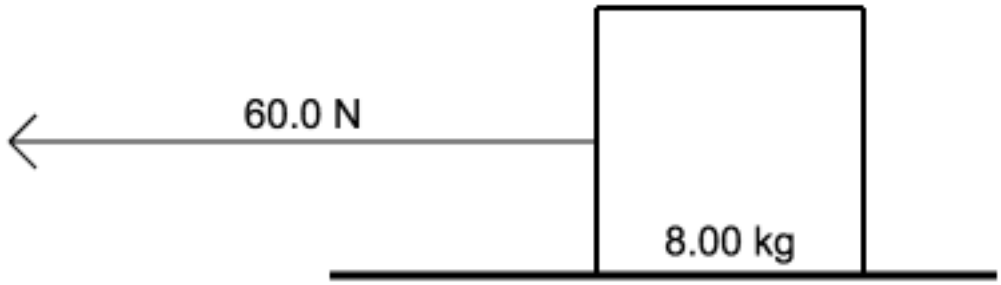
3. [4 points]
A box is at rest on a flat surface with friction. No force is being applied to the box.
Suddenly, a force of 60.0 N is applied to the left.
The mass of the box is 8.00 kg.
The coefficient of static friction between the box and the surface is 0.700.
The coefficient of kinetic friction between the box and the surface is 0.450.

a) Determine the magnitudes of gravity and normal force acting on the block.

b) Determine the *maximum* magnitude of static friction.

c) Determine if the box is moving or not. Explain your reasoning in words.

d) Draw a free-body diagram of the box below. Make sure the forces are properly named and the magnitudes are correct.



e) Explain how you determined the magnitude of the force of friction.

f) If you determined in part (c) that the box *was* moving, determine its acceleration.
For full credit on this question, you must write the formula you are using and properly apply it.
If you determined in part (c) that the box was not moving, write that acceleration is zero and explain why by explicitly referring to one of Newton's Laws.

4: A crucial error:

A physics student receives the following problem: "A box with a mass of 4 kg that is initially not moving is pulled to the right by an applied force of 28 N to the right. The coefficient of static friction between the block and the ground is 0.8 and the coefficient of kinetic friction is 0.3. Draw a correct free-body diagram of the block."

He completes the following calculations:

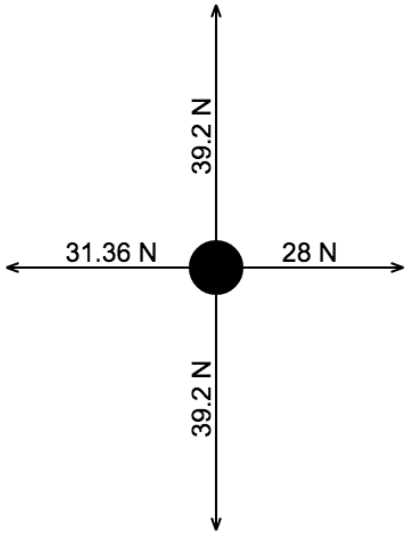
Gravity = mg = 4 * 9.8 = 39.2 N down

Normal Force = 39.2 N up

Static Friction = $F_N \mu_s$ = 39.2 * 0.8 = 31.36 N left.

Applied Force = 28 N right

Then he draws the following free-body diagram.



He writes
"the block does not move because the force of static friction is greater than the applied force."
This student made a key error!

a) Point out the mistake this student made.

b) Was the student correct that the box does not move? Explain why:

c) If the box actually had the free-body diagram the student drew, it would do something very unexpected! Explain what would happen, and why this could not possibly be the correct free-body diagram.

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.5: Complete analysis:

A box is stationary on a floor with friction. [not a ramp this time] The mass of the block is 2.00 kg. A force of 5.00 Newtons is pushing the block, but it is stationary. The coefficient of static friction is 0.8 and the coefficient of kinetic friction is 0.400.

Which type of friction affects the box, static or kinetic?

Free-Body Diagram		
Force	Magnitude	How do you determine the magnitude?

What is the maximum static friction?

5 continued:

The person pushing the box slowly increases the force she exerts on it. For each force, state if the box will begin moving or not. If it is moving, find the net force and acceleration.

Force	Will the box begin moving?	Static or kinetic friction?	Magnitude of frictional force:	Net Force	Acceleration
5.00 N					
10.0 N					
15.0 N					
18.0 N					
20.0 N					

Block Dragging 3: Static Friction

ANSWERS:

1-
gravity: 49 N DOWN
normal force: 49 N UP
max static friction = 39.2 N
The box does not move.
The actual force of static friction is 30.0 N right
a = 0

2 –
gravity: 68.6 N DOWN
normal force: 68.6 N UP
max static friction: 51.45 N
The box does not move.
The actual force of static friction is 40.0 N right.
a = 0

3 –
gravity: 78.4 N DOWN
normal force: 78.4 UP
max static friction: 55.1
The box begins to move:

kinetic friction: 35.3 N RIGHT
net force = 24.7 N LEFT
acceleration = 3.08 m/s^2 LEFT

4.

a) The student confused static friction with *maximum* static friction. The value he calculated for static friction was actually the maximum static friction.
The actual value of static friction is not the maximum, but whatever value is necessary to prevent motion.
In this case, the value of static friction would equal to the magnitude of the applied force, 28 N, so that the net force on the block would be zero.

b) Yes, the student was correct when he said that the box does not move, he only forgot to include the word "maximum" static friction. The block does not move because the applied force is less than *maximum* static friction.

c) In the free-body diagram the student drew, the net force is 3.36 N to the LEFT. Thus, the box would begin accelerating to the left! Of course, nothing in reality would begin moving to the left if you pulled it to the right.

5:

Force	Will the box begin moving?	Static or kinetic friction?	Magnitude of frictional force:	Net Force	Acceleration
5 N	no	static	5 N	0	0
10 N	no	static	10 N	0	0
15 N	no	static	15 N	0	0
18 N	yes	kinetic	7.848 N	10.152 N	5.08 m/s^2
20 N	yes	kinetic	7.848 N	12.152 N	6.08 m/s^2