Another thing FBDs are good for: Inclined Planes

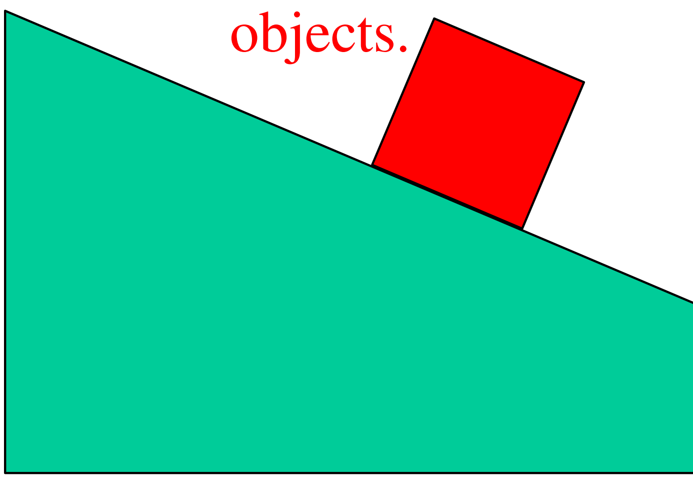
Physics is infamous for sliding blocks down inclined planes

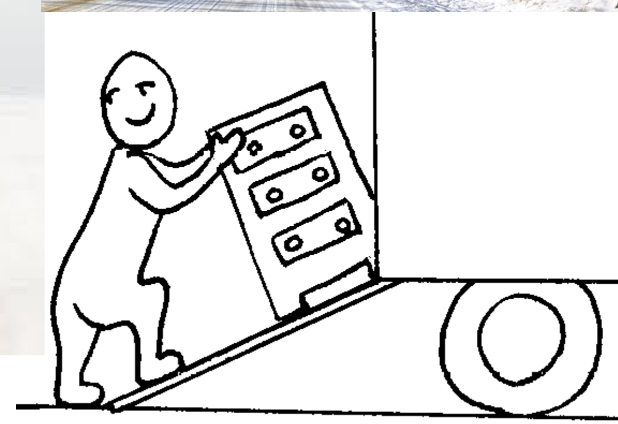
How boring! Why do we study it?

Many things we do involve inclines.

Blocks are an easy way to simplify many complex objects.

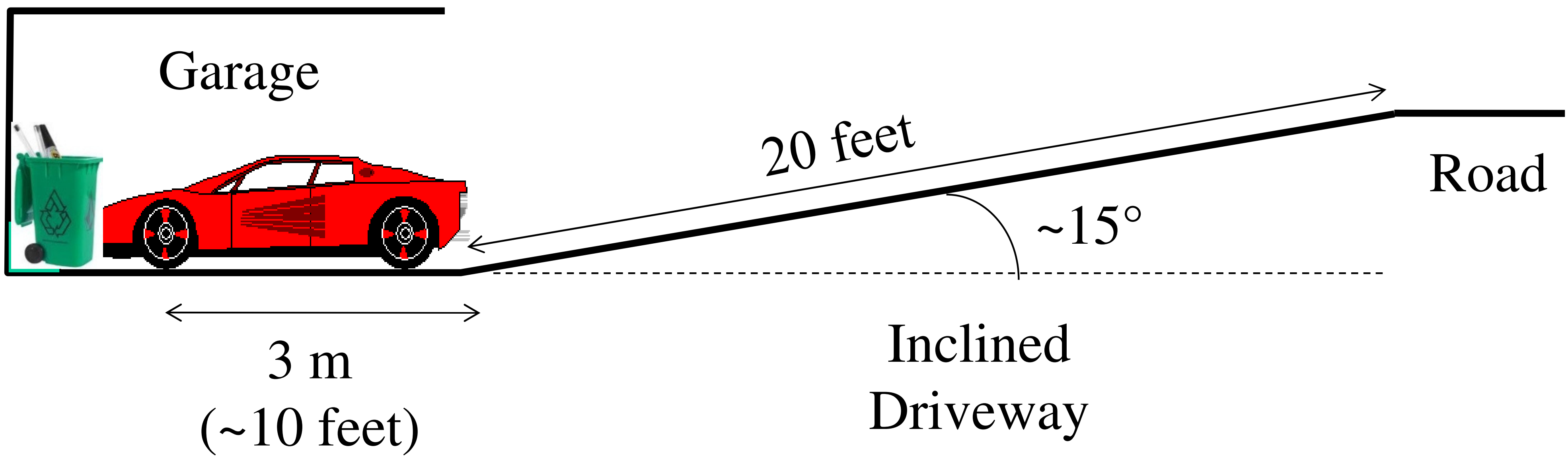
In physics, we approximate things as blocks or round objects.





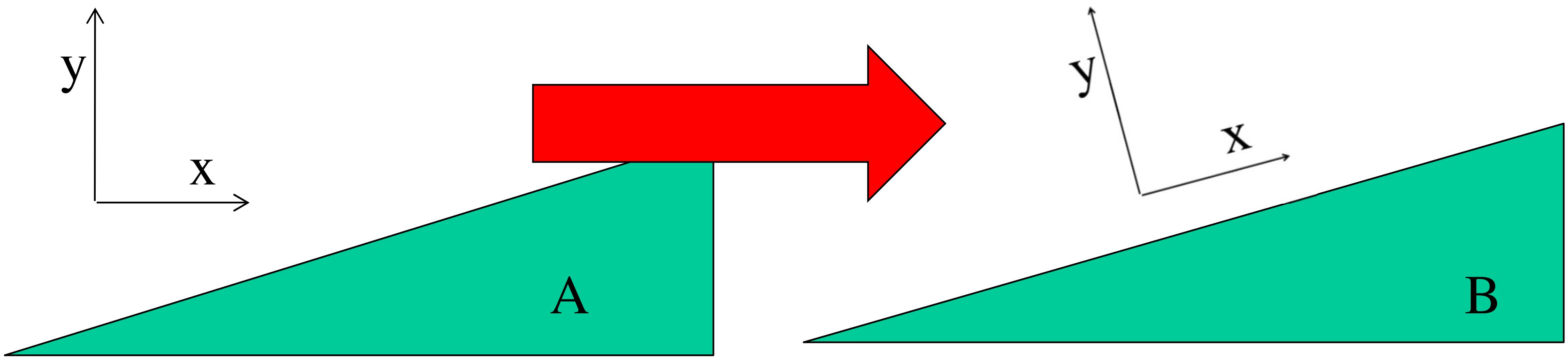
A real example: My Icy Driveway

When my driveway is a sheet of ice (ignore friction), how fast do I need to be driving to get to the top of my driveway?



