Welcome back to Physics 211

Today's agenda:

- *Weight*
- *Friction*
- *Tension*

Current assignments

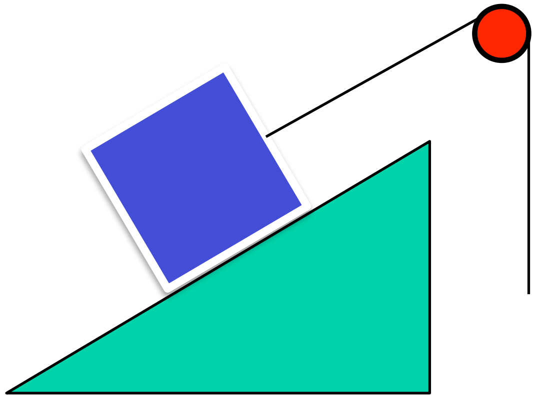
- Thursday prelecture assignment.
- HW#7 due this Friday at 5 pm.

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

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:

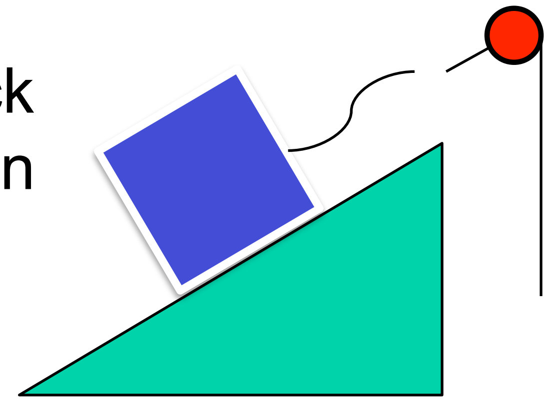
$$-N_{BP}\sin(\theta) + T_{BR}\cos(\theta) = 0$$

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

7-1.1: What happens if the tension is higher than this value?

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

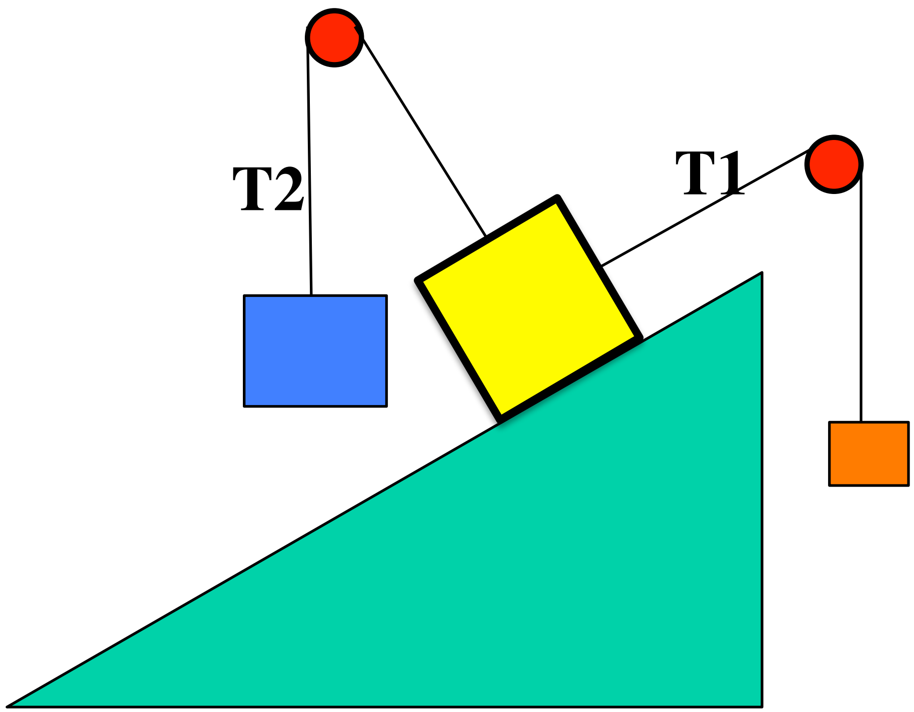
7-1.2 The string that holds the block breaks, so there is no more tension force exerted on the block.



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.

