Welcome back to Physics 211

Today's agenda:

- *Newton's Third Law*
- *Free Body Diagrams*

Newton's Laws

First Law: In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with constant velocity.

Second Law: $\boldsymbol{F}_{\text{net}} = \sum \boldsymbol{F}_{\text{on object}} = m\,\boldsymbol{a}$

Third Law: $\boldsymbol{F}_{\text{AB}} = -\,\boldsymbol{F}_{\text{BA}}$ ("action = reaction")

[regardless of type of force and of motion of objects in question]

6-2.1 Consider a person sitting on a chair. We can conclude that the **downward weight force on the person** (by the Earth) and the **upward normal force on the person** (by the chair) are equal and in opposite directions, because

1. the net force on the person must be zero
2. the two forces form a Newton's third-law pair
3. neither of the above explanations
4. both of the above explanations

6-2.2 There are two people facing each other, each on a separate cart. If person A pushes on person B, while person B does nothing, what will be the resulting motion of the carts?

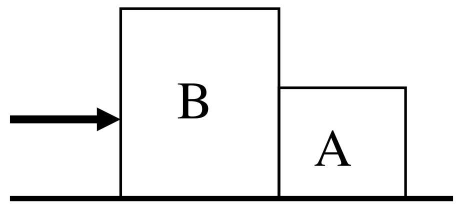
1. Cart A doesn't move and Cart B moves backwards
2. Cart B doesn't move and Cart A moves backwards
3. Both carts move in opposite directions
4. Neither cart moves

6-2.3 Two carts collide on a level track. Cart A has twice the mass of cart B and is initially moving, while cart B is initially at rest.

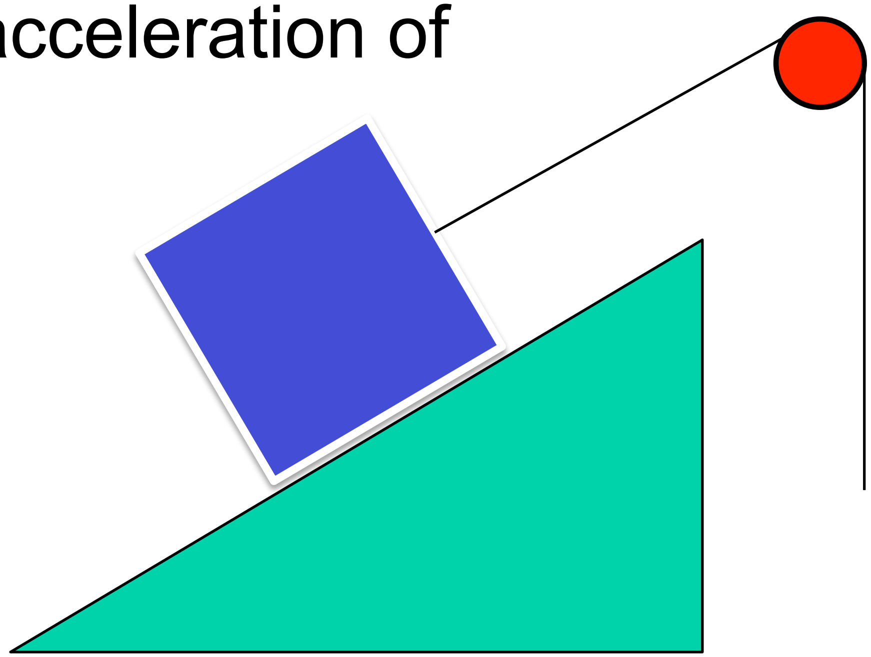
The force that cart A exerts on cart B is

1. greater than
2. less than
3. equal to the force that cart B exerts on cart A
4. Need to know how fast cart A is moving.

A force P is applied by a hand to two blocks which are in contact on a frictionless, horizontal table as shown in the figure. The blocks accelerate together to the right. Block A has a smaller mass than block B. (a) Draw free body diagrams for each block. (b) Which block experiences the larger net force? (c) Suppose that initially the mass of block A were half that of block B. If in a subsequent experiment the mass of block A were doubled, by what factor would the acceleration change assuming the pushing force remained constant?