Making 2 dimensions only 1!

Better, unless if going around an inclined curve (Ch. 7)



Why would I change x and y?

In Case A, need v_x, v_y, Δx, Δy?

Have to break up the vector components

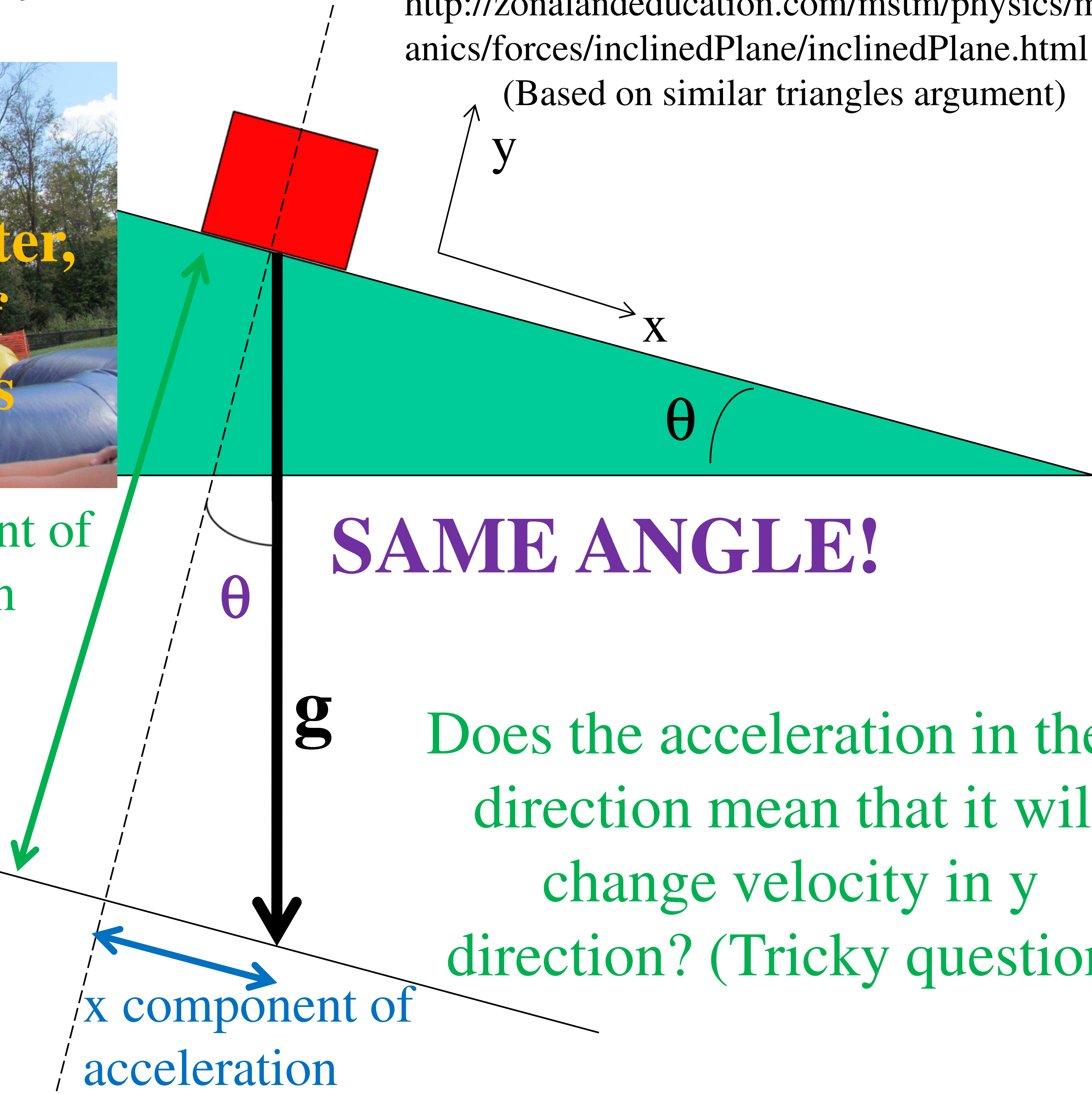
In Case B: $\Delta y=0$, $v_y=0$

Acceleration changes though: $a_x=\pm 9.8 \sin\theta$

Why $a_{g,x} = \pm 9.8 \sin\theta$?

http://zonalandeducation.com/mstm/physics/mechanics/forces/inclinedPlane/inclinedPlane.html

(Based on similar triangles argument)



Breaking up vector components:

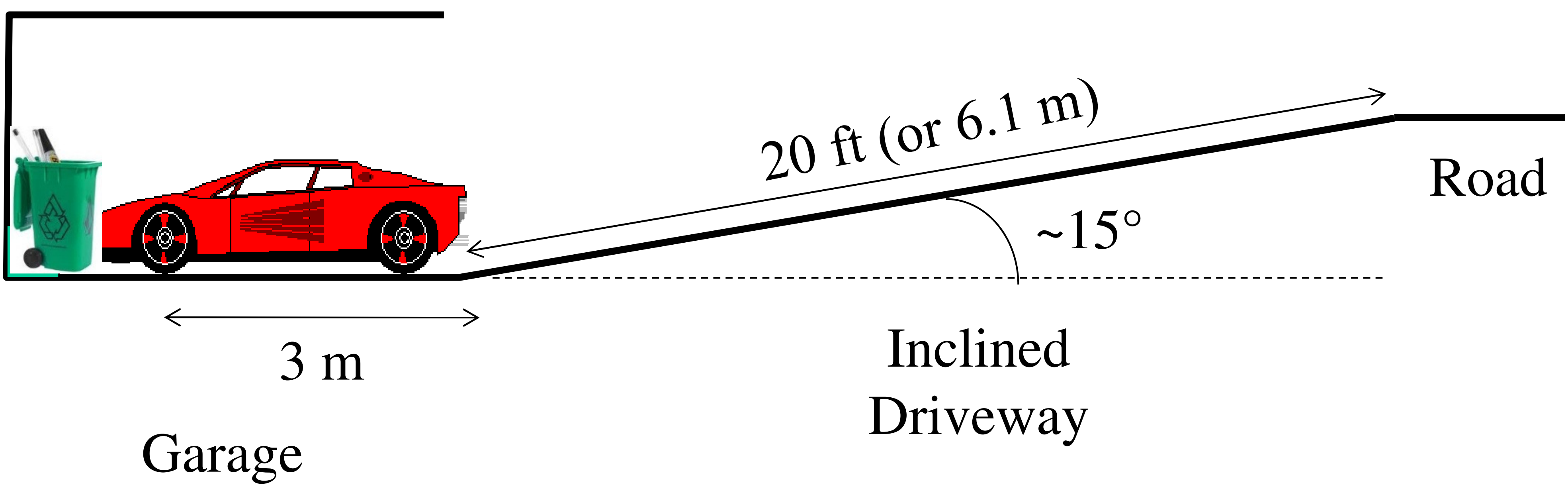
Draw a line parallel to y axis from start of the vector

Draw a line parallel to x axis from end of vector

Does the acceleration in the y direction mean that it will change velocity in y direction? (Tricky question)

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? (c) Is it feasible if my car was not in a garage?

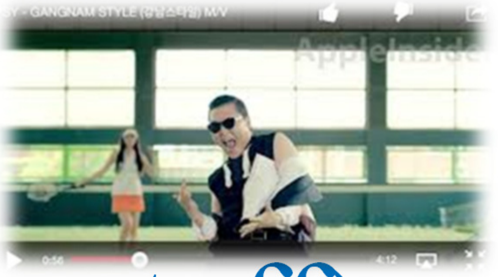


Acceleration of starting for a typical car is only 0.5g. So, how could I get out of my driveway?

http://www.youtube.com/watch?v=rzEhNCbu1_g

Introduction to Friction

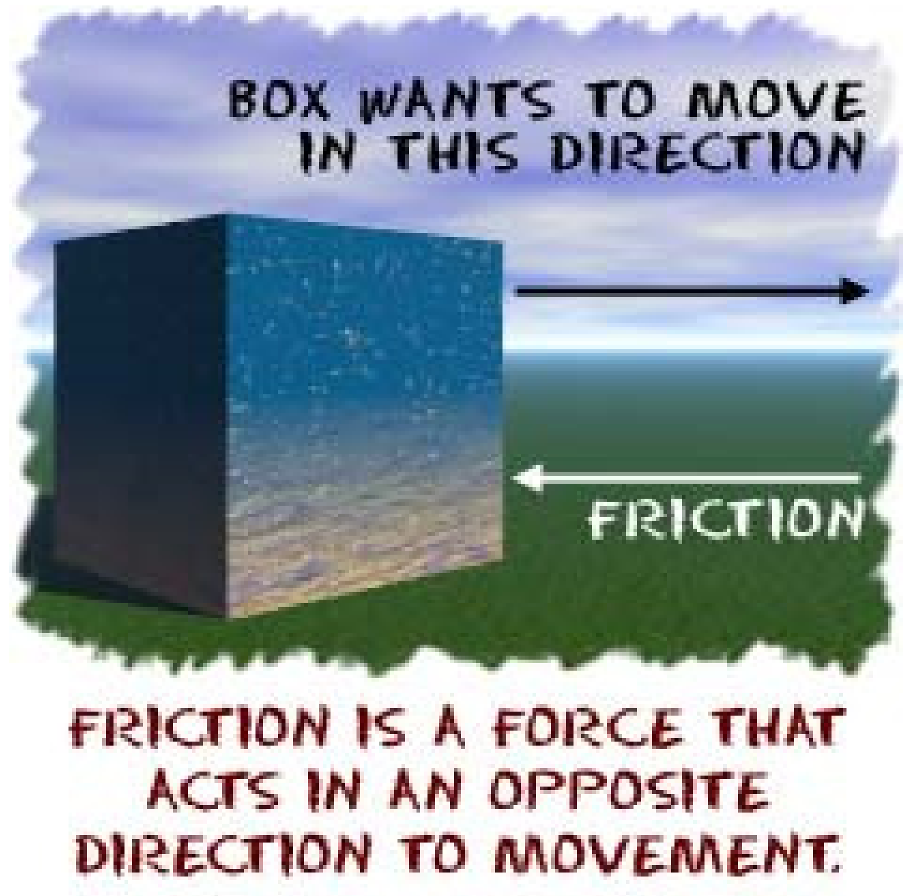
YouTube is a wonderful resource for physics videos



(in addition to other fun/silly stuff)

Main Ideas in Class Today

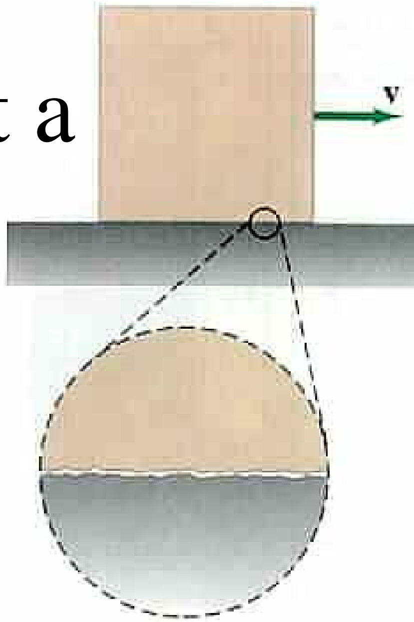
- Kinetic Friction
- Static Friction
- Friction w/Inclines
- Solving Problems

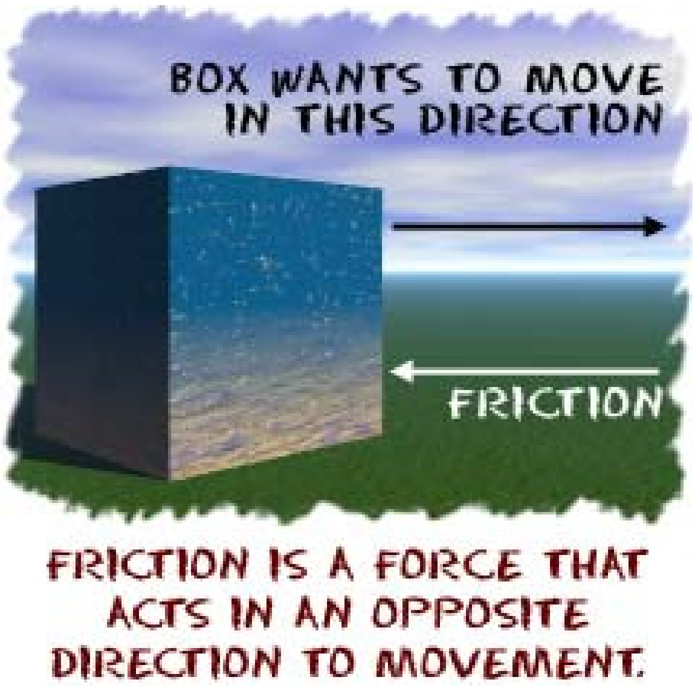


Extra Practice: 4.23, 4.27, 4.29, 4.31 (harder), 4.43, 4.49, 4.77, 4.79

Friction

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





Friction is 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 (≠ 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 on steel	0.53	0.36
Rubber on concrete	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

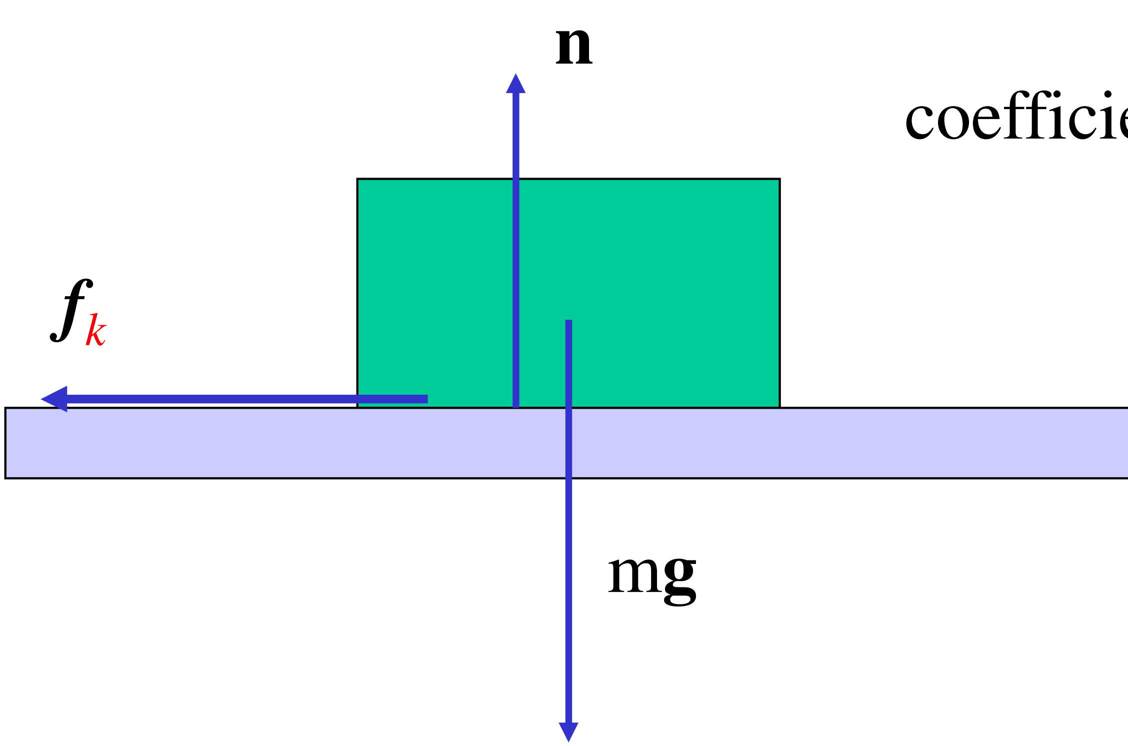
Draw a free body diagram

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

Stopping distance

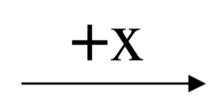
a) After brief shove or pull, what is the acceleration of the object if μ_k=0.4?

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
Materials	Kinetic Friction
Steel on steel	0.57
Aluminum on steel	0.47
Wood on brick	0.45
Copper on steel	0.36
Rubber on concrete	0.80
Wood on wood	0.20
Glass on glass	0.40
Waxed wood on wet snow	0.10
Waxed wood on dry snow	0.040
Metal on metal (lubricated)	0.060
Ice on ice	0.030
Teflon on teflon	0.040
Synovial Joints in humans	0.0030



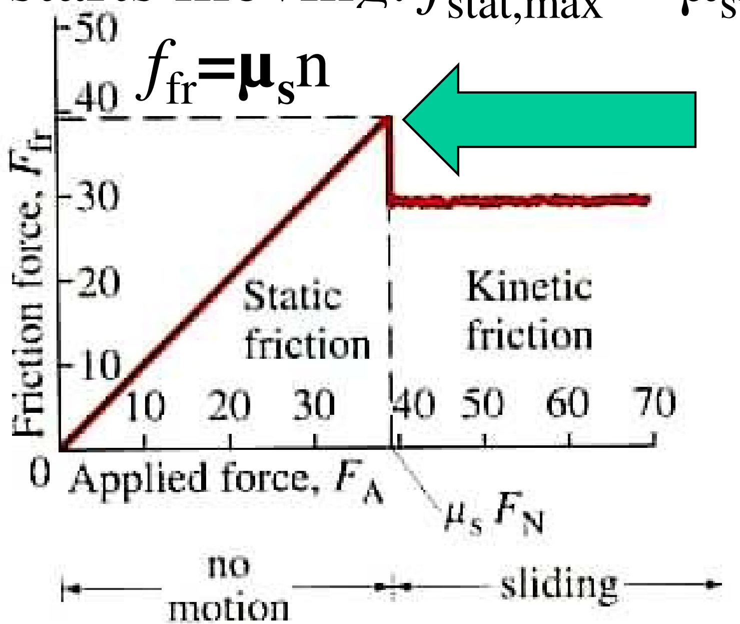
Static Friction

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

$$f_{stat} \le \mu_s n$$

- 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 object starts moving: $f_{stat,max} = \mu_s n$

	Coefficients of Friction
Materials	Static Friction
Steel on steel	0.74
Aluminum on steel	0.61
Wood on brick	0.60
Copper on steel	0.53
Rubber on concrete	1.0
Wood on wood	0.25 – 0.50
Glass on glass	0.94
Waxed wood on wet snow	0.14
Waxed wood on dry snow	–
Metal on metal (lubricated)	0.15
Ice on ice	0.10
Teflon on teflon	0.040
Synovial Joints in humans	0.010

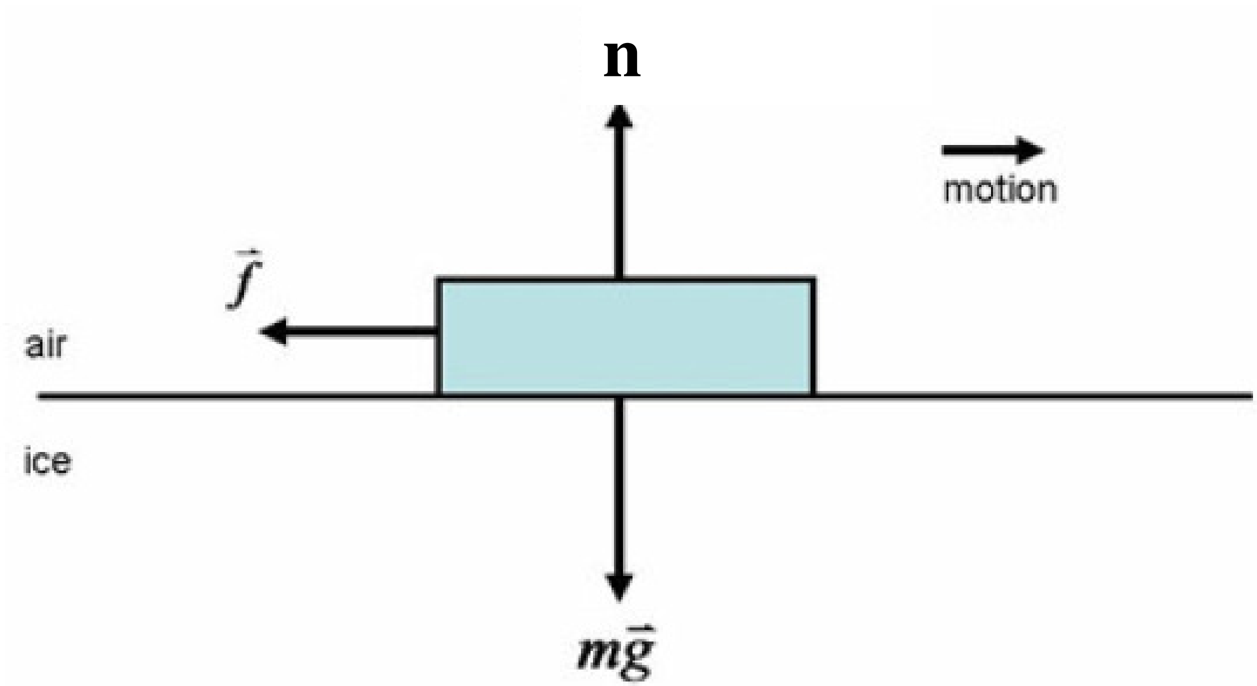


Once it starts moving, kinetic friction takes over.

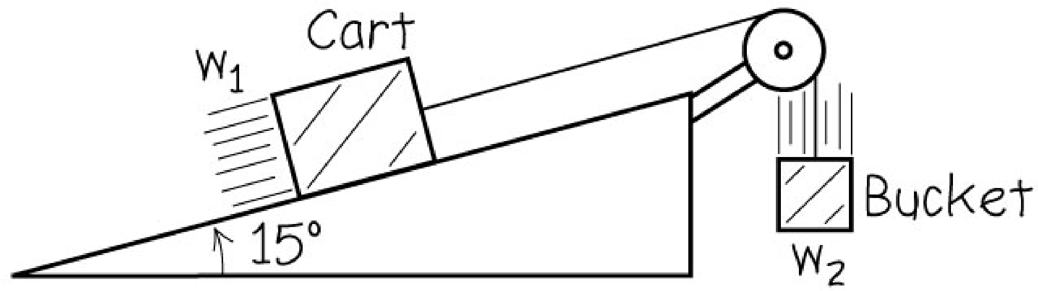
Why it is easier to move something after it gets started moving.

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.**

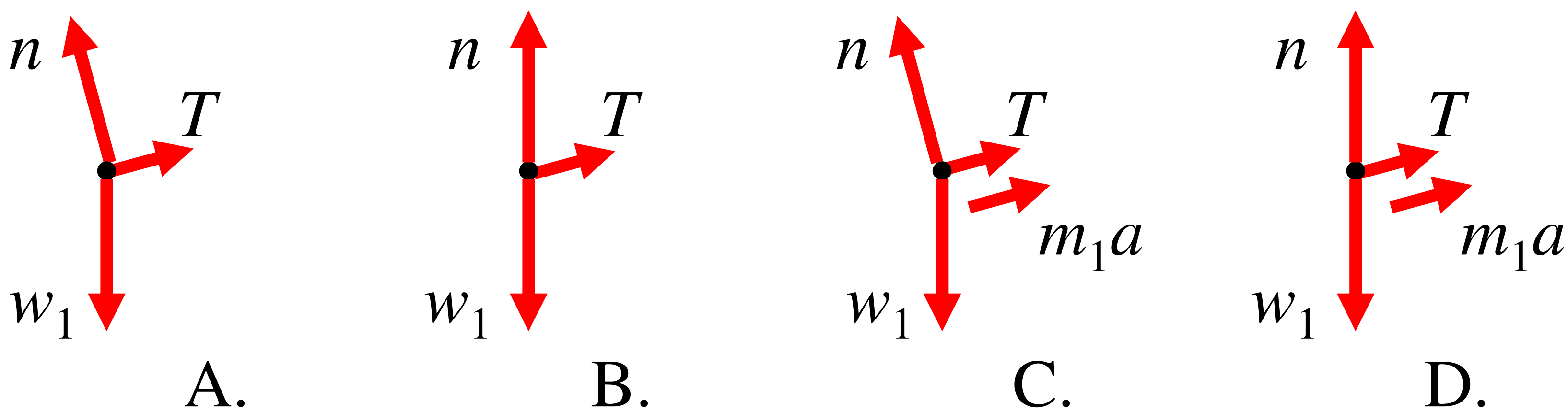


A cart (weight w_1) is attached by a lightweight cable to a bucket (weight w_2) as shown. The ramp is frictionless.



When released, the cart accelerates up the ramp.

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



Q44

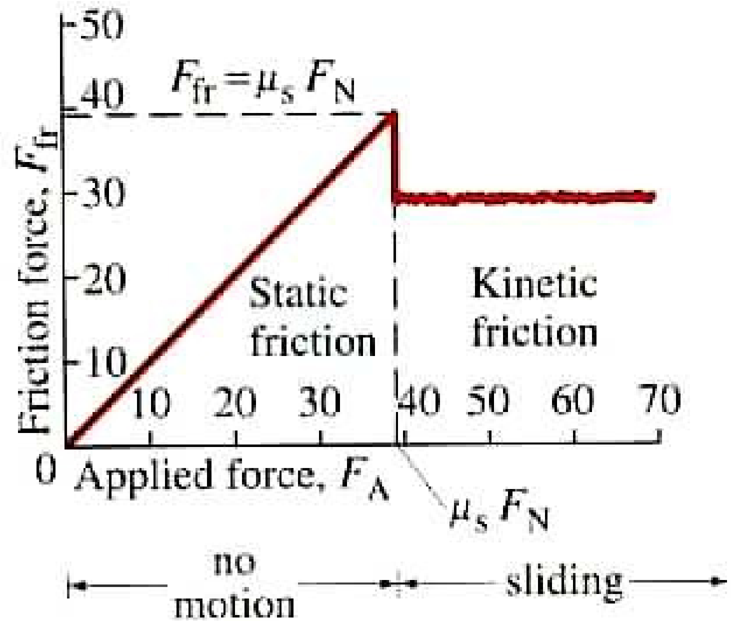
An object is held in place by friction on an inclined surface. The angle of inclination is increased until the object starts moving. If the surface is kept at this angle, the object

A. slows down.

B. moves at uniform speed.

C. speeds up.

D. none of the above



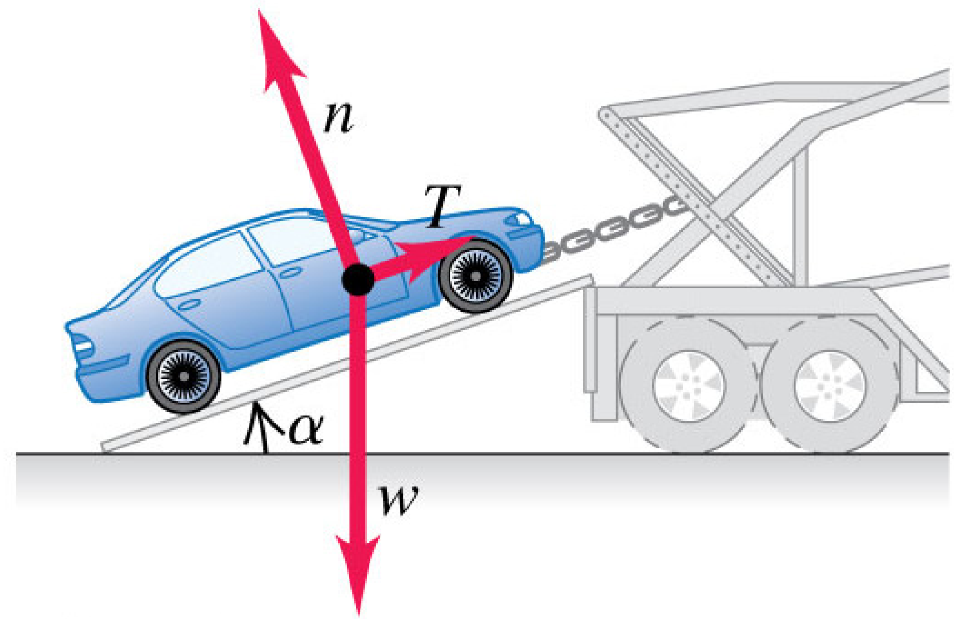
Q51

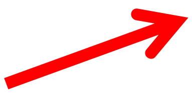
This person weighs 170 lb. Each crutch makes an angle of $\theta = 22.0°$ with the vertical (as seen from the front). Half of the person's weight is supported by the crutches, the other half by the vertical forces exerted by the ground on his feet.

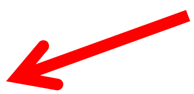
Assuming he is at rest and the force exerted by the ground on the crutches acts along the crutches, determine the smallest possible coefficient of friction between crutches and ground.