Demo: bus on an inclined plane



7-1.3 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 > $W_{BE}\sin\theta$

7-1.4 What will happen to the bus if the incline suddenly collapses if T=W cosθ?

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

Units of forces

- Typical unit: Newtons (N)
- 1 N = 1 kg*m/s^2

- Sample problem: A 10 g mass experiences an acceleration of 50 cm/s^2. What is the force on the object in N?

“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

Friction: active area of research!

- Lots of “bumps” in real data
- Big uncertainties in:
  - predicting earthquakes
  - precisely controlling motions for medical robots
- The model used in this class is an **approximation**.

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

- depends on the types 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.

7-1.5 A 2.4-kg block of wood is at rest on a concrete floor. (Using g = 10 m/s^2, its weight force is about 24 N.)

No other object is in contact with the block. If the coefficient of static friction is μ_s = 0.5, the frictional force on the block is:

1. 0 N
2. 8 N
3. 12 N
4. 24 N

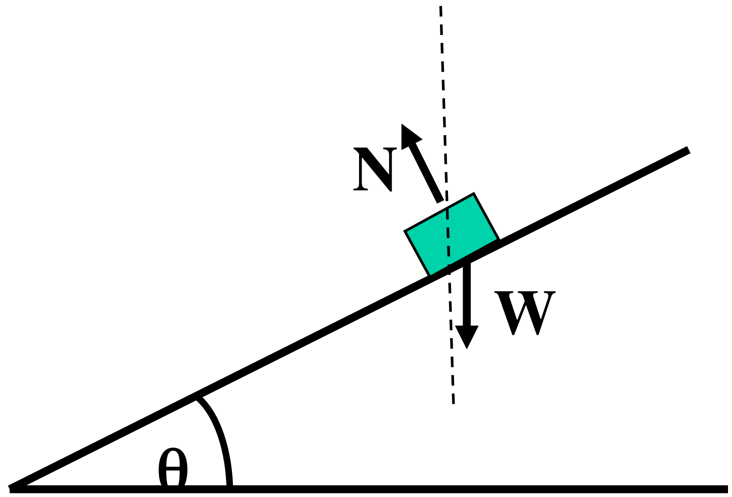
7-1.6 A 2.4-kg block of wood is at rest on a concrete floor. (Using g = 10 m/s^2, its weight force is about 24 N.)

Somebody is pulling on a rope that is attached to the block, such that the rope is exerting a horizontal force of 8 N on the block. If the coefficient of static friction is μ_s = 0.5, the frictional force on the block is:

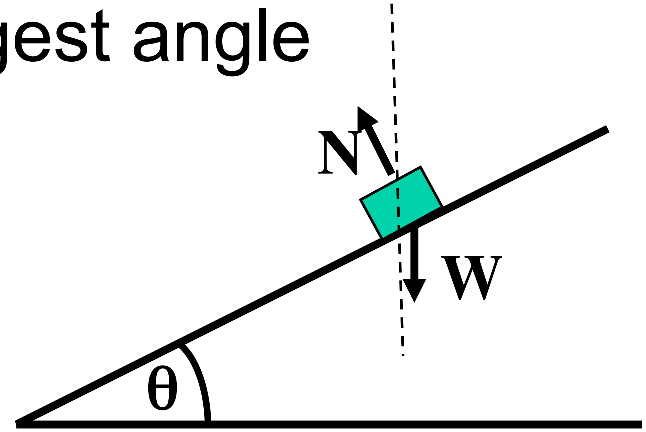
1. 0 N
2. 8 N
3. 12 N
4. 24 N

7-1.7 A block is sitting at rest on an incline with friction. Which way does the friction force on the block point?

1. Down and to the left (along incline)
2. Up and to the right (along incline)
3. Straight left
4. Straight right



Sample problem: What is the largest angle before the block slips?



7-1.8 Having no choice, you have parked your old heavy car on an icy hill, but you are worried that it will start to slide down the hill.

Would a lighter car be less likely to slide when you park it on that icy hill?

1. No, the lighter car would start sliding at a less steep incline.
2. It doesn't matter. The lighter car would start sliding at an incline of the same angle.
3. Yes, you could park a lighter car on a steeper hill without sliding.

