Welcome back to Physics 211

Today's agenda:

- *Relative Motion*
- *Forces*
- *Newton's laws of motion*

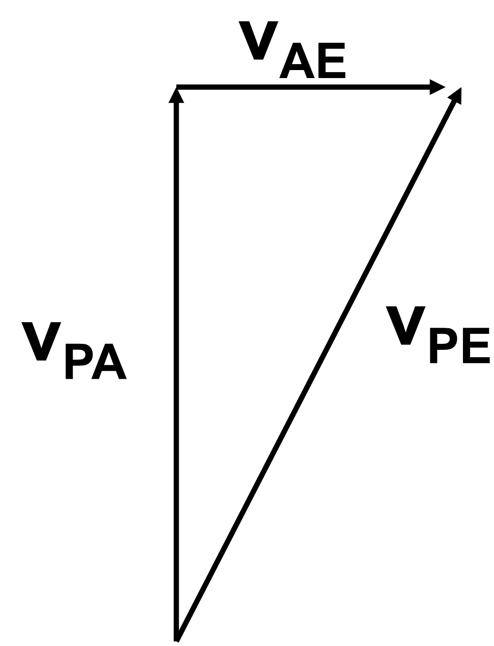
Assignments

- *HW#6 due this Friday*
- *Reading assignment for this Thursday: Dynamics: Ch 6 and do prelecture!*

Relative Motion in 2D

- Consider airplane flying in a crosswind
  - velocity of plane relative to air, $\mathbf{v}_{PA}$ = 240 km/h N
  - wind velocity, air relative to earth, $\mathbf{v}_{AE}$ = 100 km/h E
  - what is velocity of plane relative to earth, $\mathbf{v}_{PE}$?

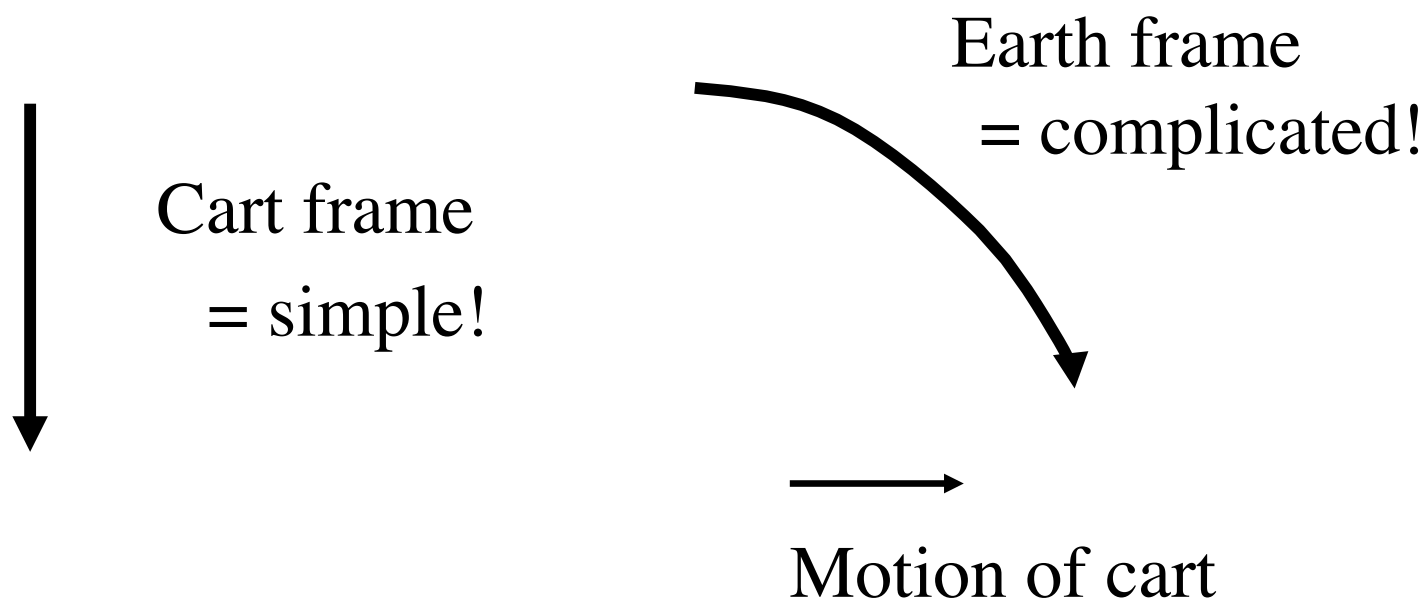
$$\mathbf{v}_{PE} = \mathbf{v}_{PA} + \mathbf{v}_{AE}$$



Sample Problem: While standing still, Otto shoots a basketball into the air at 4 m/s with a launch angle of 30 degrees. Just as he is shooting, a cameraman rolls by in a car moving at 2 m/s (along the x-axis). What is the apparent launch angle in the frame of the camera?

Relative Motion in 2D

- Motion may look quite different in different inertial frames, e.g., ejecting ball from moving cart



Acceleration is same for all inertial FOR!

- We have:

$$v_{PA} = v_{PB} + v_{BA}$$

- For velocity of P measured in frame A in terms of velocity measured in B

→ $\Delta v_{PA}/\Delta t = \Delta v_{PB}/\Delta t$ since v_{BA} is *constant*

→ Thus acceleration measured in frame A or frame B is same!

Physical Laws

- Since all FOR agree on the *acceleration* of object, they all agree on the *forces* that act on that object

- All such FOR are equally good for discovering the laws of mechanics

Forces

- are interactions between ***two*** objects (*i.e.,* a push or pull of one object on another)
- can be broadly categorized as *contact* or *non-contact* forces
- have a *direction* and a *magnitude* -- **vectors**
- can be used to *predict* and *explain* the motion of objects
- described by *Newton's Laws of Motion*

Newton's *First* law
(Law of inertia)

In the absence of a net external force, an object at rest remains at rest, and an object in motion continues in motion with constant velocity (i.e., constant speed and direction).

Clicker 6-1.1 A locomotive is pulling a long freight train at ***constant speed*** on straight tracks. The horizontal forces on the train cars are as follows:

1. No horizontal forces at all.
2. Only a "pull" by the locomotive.
3. A "pull" by the locomotive and a friction force of equal magnitude and opposite direction.
4. A "pull" by the locomotive and a somewhat smaller friction force in the opposite direction.

Common forces
1. Weight

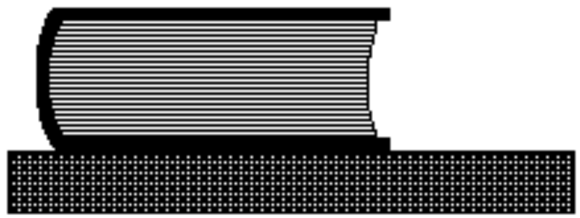
- Gravitational force (weight)
  - Universal force of attraction between 2 massive bodies
  - For object near earth's surface directed "downward" with magnitude mg
  - Notation: W_{BE}

Common forces
2. Normal forces

- Two objects A, B touch → exert a force at 90^o to surface of contact

- Notation: N_{AB} is normal force on A due to B

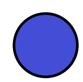
6-1.2 A book is at rest on a table. Which of the following statements is correct? The vertical forces exerted **on the book** (and their respective directions) are



1. A weight force (down) only.
2. A weight force (down) and another force (up).
3. A weight force (down) and two other forces (one up and one down).
4. There is no force exerted on the book; the book just exerts a force on the table (which is downward).

Free-body diagram for book on table

- To solve problem introduce idea of **free body diagram**
- Show all forces exerted ***on*** the book.
- Do ***not*** show forces exerted ***by*** the book on anything else.



Remarks on free-body diagram for book

- Use point to represent object
- On earth, there will always be weight force (downwards, magnitude = mg)
- Since **not** accelerating, must be upward force also – N_{BT} normal force on book due to table
- No net force → $|N_{BT}| = mg$

Newton's *Second Law*

Second Law:

$$\boldsymbol{F}_{\text{on object}} = m\,\boldsymbol{a}_{\text{of object}}$$

where $\boldsymbol{F}_{\text{net}}$ is the vector sum of all *external* forces on the object considered

- m = (inertial) mass

Illustration of Newton's *Second Law*

Pull cart with constant force as displayed on force-meter

- How does cart respond?

$$\boldsymbol{F}_{\text{on object}} = m\,\boldsymbol{a}_{\text{of object}}$$

Newton's *Third law*

- Forces always occur in relation to pairs of objects.

- If A exerts some force on B, then B will exert a force back on A which is equal in magnitude but opposite in direction

Notation

- Force on A due to B = $\mathbf{F}_{AB}$
- Force on B due to A = $\mathbf{F}_{BA}$
- 3rd law states:

$$\mathbf{F}_{AB} = -\mathbf{F}_{BA}$$

- $\mathbf{F}_{AB}$ and $\mathbf{F}_{BA}$ referred to as 3rd law pair

Newton's Laws

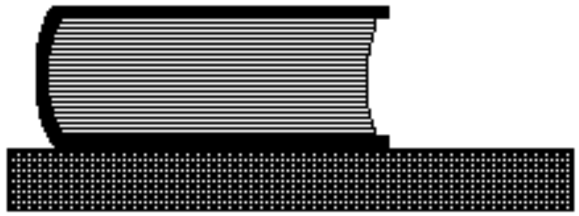
First Law: In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with constant velocity.

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

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

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

6-1.3 A book is at rest on a table. Which of the following statements is correct?



1. The book exerts a force on the table, but the table does not exert a force on the book.
2. The table exerts a force on the book, but the book does not exert a force on the table.
3. The book exerts a large force on the table. The table exerts a smaller force on the book.
4. The book exerts a force on the table, and the table exerts a force of the same magnitude on the book.

6-1.4 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 direction, 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

Free-body diagrams: Person sitting on chair

Chair

(incomplete)

Person

Earth

6-1.5 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?

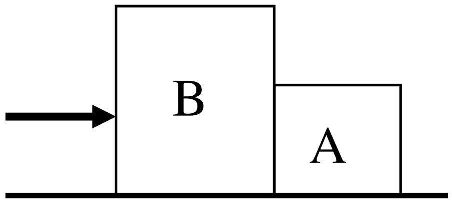
1. Cart A doesn’t move and Cart B moves backwards
2. Cart B doesn’t move and Cart A moves backwards
3. Both carts move in opposite directions
4. Neither cart moves

6-1.6 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.

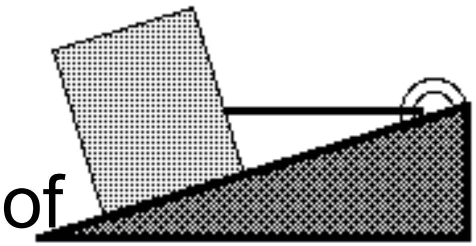
The force that cart A exerts on cart B is

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?

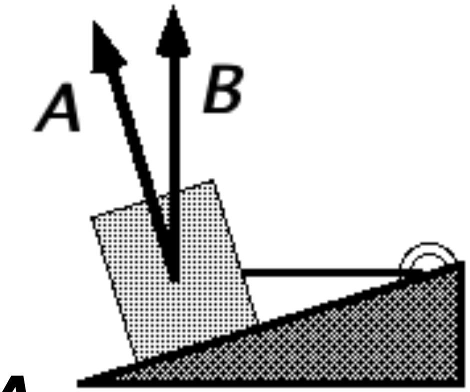


6-1.7 A block is held in place on a friction-less incline by a massless string, as shown. The acceleration of the block is



1. zero
2. straight down
3. down and to the left (along the incline)
4. not zero, but neither of 2 or 3

6-1.8 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***.
3. the force given by vector ***A**,* but it's not a normal force.
4. the force given by vector ***B**,* but it's not a normal force.

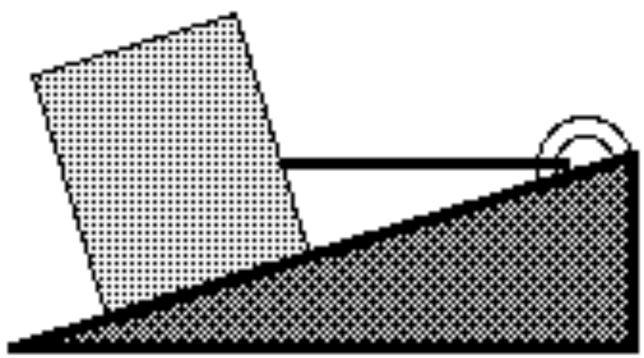
Normal force

- **Always** perpendicular to surface of contact

- Generic name given to contact force between 2 objects

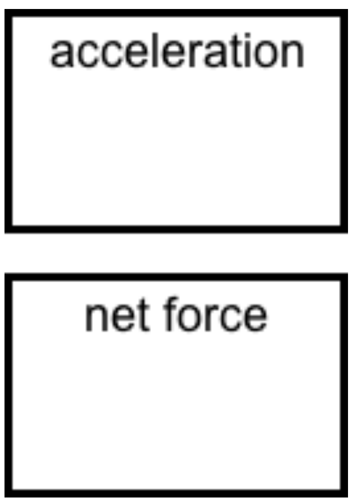
Other forces

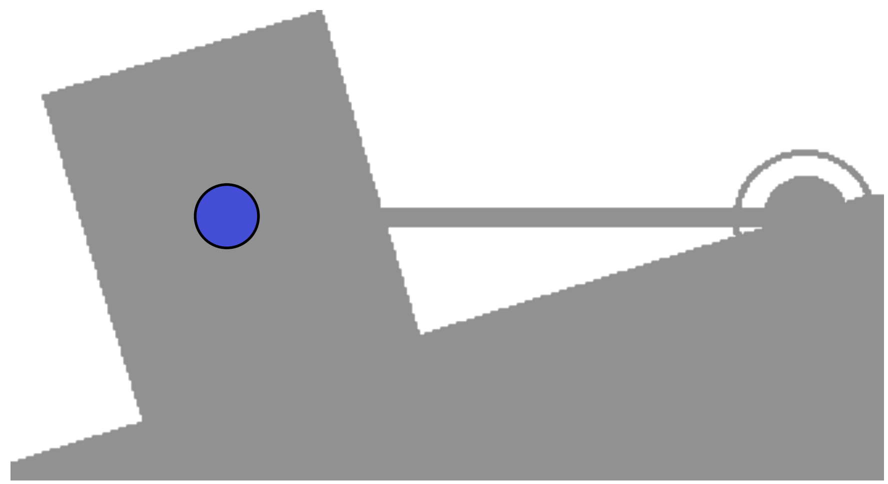
Besides normal force what other forces are present for block on inclined plane?



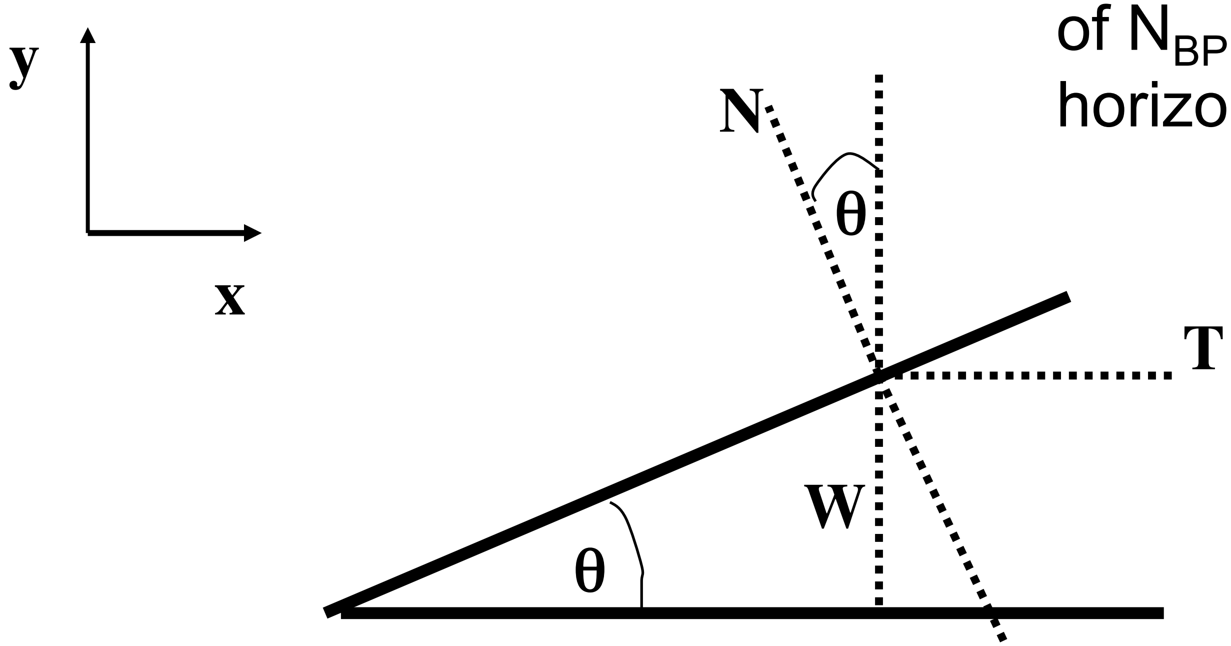
Free-body diagram: Block on frictionless incline

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





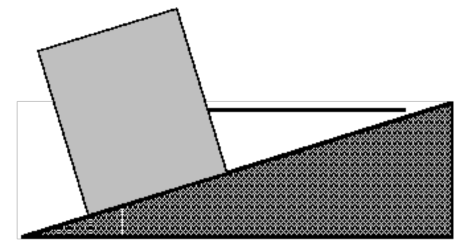
Geometry…



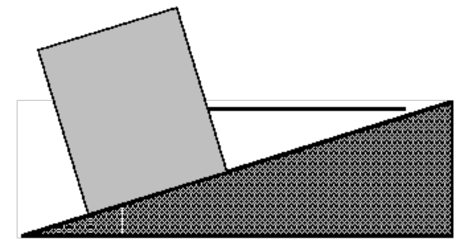
vertical component of N_{BP} is $N_{BP}\cos(\theta)$; horizontal is $N_{BP}\sin(\theta)$

Force components: Block on frictionless incline

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



6-1.9 When the block is held in place as shown, the magnitude of the normal force exerted on the block by the incline is



1. greater than the magnitude of the weight force (on the block by the Earth),
2. equal to the magnitude of the weight, or
3. less than the magnitude of the weight.
4. Can’t tell.

Solving system

- *Vertical* equilibrium:

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

- *Horizontal* equilibrium:

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

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

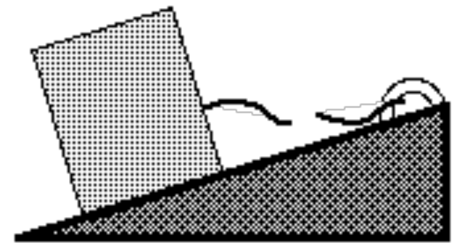
What have we learned?

- 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

Reading assignment

- Ch 6 in textbook

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.

Discussion

- Say normal does not change. What will be the new net force? Same as old, but "minus" the tension, i.e. straight to the left (and not zero).

- So what would the block do? Accelerate. OK -- Straight to the left? NO, can't be correct answer.

- Acceleration is down the incline, so normal gets smaller.