A cable attached to a car **pulls the car up** the ramp (angle α).

Which direction should friction point?



A. 

B. 

C. 

D. 

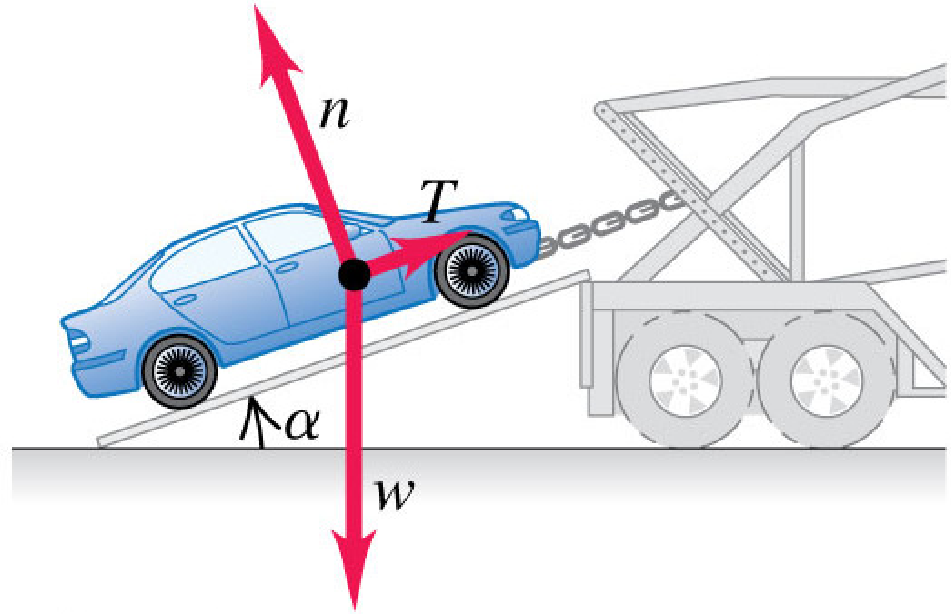
E. not enough information given to decide

Inclines & Friction

Q48

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

Which direction should friction point?



A. ↗

B. ↙

C. ↑

D. ↓

E. not enough information given to decide

Q49

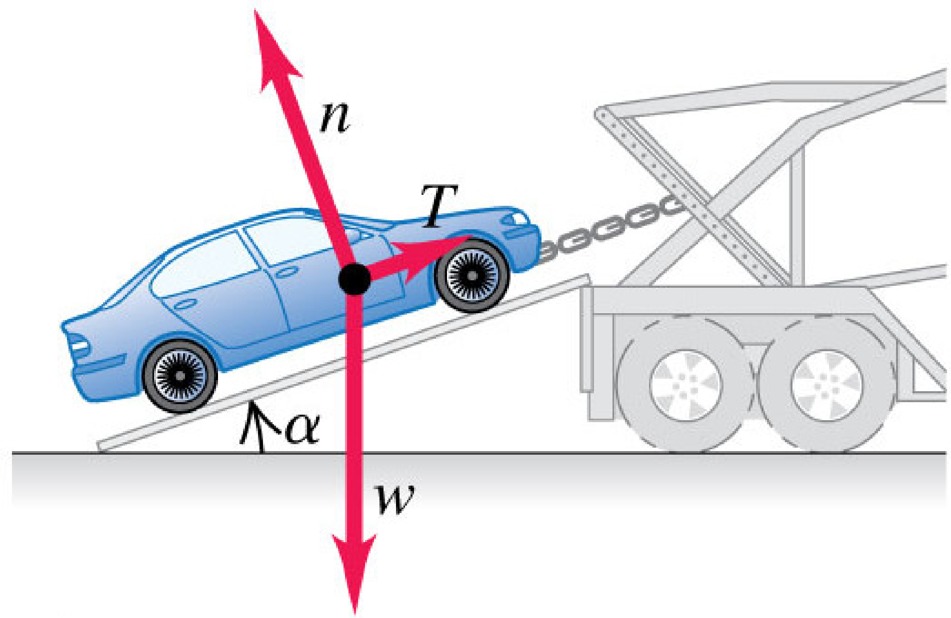
Clicker Answers

Chapter/Section: Clicker #=Answer

44=A, 48=B, 49=A, 50=A, 51=C

A cable attached to a car holds the car at rest on the frictionless ramp (angle α).

The ramp exerts a normal force on the car. How does the magnitude n of the normal force compare to the weight w of the car?



A. $n = w$

B. $n > w$

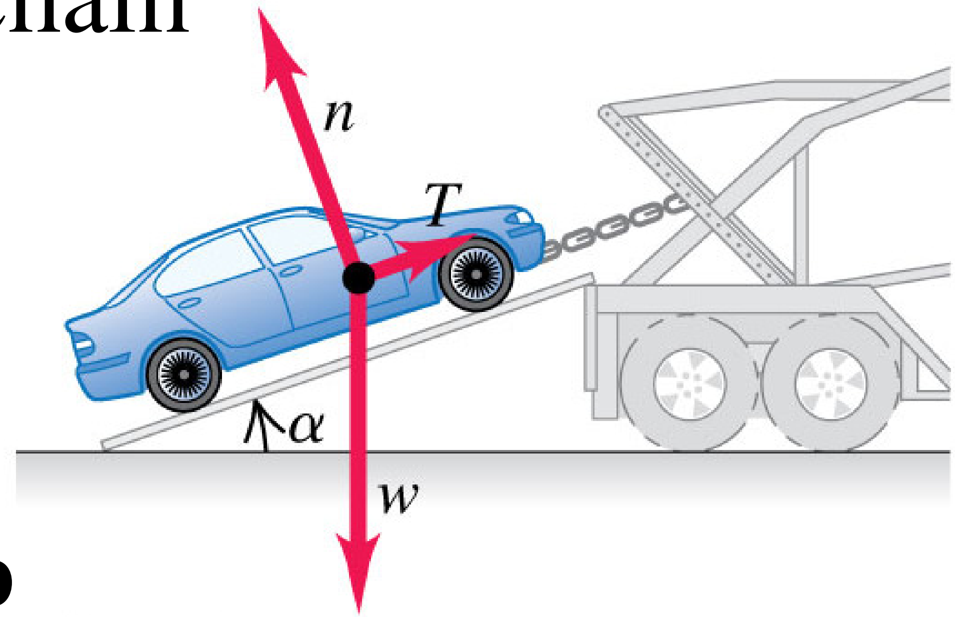
C. $n < w$

D. not enough information given to decide

Q45

If the cable moves at a constant speed, in which case (if any) would the tension in the chain be larger?