What if $\theta > \tan^{-1}\mu_s$?

The magnitude of the **force of *kinetic* 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
- does ***not*** depend on the speed with which one object is moving relative to the other

$$f_{B,T}^{\text{kinetic}} = \mu^{\text{kinetic}} N_{B,T}$$

7-1.9 : A block of mass 1 kg sits on an incline with angle 30 degrees. The static friction coefficient is 0.2 and the kinetic friction coefficient is 0.1. Does the block slide? If so, what is the magnitude of its acceleration?

1. It doesn't slide.
2. It slides with $|a| = 3.2\ m/s^2$
3. Slides with $|a| = 4.1\ m/s^2$
4. Slides with $|a| = 9.8\ m/s^2$
5. None of the above.

Summary of friction

- 2 laws of friction: *static* and *kinetic*
- Static friction tends to oppose motion and is governed by **inequality**

$$F_s \leq \mu_s N$$

- Kinetic friction is given by **equality** $F_K = \mu_K N$

Weight, mass, and acceleration

- What does a bathroom scale ``weigh''?

- Does it depend on your frame of reference?

- Consider elevators….

Sample problem: If a scale measures 200 lbs for a person who weighs 160 lbs at rest, how fast is the elevator accelerating?

7-1.10 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.

Demo: Force on a person in an elevator

Conclusions

- Scale reads magnitude of normal force $|N_{PS}|$

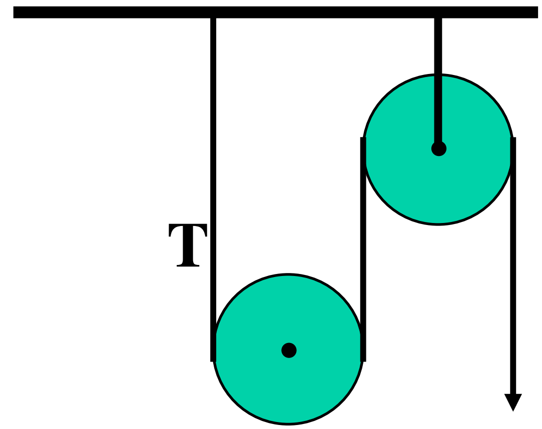
- Reading on scale does *not* depend on velocity (principle of relativity again!)

- Depends on acceleration *only*
  - * $a > 0 \rightarrow$ normal force bigger
  - * $a < 0 \rightarrow$ normal force smaller

Tension

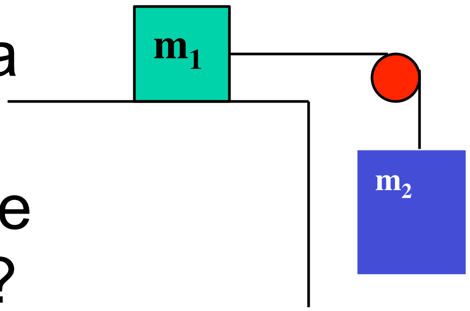
- For an <u>ideal</u> string or rope connecting two objects:
  - does not stretch → *inextensible*
  - has zero mass
  - If A and B interact through a massless string, we can omit the string and treat F_{AB} and F_{BA} as an action-reaction pair
- Often, two objects connected by a rope accelerate at the same rate

Pulleys



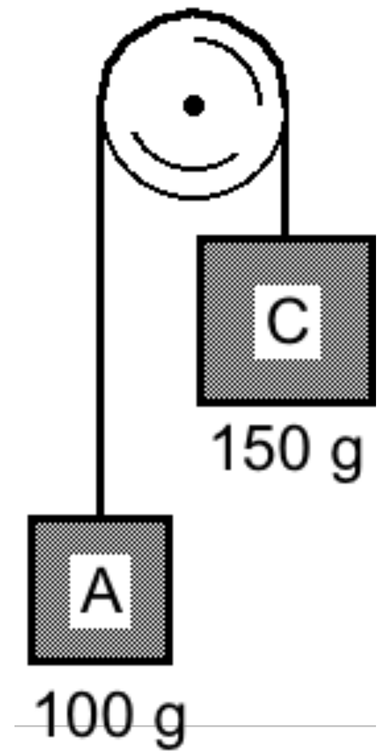
- For an <u>ideal</u> pulley:
  - The pulley has zero mass
  - There is no friction on the pulley
- Tension in a massless string remains constant as it passes over the ideal pulley
- Because Pulleys change direction, the direction of acceleration may change!

