Welcome back to Physics 215

Today's agenda:

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

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*

Types of forces

Contact forces
- *normal*
- *frictional*
- *tension*

Non-contact forces
- gravitational
- *electric*
- *magnetic*

SG: A hovercraft puck is a plastic disk with a built-in ventilator that blows air out of the bottom of the puck. The stream of air lifts up the puck and allows it to glide with negligible friction and at (almost) constant speed on any level surface.

After the puck has left the instructor's hands the *horizontal* forces on the puck are:

A. the force of the motion.
B. the force of inertia.
C. the force of the motion and the force of inertia.
D. Neglecting friction and air drag, there are no horizontal forces.

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).

Remarks

- Compatible with principle of relativity
  - All FOR moving with constant velocity will agree that no forces act
- Since forces are vectors, this statement can be applied to any components -- *(x, y, z)* separately
- Only **net** force required to be zero…

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

A. No horizontal forces at all.
B. Only a "pull" by the locomotive.
C. A "pull" by the locomotive and a friction force of equal magnitude and opposite direction.
D. A "pull" by the locomotive and a somewhat smaller friction force in the opposite direction.

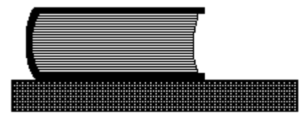
Common forces
1. Weight

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

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 of A on B

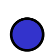
SG A book is at rest on a table. Which of the following statements is correct? The vertical forces exerted **on the book** (and their respective directions) are



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.



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
- Acceleration measured relative to inertial FOR.

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

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

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

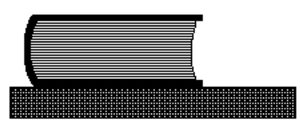
Newton's Laws

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]

SG: A book is at rest on a table.
Which of the following statements is correct?



A. The book exerts a force on the table, but the table does not exert a force on the book.
B. The table exerts a force on the book, but the book does not exert a force on the table.
C. The book exerts a large force on the table. The table exerts a smaller force on the book.
D. The book exerts a force on the table, and the table exerts a force of the same magnitude on the book.

SG 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

A. the net force on the person must be zero
B. the two forces form a Newton's third-law pair
C. neither of the above explanations
D. both of the above explanations

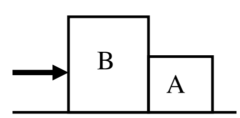
Free-body diagrams: Person sitting on chair

Chair Person Earth (incomplete)

SG: 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

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?



2^{nd} and 3^{rd} Law demos

- Carts equipped with force probes
- Force and acceleration . . .
- Force *vs.* time on motion detector
  - During collision equal and opposite forces seen

SG 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.

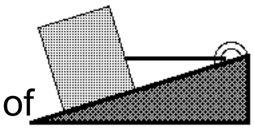
The force that cart A exerts on cart B is

A. greater than
B. less than
C. equal to

the force that cart B exerts on cart A.

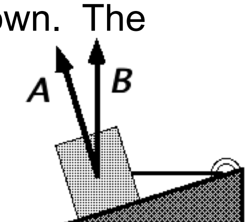
D. Need to know how fast cart A is moving.

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



A. zero
B. straight down
C. down and to the left (along the incline)
D. not zero, but neither of B or C

SG: 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

Reading for next Tuesday

- Friction and drag. Chapters 6.2, 6.4