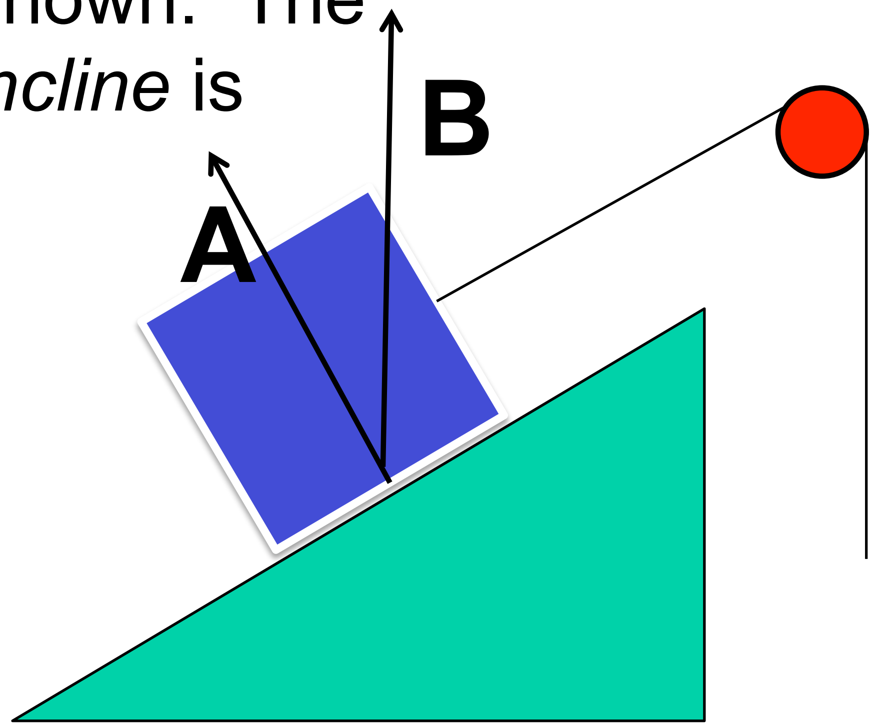
6-2.4 A block is held in place on a friction-less incline by a massless string, as shown. The acceleration of the block is



1. zero
2. straight down
3. down and to the left (along the incline)
4. not zero, but neither 2 nor 3

A block is held in place on a *frictionless* incline by a massless string, as shown. The force *on* the *block by* the *incline* is

1. a normal force given by vector ***A***.
2. a normal force given by vector ***B***.

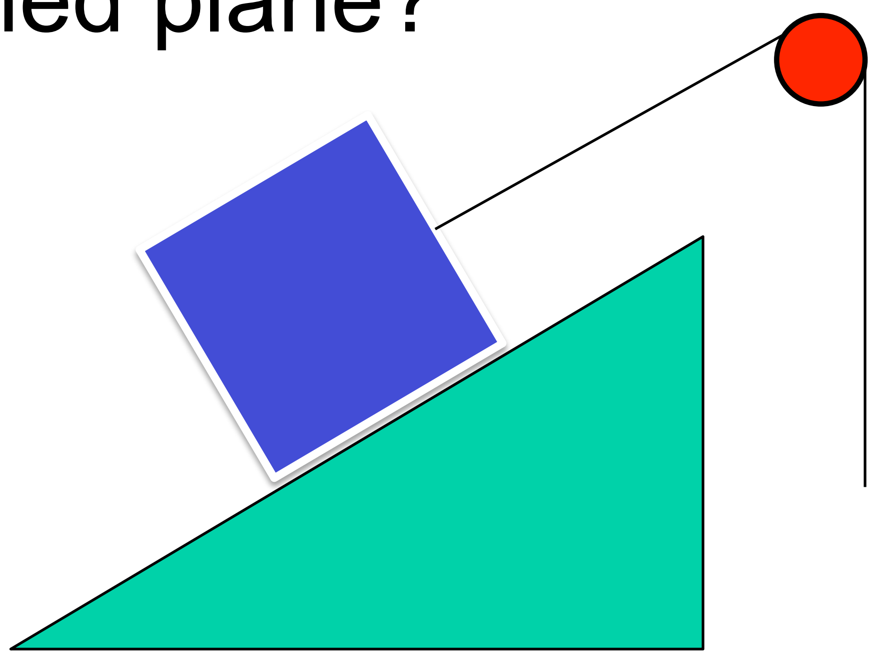


Normal force

- **Always** perpendicular to the surface of contact
- Generic name given to contact force between 2 objects

Other forces

Besides normal force what other forces are present for block on inclined plane?

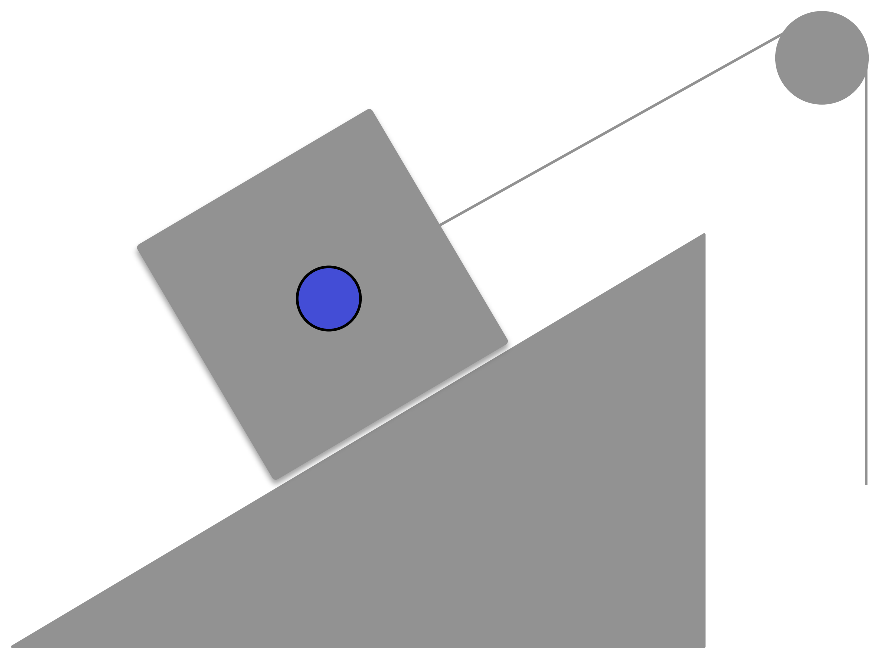


Free-body diagram: Block on frictionless incline

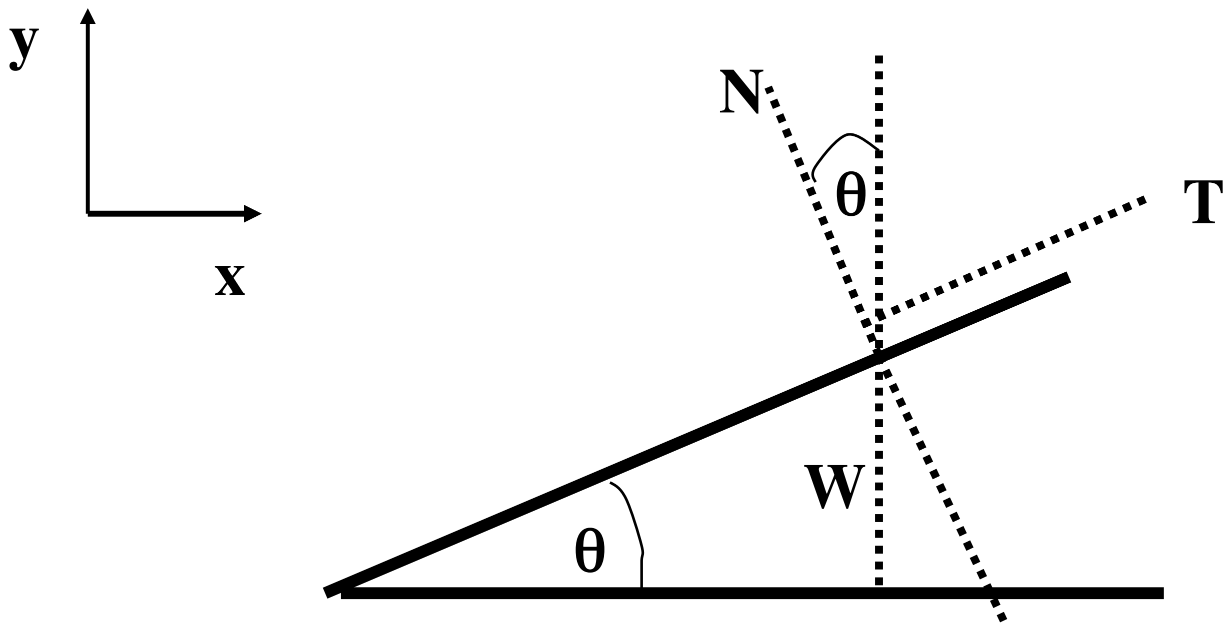
- Show all forces exerted *on* the block.
- Do *not* show forces exerted *by* the block on anything else.

acceleration

net force



Geometry…

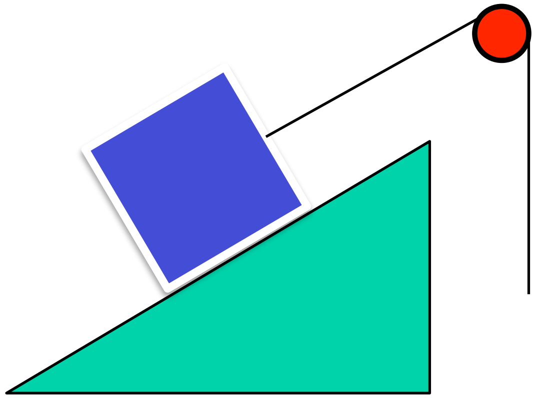


Triangle for Normal force on this inclined plane problem:

Triangle for Tension force on this inclined plane problem:

Force components: Block on frictionless incline

F = 0 **implies all components of F are zero! Horizontal and vertical**



Solving system

- *Vertical* equilibrium:

$$N_{BP}\cos(\theta) + W_{BE} + T_{BR}\sin(\theta) = 0$$

- *Horizontal* equilibrium:

$$-N_{BP}\sin(\theta) + T_{BR}\cos(\theta) = 0$$

2 equations → solve for N_{BP} and T_{BR} in terms of W_{BE} and θ (Example in a minute)

What have we learned?

- If at rest – net force = 0, since a = 0 !
- Write down FBD – identify all forces present
- Take force components in 2 (in 2D) directions to find unknowns
- Don’t plug in numbers until end

Sample Problem: The block has mass 577g, and the angle is 30 degrees, how much tension T1 is required to keep the block from moving?

Solving system

- *Vertical* equilibrium:

$$N_{BP}\cos(\theta) + W_{BE} + T_{BR}\sin(\theta) = 0$$

- *Horizontal* equilibrium:

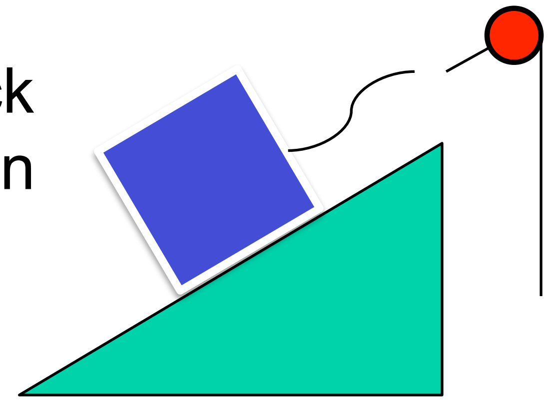
$$-N_{BP}\sin(\theta) + T_{BR}\cos(\theta) = 0$$

2 equations → solve for N_{BP} and T_{BR} in terms of W_{BE} and θ

6-2.5: What happens if the tension is higher than this value?

1. The bus moves down the incline.
2. The bus moves up the incline.
3. The bus doesn’t move
4. The bus is lifted up into the air
5. None of the above

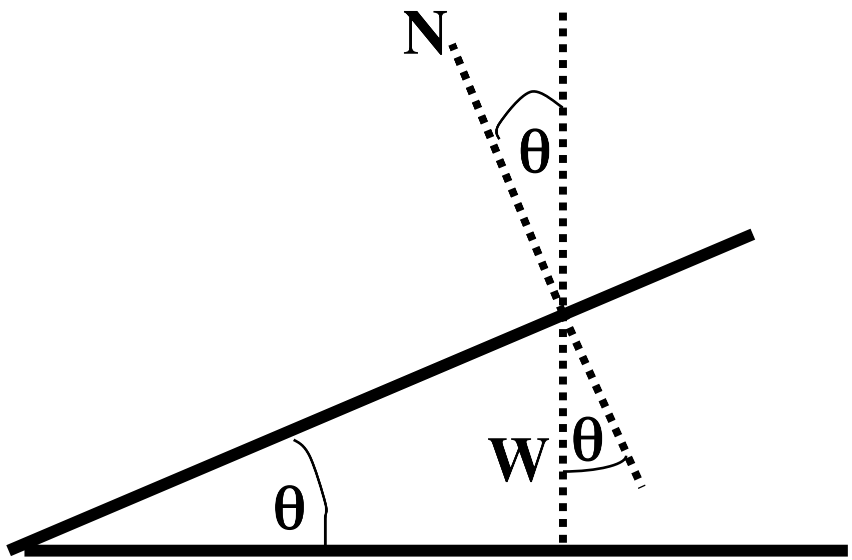
6-2.6 The string that holds the block breaks, so there is no more tension force exerted on the block.



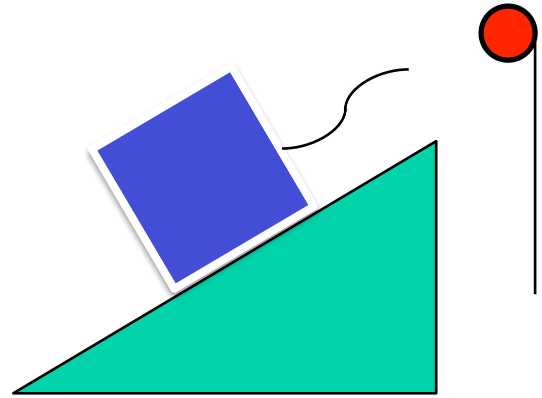
Will the magnitudes of either of the other two forces on the block (*i.e.,* the weight and the normal force) change?

1. Both weight and normal force will change.
2. Only the weight force will change.
3. Only the normal force will change.
4. Neither one of the two forces will change.

Geometry (2)



Force components: Block on frictionless incline



- The string that holds the block breaks.
- What *does* happen?
- **Take components now along and perpendicular to incline**

acceleration

net force

Components of normal force

Components of weight force

Components of tension force

Solving for second case

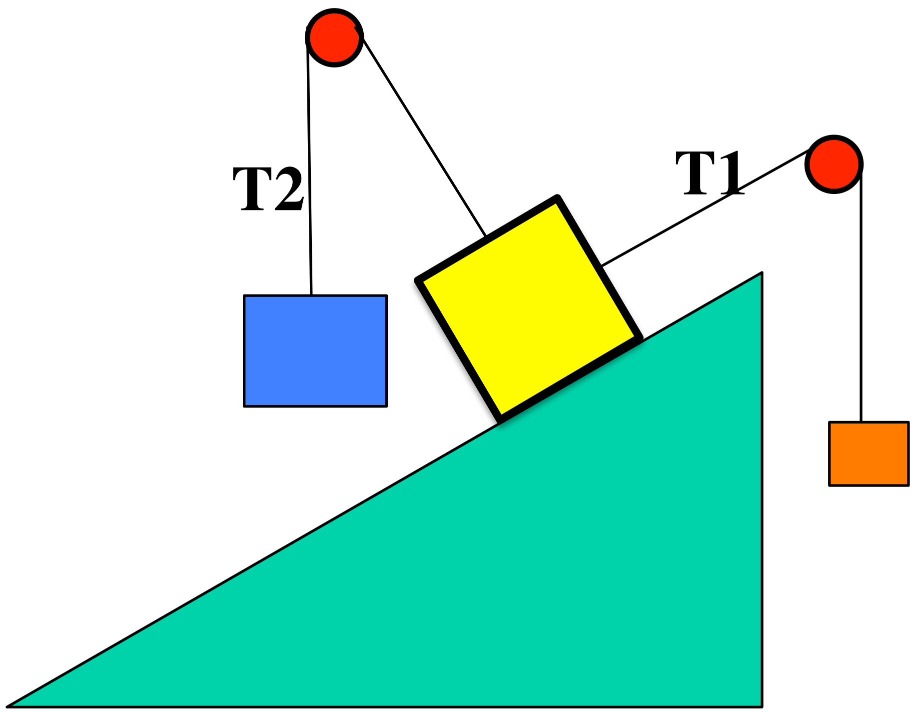
- Since acceleration is down incline, component of net force at 90 degrees to slope is zero.

$$N_{BP} - W_{BE}\cos(\theta) = 0$$

- Using second law applied to components along incline:

$$a = -W_{BE}\sin(\theta)/m_{block}$$

Demo: bus on an inclined plane



6-2.7 What is the smallest tension T2 that will make the bus lift up into the air?

1. The bus will be lifted if any tension T2 is applied (T2 > 0)
2. T2 > weight of the bus due to earth = W_{BE}
3. T2 > $W_{BE} \cos\theta$
4. T2 > $W_{BE} \sin\theta$

6-2.8 What will happen to the bus if the incline suddenly collapses if $T = W \cos\theta$?

1. The bus will stay in exactly the same spot
2. The bus will fall straight down
3. The bus will move a little bit down and to the left
4. The bus will move a little bit up and to the right

Conclusion

- Normal forces can change when small changes are made to the situation.
- Can choose any 2 directions to find force components, but it pays to pick ones that simplify equations

Summary

- To solve problems in mechanics, identify all forces and draw free body diagrams for all objects
- If more than one object, use Newton's Third law to reduce number of independent forces
- Use Newton's Second law for all components of net force on each object
- Choose component directions to simplify equations

Weight, mass, and acceleration

- What does a bathroom scale ``weigh''?
- Does it depend on your frame of reference?
- Consider elevators….

Thinking about elevators…

- Y-axis: up is positive
- If an elevator is moving upward, then
  - if it speeds up the acceleration is ________
  - If it slows down the acceleration is _______
- If an elevator is moving downward
  - Speeding up: a   0
  - Slowing down: a   0

6-2.6 A person is standing on a bathroom scale while riding an express elevator upwards (towards the top) in a tall office building. When the elevator is at rest, the scale reads about 160 lbs.

While the elevator is moving, the reading is frequently changing, with values ranging anywhere from about 120 lbs to about 200 lbs.

At a moment when the scale shows the *maximum* reading (*i.e.,* 200 lbs) the elevator

1. Must be slowing down
2. Must be speeding up
3. could be slowing down or speeding up
4. I'm not sure.

Sample problem: What is the force that the scale must exert on the person in the elevator? If that force is 200 lbs for a person who weighs 160 lbs at rest, how fast is the elevator accelerating?

Conclusions

- Scale reads magnitude of normal force $|N_{PS}|$
- Reading on scale does *not* depend on velocity (principle of relativity again!)
- Depends on acceleration *only*
  - * $a > 0 \rightarrow$ normal force bigger
  - * $a < 0 \rightarrow$ normal force smaller

"Weight": W_{OE}

- Free fall: only force acting is gravity
  - a = g
- From Newton's 2nd law, a = F/m
  - But F = W_{OE} (gravitational force on object due to earth)
  - So g = a =
- In this class, when we say "weight" we usually mean "force due to gravity" = "force on a scale when at rest": W_{OE} = mg

Forces of friction

- There are two types of situations in which frictional forces occur:
  - Two objects "stick to each other" while at rest relative to one another ***(static friction)****.*
  - Two objects "rub against each other" while moving relative to each other ***(kinetic friction)****.*
- We will use a macroscopic description of friction that was obtained by experiment.

Friction demo

- Static friction: depends on surface and normal force for pulled block
- Kinetic friction: generally **less** than maximal static friction

The *maximum* magnitude of the **force of static friction** between two objects

- depends on the type of surfaces of the objects
- depends on the normal force that the objects exert on each other
- does **not** depend on the surface area where the two objects are touching

$$f_{\mathrm{B,T}}^{\mathrm{static}} \leq \mu^{\mathrm{static}} N_{\mathrm{B,T}}$$

The *actual* magnitude of the force of static friction is generally less than the maximum value.