Sample problem: Two blocks are connected by a massless rope. Mass m_1 sits on top of a frictionless table top, while $m_2 > m_1$ hangs off the table as shown. What is the acceleration of m_2?



7-1.7 Blocks A and C are initially held in place as shown. After the blocks are released, block A will accelerate up and block C will accelerate down.

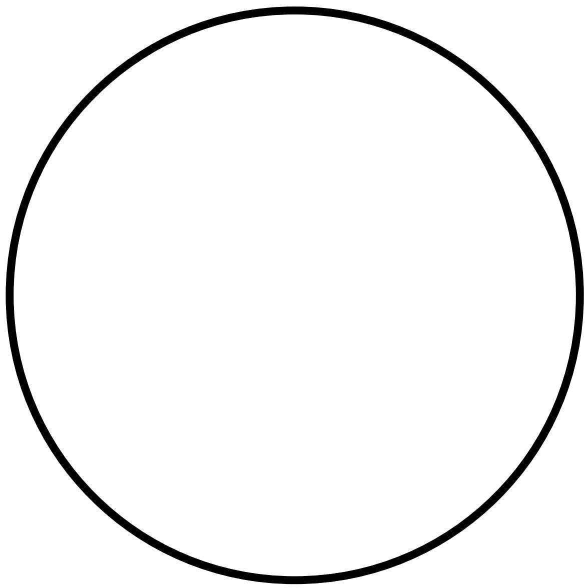
The magnitudes of their accelerations are the same. What is the magnitude of the acceleration?



1. $3.9\ m/s^2$
2. $5.9\ m/s^2$,
3. $9.8\ m/s^2$
4. $2.0\ m/s^2$
5. None of the above

Forces in circular motion

- **Motion around circular track, constant speed (for now):**

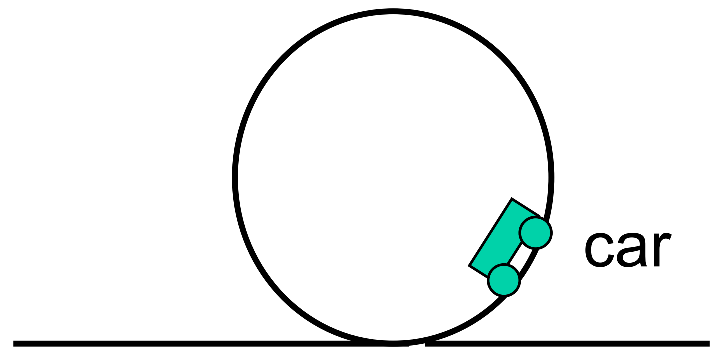


$$\mathbf{a_{rad} = v^2/r}$$

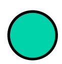
Motion on loop-the-loop

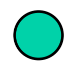
What is normal force on car at top and bottom of loop?

Neglect friction; assume moves with speed v_B at bottom and v_T at top



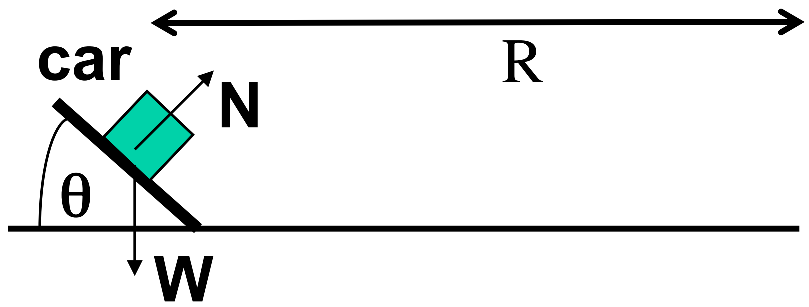
At bottom





At top

Motion of car on banked circular track (<u>no</u> friction)



a =

Speed v

Horizontal forces:

Vertical: