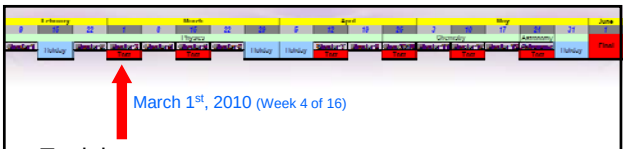


March 1st, 2010 (Week 4 of 16)

Tonight…

- ✓ Test Chapters 1 and 2
  - Closed book
  - Closed notes
  - Closed neighbor
  - Closed phone
  - Good Luck!!!
  - When you are finished, please place it on my desk.
- ✓ Return Pop Quiz Chapter 1
- ✓ Turn-In homework for Chapter 1
- ✓ Turn-In homework for Chapter 2
- ✓ Lecture Chapter 3
  - I am hoping to begin around 8:00??
  - Hot Dog Lady is open for food

Force and Motion – *Cause and Effect*

- In chapter 2 we studied motion but not its cause.
- In this chapter we will look at both force and motion – the cause and effect.
- We will consider Newton's:
  - *Newton's three laws of motion*
  - *Newton's law of universal gravitation*
  - *Buoyancy and momentum*

Isaac Newton (1643 - 1727)

- Only 25 when he formulated most of his discoveries in math and physics
- His book *Mathematical Principles of Natural Philosophy* is considered to be the most important publication in the history of Physics.

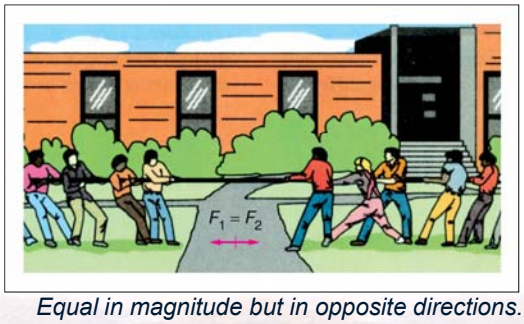
Major achievements:

1. Invented calculus as a necessary tool to solve mathematical problems related to motion
2. Discovered the three laws of motion
3. Discovered the universal law of mutual gravitation

Force and Net Force

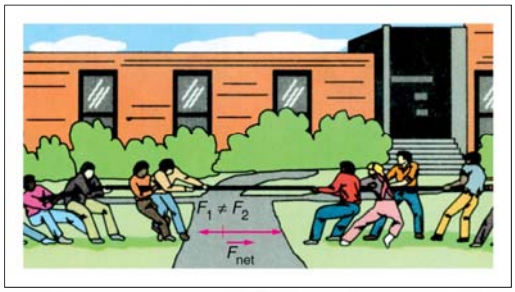
- Force – a vector quantity capable of producing motion or a change in motion
  - *A force is capable of changing an object's velocity and thereby producing acceleration.*
- A given force may not actually produce a change in motion because other forces may serve to balance or cancel the effect.

Balanced (equal) forces, therefore no motion.



Equal in magnitude but in opposite directions.

Unbalanced forces result in motion



Net force to the right

Newton's First Law of Motion

- Aristotle considered the natural state of most matter to be at rest.
- Galileo concluded that objects could naturally remain in motion indefinitely.
- Newton's 1st Law of Motion – *An object will remain at rest or in uniform motion in a straight line unless acted on by an external, unbalance force.*

Objects and Newton's 1st Law

- An object will remain at rest or in uniform motion in a straight line unless acted on by an external, unbalance force.
- Balanced forces have equal magnitude in opposite directions
- An external force is a force applied to the entire object or system.

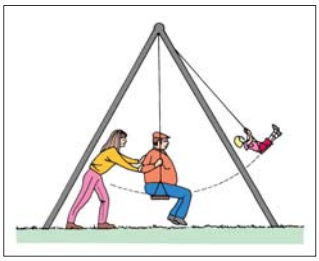
Newton's 1st law

Motion and Inertia

- Inertia - the natural tendency of an object to remain in a state of rest or in uniform motion in a straight line *(first introduced by Galileo)*
- Basically, objects tend to maintain their state of motion and resist change.
- Newton went one step further and related an object's mass to its inertia.
  - *The greater the mass of an object, the greater its inertia.*
  - *The smaller the mass of an object, the less its inertia.*

Newton's 1st law

Mass and Inertia



The large man has more inertia – more force is necessary to start him swinging and also to stop him – due to his greater inertia

Newton's 1st law

Mass and Inertia

Quickly pull the paper and the stack of quarters tend to stay in place due to inertia.

Newton's 1st law

"Law of Inertia"

- Because of the relationship between motion and inertia:
- Newton's *First Law of Motion* is sometimes called the *Law of Inertia*.
- Seatbelts help 'correct' for this law during sudden changes in speed.

Newton's 1st law

Newton's Second law of Motion

- *Acceleration* α $\frac{Force}{mass}$
- Acceleration (change in velocity) produced by a force acting on an object is directly proportional to the magnitude of the force *(the greater the force the greater the acceleration.)*
- Acceleration of an object is inversely proportional to the mass of the object *(the greater the mass of an object the smaller the acceleration.)*
- *a = F/m* or *F = ma*

Newton's 2nd law

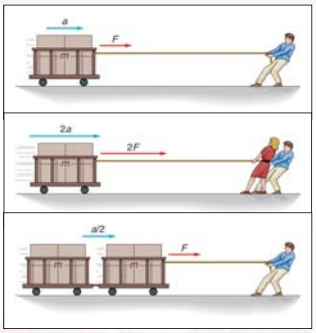
Force, Mass, Acceleration

a) Original situation

$a \alpha \frac{F}{m}$

b) If we double the force we double the acceleration.

c) If we double the mass we half the acceleration.



Newton's 2nd law

F = ma

- *"F"* is the net force (unbalanced), which is likely the vector sum of two or more forces.
- "*m*" & "*a*" are concerning the whole system
- *Units*
- Force = mass x acceleration = kg x m/s^2 = N
- N = kg x m/s^2 = newton -- this is a derived unit and is the metric system (SI) unit of force

Newton's 2nd law

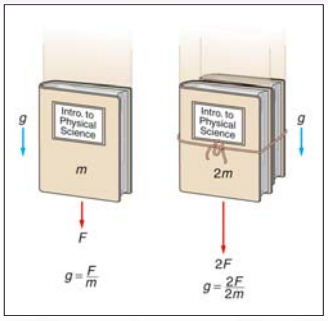
Mass & Weight

- Mass = amount of matter present
- Weight = related to the force of gravity
- Earth: weight = mass x acc. due to gravity
- w = *mg* (special case of *F = ma*) Weight is a force due to the pull of gravity.
- Therefore, one's weight changes due to changing pull of gravity – like between the earth and moon.
- Moon's gravity is only 1/6th that of earth's.

Newton's 2nd law

Acceleration due to gravity is *independent* of the mass.

Both *F* & *m* are doubled, resulting in *g* remaining constant.



Newton's 2nd law

Friction

- Friction – resistance to relative motion that occurs whenever two materials are in contact with each other.
  - Ever-present and found in all states (solids, liquids, and gases) of matter
- In some cases we want to increase friction (sand on ice), in other cases we want to reduce friction (motor oil).

Newton's 2nd law

Two Types of Friction

- Static friction occurs when the frictional force is sufficient to prevent relative motion between surfaces
- Kinetic (or sliding) friction occurs when there is relative motion between surfaces in contact.
- Kinetic friction is generally less than static friction
  - Usually it takes less force to keep something moving than to start it moving.

Newton's 2nd law

Coefficients of Friction

- Coefficients of friction (μ) are dimensionless quantities used to characterize particular contact situations.
- Both, coefficients of static friction (μ_s) and coefficients of kinetic friction (μ_k) are determined experimentally for a wide range of contact surfaces.
- Usually (μ_s) > (μ_k).

Newton's 2nd law

Approximate values for Coefficients of Static and Kinetic Friction between several surfaces

Friction Between Materials	μ_s	μ_k
Aluminum on aluminum	1.90	1.40
Aluminum on steel	0.61	0.47
Steel on steel		
dry	0.75	0.48
lubricated	0.12	0.07
Teflon on steel	0.04	0.04
Teflon on Teflon	0.04	0.04
Rubber on concrete		
dry	1.20	0.85
wet	0.80	0.60
Wood on wood	0.58	0.40
Lubricated ball bearings	< 0.01	< 0.01

Newton's 2nd law

Newton's Third Law of Motion

- For every action there is an equal and opposite reaction.

or

- Whenever on object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.
- action = opposite reaction
- $F_1 = -F_2$ or $m_1a_1 = -m_2a_2$

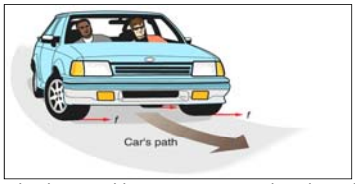
Newton's 3rd law

Newton's Third Law of Motion

- $F_1 = -F_2$ or $m_1a_1 = -m_2a_2$
- Jet propulsion – exhaust gases in one direction and the rocket in the other direction
- Gravity – jump from a table and you will accelerate to earth. In reality BOTH you and the earth are accelerating towards each other
  - *You – small mass, huge acceleration (m_1a_1)*
  - *Earth – huge mass, very small acceleration ($-m_2a_2$)*
  - *BUT → $m_1a_1 = -m_2a_2$*

Newton's 3rd law

Newton's Laws in Action



- Friction on the tires provides necessary centripetal acceleration.
- Passengers continue straight ahead in original direction and as car turns the door comes toward passenger – 1st Law
- As car turns you push against door and the door equally pushes against you – 3rd Law

Newton's 3rd law

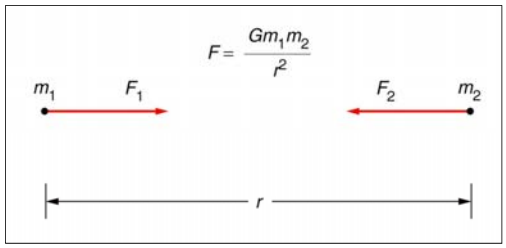
Newton's Law of Gravitation

- Gravity is a *fundamental force* of nature
  - We do not know what causes it
  - We can only describe it
- Law of Universal Gravitation – Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them

Newton's Law of Gravitation

- Equation form: $F = \frac{Gm_1m_2}{r^2}$
- G is the universal gravitational constant
- G = 6.67 x 10^{-11} N·m^2/kg^2
- G:
  - *is a very small quantity*
  - *thought to be valid throughout the universe*
  - *was measured by Cavendish 70 years after Newton's death*
  - *not equal to "g" and not a force*

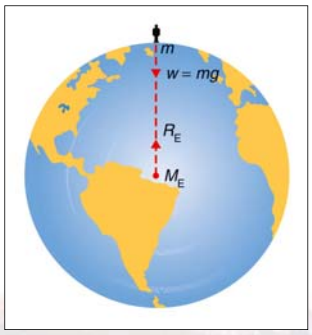
Newton's Law of Gravitation



- The forces that attract particles together are equal and opposite
- $F_1 = -F_2$ or $m_1a_1 = -m_2a_2$

Newton's Law of Gravitation

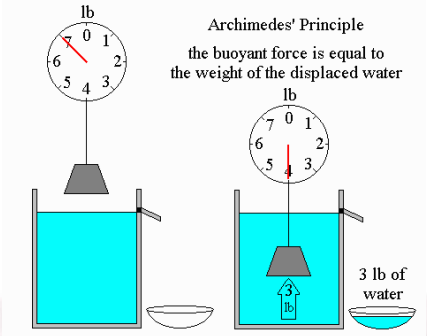
- $F = \frac{Gm_1m_2}{r^2}$
- For a homogeneous sphere the gravitational force acts as if all the mass of the sphere were at its center



Archimedes - Buoyancy

- Buoyant force – the upward force resulting from an object being wholly or partially immersed in a fluid.
- The Archimedes' Principle – An object immersed in a fluid experiences a buoyant force equal to the weight of the volume of fluid displaced.
- Both liquids and gases are considered fluids.

Archimedes - Buoyancy



Archimedes - Buoyancy

- The buoyant force depends on the weight of the fluid displaced.
  - The weight of the fluid displaced depends on the density of the fluid and the volume displaced.
- Salt water is more dense than fresh water.
  - Therefore, one floats higher in salt water, since one needs to displace less salt water to equal one's weight.

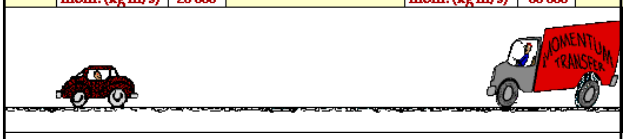
Examples of Buoyancy

- Ships float because the average density of the ship is less than the water it would displace.
- Oil floats on water, since oil is less dense than water
- Cream floats on milk, since cream is less dense than milk.
- By taking in, or pumping out water, submarines can vary their buoyancy.

Momentum

Car	
mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck	
mass (kg)	3000
vel. (m/s)	-20.0
mom. (kg m/s)	-60 000



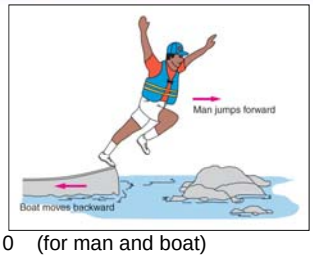
Momentum

- Linear momentum = mass x velocity
- $\rho = mv$
- If we have a system of masses, the linear momentum is the sum of all individual momentum vectors.
- $P_f = P_i$ (final = initial)
- $P = \rho_1 + \rho_2 + \rho_3 + \ldots$ (sum of the individual momentum vectors)

Law of Conservation of Linear Momentum

- Law of Conservation of Linear Momentum - the total linear momentum of an isolated system remains the same if there is no external, unbalanced force acting on the system
- Linear Momentum is 'conserved' as long as there are no external unbalance forces.
  - *It does not change with time.*

Conservation of Linear Momentum



- $P_i = P_f = 0$ (for man and boat)
- When the man jumps out of the boat he has momentum in one direction and, therefore, so does the boat.
- Their momentums must cancel out! (= 0)

Chapter 3 - Important **Equations**

- $F = ma$ (2nd Law) or $w = mg$ (for weight)
- $F_1 = -F_2$ (3rd Law)
- $F = (Gm_1m_2)/r^2$ (Law of Gravitation)
- $G = 6.67 \times 10^{-11}$ N-m^2/kg^2 (gravitational constant)
- $g = GM/r^2$ (*acc.* of gravity, M=mass of sph. object)
- $p = mv$ (linear momentum)
- $P_f = P_i$ (conservation of linear momentum)

Questions…

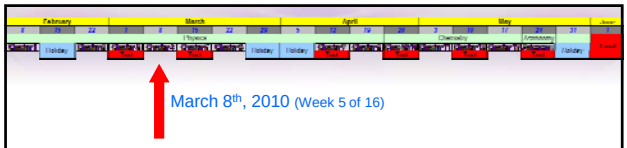
4. A force of 2.1 N is exerted on a 7.0 g rifle bullet. What is the bullet's acceleration?
9. What is the weight in Newtons of a 120 pound person? *(1 kg = 2.20 pounds)*
21. Two ice skaters stand together as illustrated below. They "push off" and travel directly away from each other, the boy with a velocity of 0.50 m/s. If the boy weighs 735 N and the girl 490 N, what is the girl's velocity after they push off? (Consider the ice to be frictionless.)

Special Question:

What are Newton's three laws of motion?

Newton's Three Laws of Motion

1. A body **at rest** will stay **at rest** unless acted upon by an **external force**. A body **in motion** will stay **in motion** unless acted upon by an **external force**.
2. F=ma
3. For every force there is an **equal and opposing** force.



March 8th, 2010 (Week 5 of 16)

Next Week…

✓Lecture Chapter 4
✓Turn In homework Chapter 3

End of Day