PSCI 1421: Lecture 6 Chapter 3: Force and Motion Cont

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What's in today's menu?

- Newton's Third Law of Motion
- Newton's Law of Gravitation
- Buoyancy
- Momentum

What did we study?

- Net force/Balance and unbalance forces
- Newton's First Law of Motion/Law of Inertia
- Newton's Second Law of Motion/ $F = ma$

What did we learn?

- When more than one force acts, a net, or unbalanced, force is need
- A single applied force will produce an acceleration
- How much inertia do you have?
- Newton's First Law of Motion is sometimes called the law of inertia
- According to Newton's second law, an external, net force will produce an acceleration

Mass & Weight

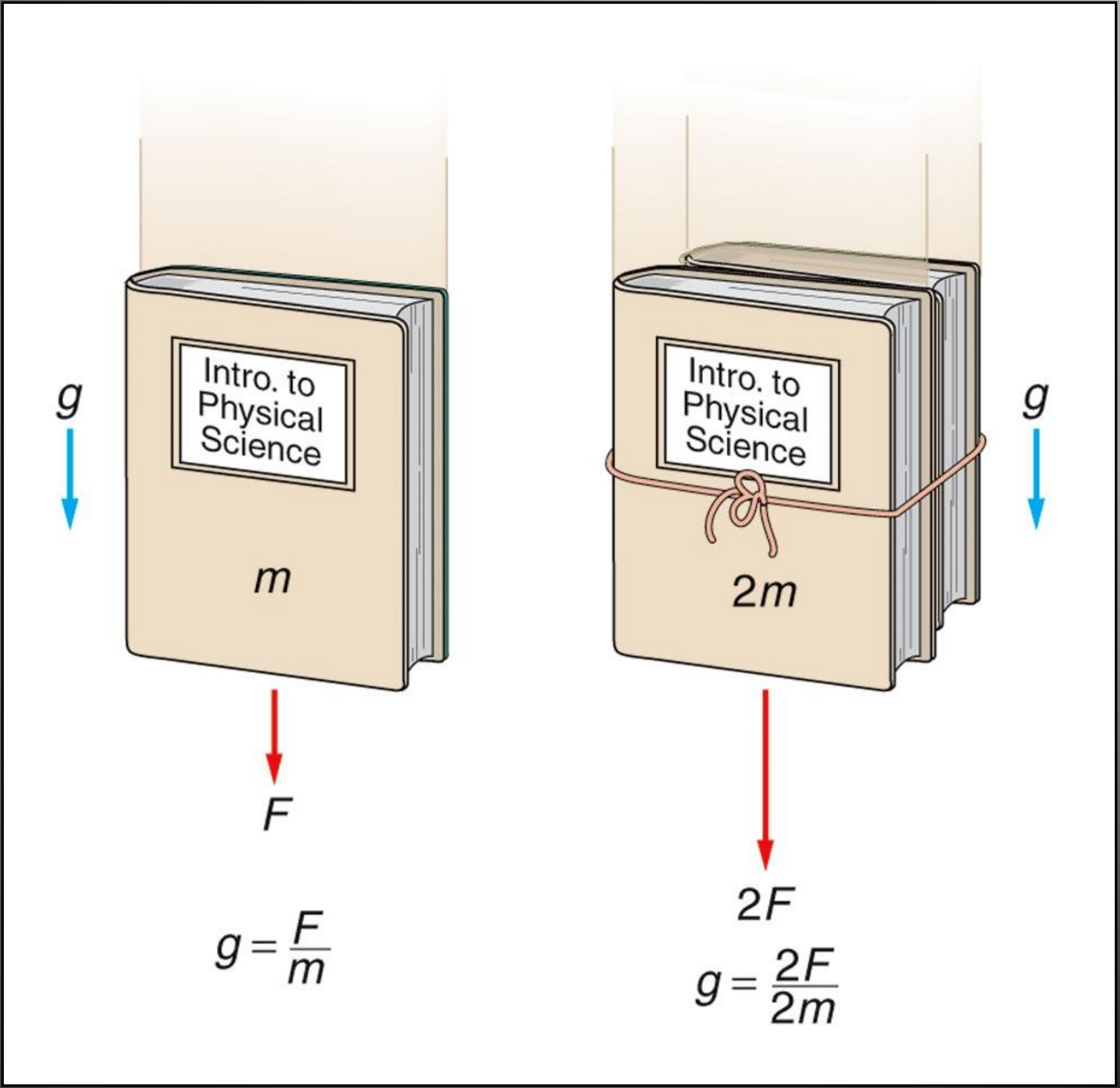
- Mass = amount of matter present
- Weight =related to the force of gravity
- Earth: weight = mass x acc. due to gravity
- $w = mg$ (special case of $F = ma$) Weight is a force due to the pull of gravity.
- Therefore, one's weight changes due to changing pull of gravity – like between the earth and moon.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

Computing Weight – an example

What is the weight of a 3.50 kg mass on (a) earth, and (b) the moon? (in N and lb)

1 lb = 4.45 N

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



Both are doubled!

Friction

- It is the ever-present resistance to relative motion that occurs whenever two materials are in contact with each other.
- Classified into two types: static friction and sliding (or kinetic).
- Static friction occurs when the frictional force is sufficient to prevent relative motion between surfaces.
- Sliding friction, or kinetic friction, occurs when there is relative (sliding) motion between the surfaces in contact.
- Static friction larger than sliding friction

Newton's Third Law of Motion

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

or

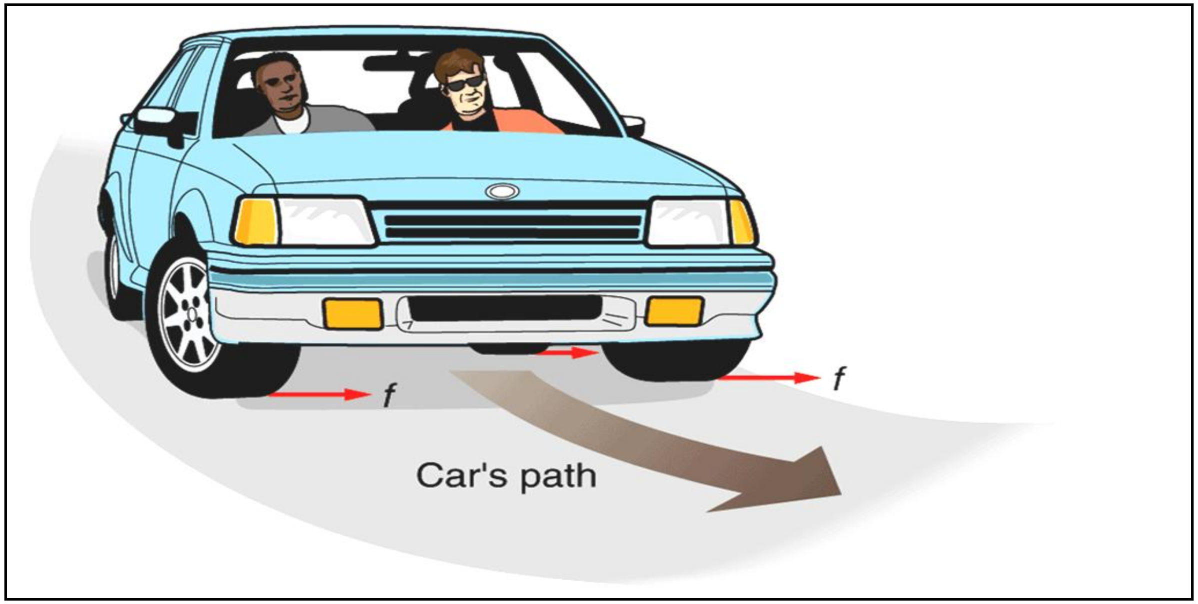
- Whenever on object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.
- action = opposite reaction
- $F_1 = -F_2$ or $m_1 a_1 = -m_2 a_2$

Newton's Third Law of Motion

- $F_1 = -F_2$ or $m_1 a_1 = -m_2 a_2$
- 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* ($m_1 a_1$)
  - *Earth – huge mass, very small acceleration* ($-m_2 a_2$)

BUT → $m_1 a_1 = -m_2 a_2$

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 Law of Gravitation

- What keeps the Moon in orbit around the Earth?
- Are astronauts seen floating in the international Space Station really weightless?

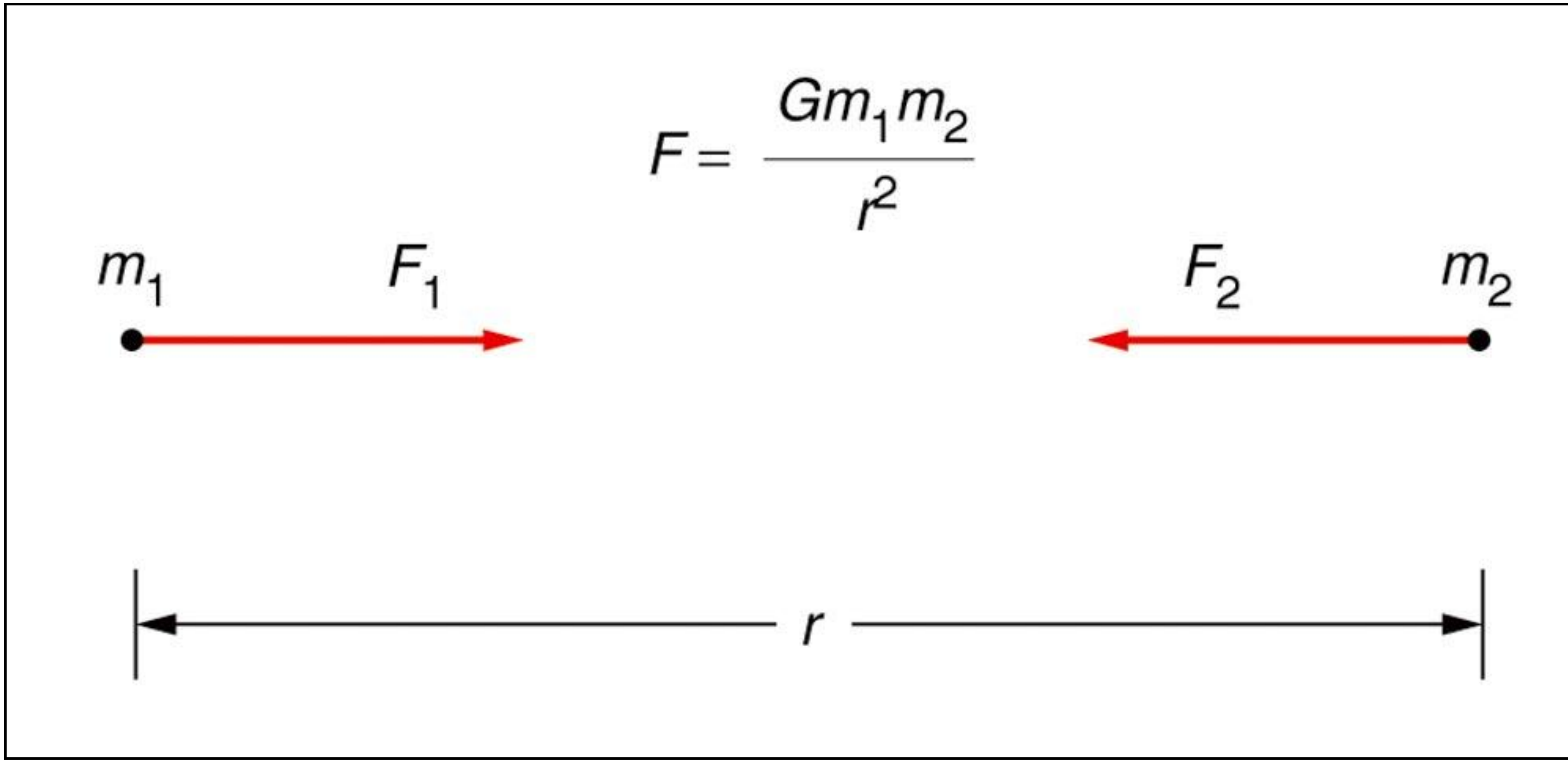
Newton's Law of Gravitation

- 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 = 6.67×10^{-11} $N{\cdot}m^2/kg^2$
  - 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

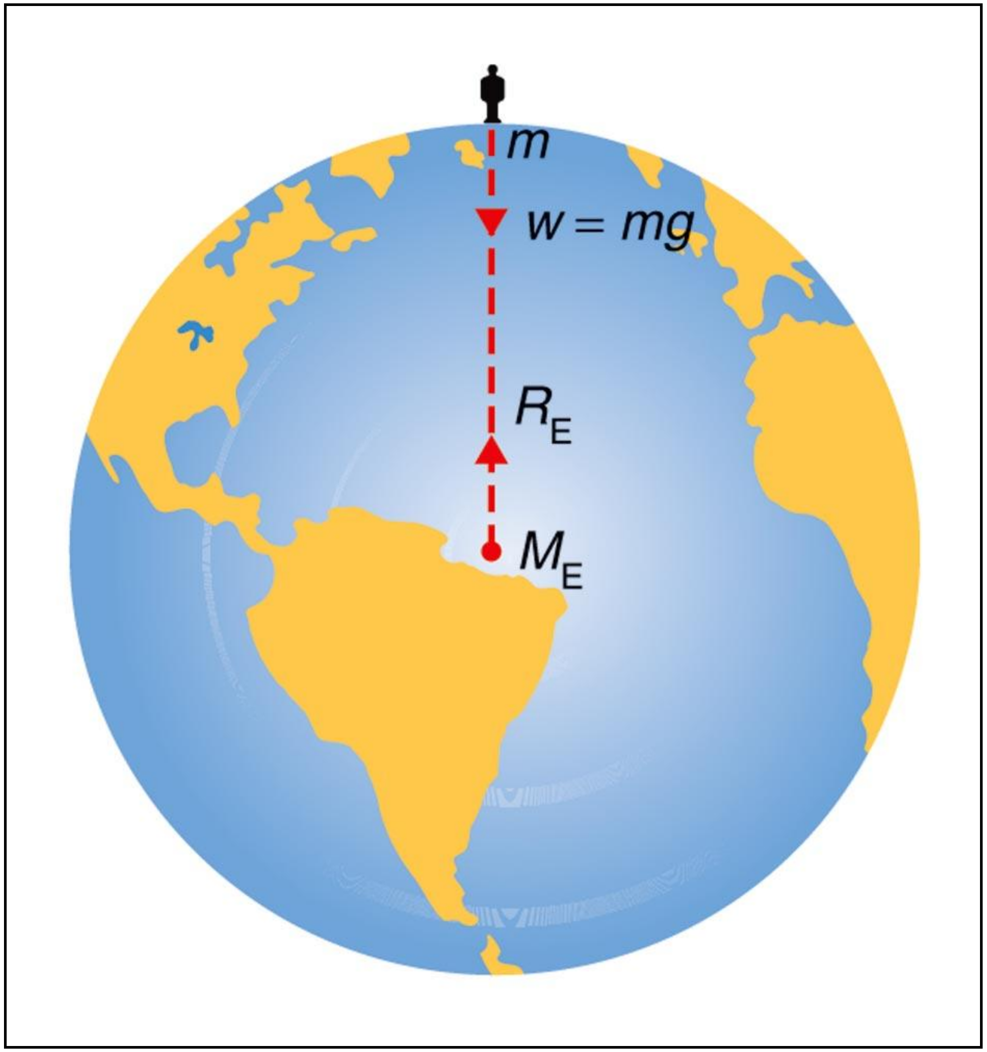


- The forces that attract particles together are equal and opposite
- $F_1 = -F_2$ or $m_1 a_1 = -m_2 a_2$

