Biggest Error in Last Section: Using the wrong sign for force (It depends on if your force points in the direction you called positive) $\vec{F}_G = weight = mg$ +yGround $\sum F_v = -F_G = -mg$

<u>Second biggest</u>: g=+9.8m/s2, but you figure out the sign of the force based upon its direction with respect to the direction you called positive.



My Icy Driveway

When my driveway is a sheet of ice (ignore friction on slope), (a) how fast do I need to be driving to get to the top of my driveway? (b) Is this feasible on an icy day?



So, how could I get out of my driveway?

Main Ideas in Class Today

- Kinetic Friction
- Static Friction
- Friction w/Inclines
- Solving Problems



FRICTION IS A FORCE THAT ACTS IN AN OPPOSITE DIRECTION TO MOVEMENT.

Extra Practice: 4.23, 4.27, 4.29, 4.31 (harder), 4.43, 4.49, 4.77, 4.79

Friction

Kinetic friction: force that opposes the motion of an object when sliding against a surface (even air causes air resistance)



FRICTION IS A FORCE THAT ACTS IN AN OPPOSITE DIRECTION TO MOVEMENT.

Friction is the reason you always have to put energy into machines in order for them to continue working.



Why we have not yet discovered a real perpetual motion machine (where no energy is required). Most scientists think it's not possible.

The amount of friction between two objects depends upon how smooth or rough the surfaces are. No surface is perfectly smooth.

Kinetic Friction (f_k) :

friction when moving, slows you down

- $f_k = \mu_k n$ (Greek letter μ is pronounced "mu")
 - μ_k is coefficient of kinetic friction, depends on surfaces (table 4-2 in book gives examples)
 - equation valid for magnitudes only (\neq vector formula) since $\mathbf{f}_{k\perp} \mathbf{n}$

Coefficients of Friction		
Materials	Static Friction	Kinetic Friction
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Wood on brick	0.60	0_45
Copper an steel	0.53	0_36
Rubber an cancrete	1.0	0_80
Wood on wood	0_25 - 0_50	0_20
Glass on glass	0_94	0_40
Waxed wood on wet snow	0.14	0_10
Waxed wood on dry snow	_	0_040
Metal on metal (lubricated)	0.15	0_060
Ice on ice	0_10	0_030
Teflon on teflon	0.040	0_040
Synovial Joints in humans	0_010	0_0030

oull

Draw a free body diagram

If you are pulling this, do you want much friction?

Stopping distance

a) After brief shove or pull, what is the acceleration of the object if $\mu_k = 0.4$? b) If it starts at a velocity of 10 m/s, how far will it go before it stops?



coefficient of kinetic friction is 0.4

	Coefficients of Friction	
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Steel on steel	0_57	
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Waxed wood on dry snow	0_040	
Metal on metal (lubricated)	0_060	
Ice on ice	0_030	
Tefion on tefion	0_040	
Synovial Joints in humans	0.0030	

 $+\mathbf{X}$

Static Friction

• Force that keeps object from sliding against a surface when it is at rest

 $f_{\text{stat}} \leq \mu_{\text{s}} n$

- μ_s is coefficient of static friction, also depends on surface
- equation valid for magnitudes only (\neq vector formula)
- Static friction force increases with applied force until

	Coefficients of Frictio
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Ice on ice	0_10
Tefion on tefion	0_040
Synovial Joints in humans	0_010



Once it starts moving, kinetic friction takes over. Why it is easier to move something after it gets started moving.

Hockey puck

A hockey puck is struck by a hockey stick and given an initial speed of 20.0 m/s on a frozen pond. The puck remains on the ice and slides 120 m, slowing down steadily (meaning constant acceleration) until it comes to rest. **Determine the coefficient of kinetic friction between the puck and the ice.**



A cart (weight w_1) is attached by a lightweight cable to a bucket (weight w_2) as shown. The ramp is frictionless.



When released, the cart accelerates up the ramp.

Which of the following is a *correct* free-body diagram for the *cart*?



An object is held in place by friction on an inclined surface. The angle of inclination is increased until the object starts moving. If the surface is kept at this angle, the object

- **A.** slows down.
- **B.** moves at uniform speed.
- **C.** speeds up.
- **D.** none of the above



This person weighs 170 lb. Each crutch makes an angle of $\theta = 22.0^{\circ}$ with the vertical (as seen from the front). Half of the person's weight is supported by the crutches, the other half by the vertical forces exerted by the ground on his feet.

Assuming he is at rest and the force exerted by the ground on the crutches acts along the crutches, determine the smallest possible coefficient of friction between crutches and ground. A cable attached to a car **pulls the car up** the ramp (angle α).

Which direction should friction point?

B.



C. The second se

E. not enough information given to decide



A cable attached to a car lowers the car down the ramp (angle α).

Which direction should friction point?

B.

C.