(Harder)



A. **When car goes up ramp**

B. **When car goes down ramp**

C. **Both cases would have the same tension**

D. **Not enough information given to determine**

Q50

You are pushing a wooden crate across the floor at constant speed. You decide to turn the crate on end, reducing by half the surface area in contact with the floor. In the new orientation, to push the same crate across the same floor with the same speed, the force that you apply must be about

A. four times as great
B. twice as great
C. equally great
D. half as great
E. one-fourth as great

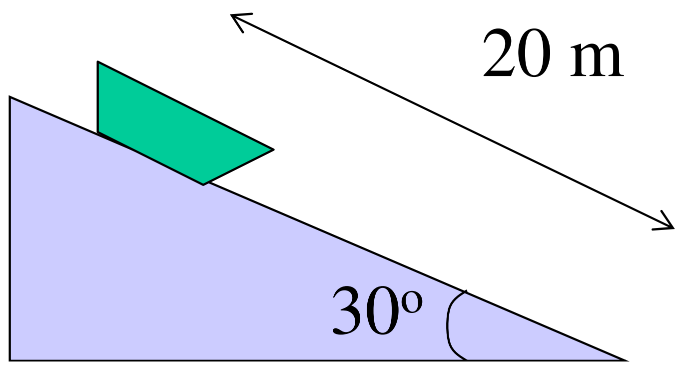
as the force required before you changed the crate's orientation.

Q52

A 20 kg sled slides down a 30° hill after receiving a tiny shove (only enough to overcome static friction, not enough to give significant initial velocity, assume $v_o=0$).

A) If there is friction of $\mu_k=0.1$, what is the acceleration of the sled? B) If the length of the hill is 20 m, how long does it take the sled to reach the bottom of the hill if it starts from rest?

Inclines & Friction



Rolling Along or Not

(Not obvious, but useful to know)

What kind of friction allows you to roll things? For example, your car tires on the road.

A) Static friction

B) Kinetic friction

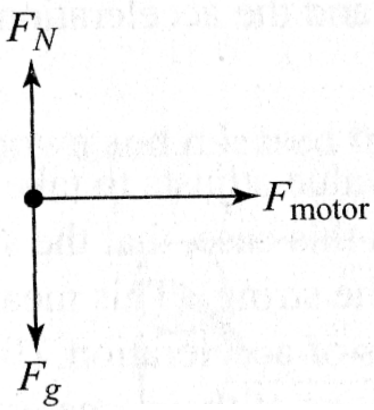
C) Both

D) Neither

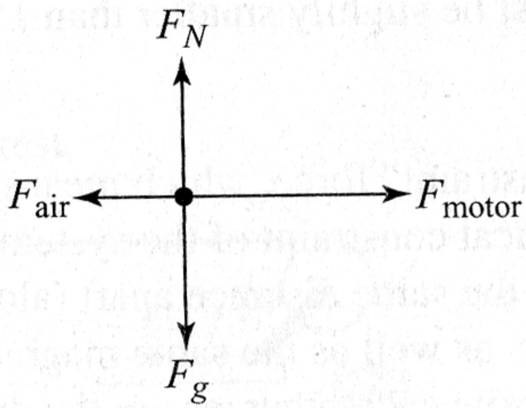
Q53

Q47

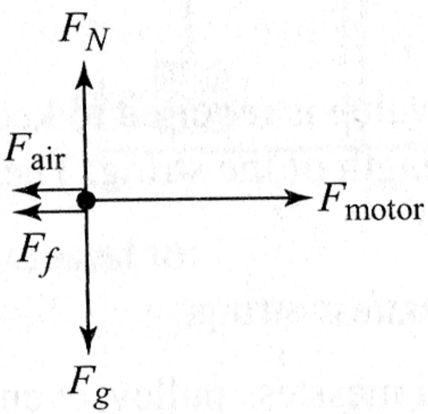
Forces on Cars



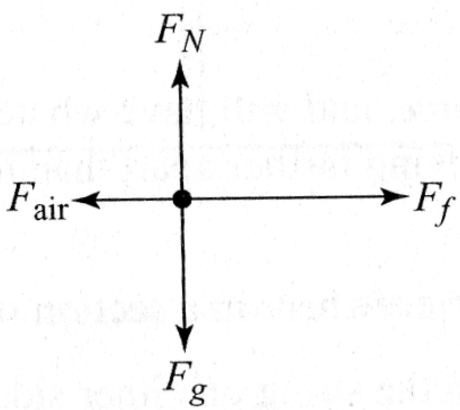
(a)



(b)

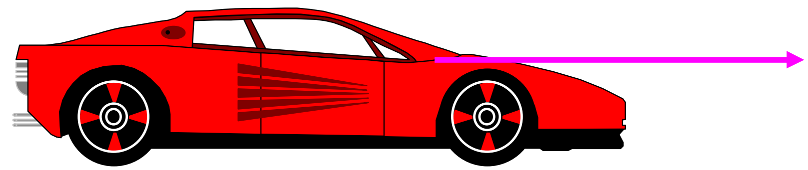


(c)



(d)

(e) None of the Above



A car accelerates down a straight highway. Which of the free-body diagrams shown best represents the forces on the car?

Friction prevents the wheels from just spinning in place. This is why a car on ice sometimes can’t move.

Clicker Answers

Chapter/Section: Clicker #=Answer

44=A, 45=C, 46=D, 47=E, 48=B, 49=A, 50=A, 51=C, 52=C, 53=A