Newton's Law of Gravitation

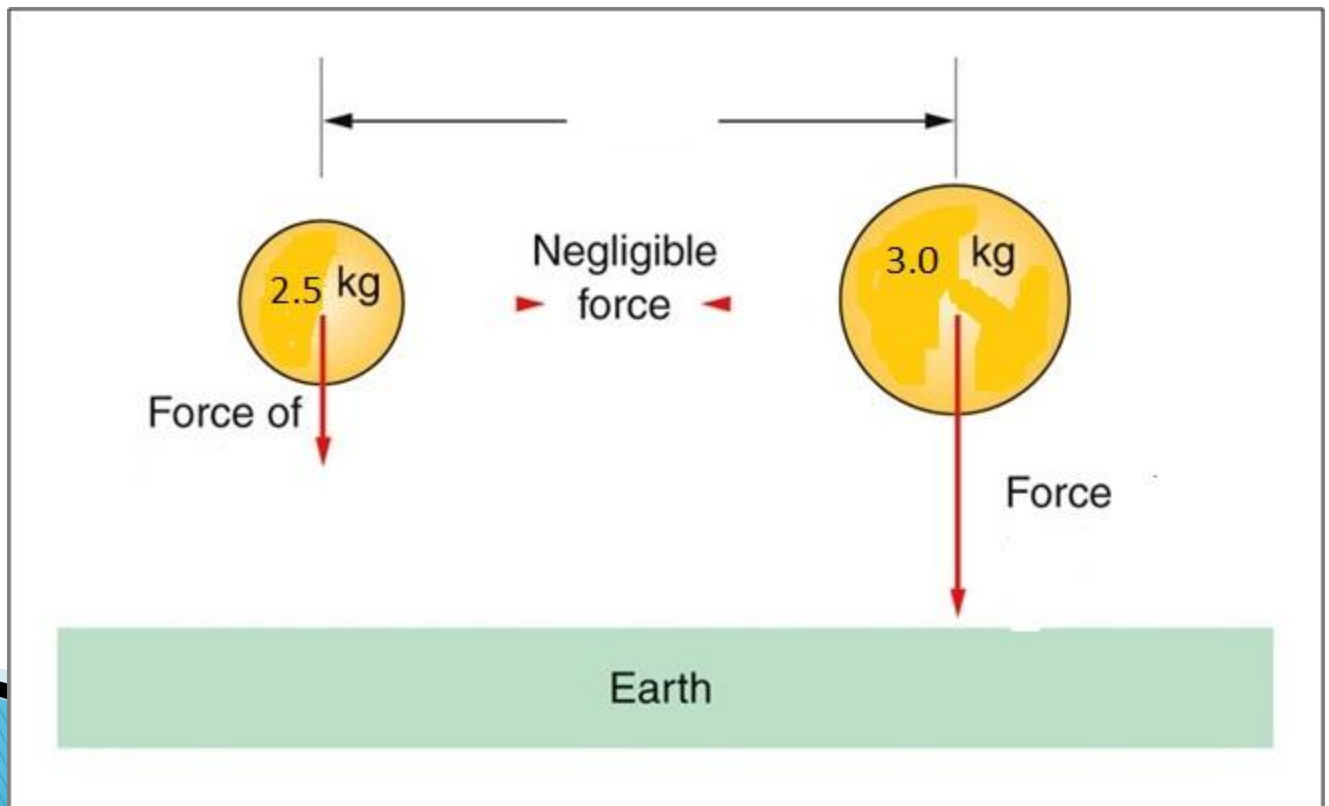
- $F = \dfrac{Gm_1m_2}{r^2}$

- For a homogeneous sphere the gravitational force acts as if all the mass of the sphere were at its center



Applying Newton's Law of Gravitation

- Example: Two objects with masses of 2.5 kg and 3.0 kg are 2.0 m apart. What is the force in each mass in Newtons and pounds? What is the magnitude of the gravitational force between the masses?



Force of Gravity on Earth

- $F = \frac{GmM^E}{R^2_E}$ [force of gravity on object of mass m]
  - M_E and R_E are the mass and radius of Earth
  - This force is just the object's weight ($w = mg$)
- $\therefore\ w = mg = \frac{G\,mM^E}{R_E{}^2}$
- $g = \frac{GM^E}{R^2_E}$
- *m* cancels out $\therefore$ *g* is independent of mass

Acceleration due to Gravity for a Spherical Uniform Object

- $g = \frac{GM}{r^2}$
  - g = acceleration due to gravity
  - M = mass of any spherical uniform object
  - r = distance from the object's center

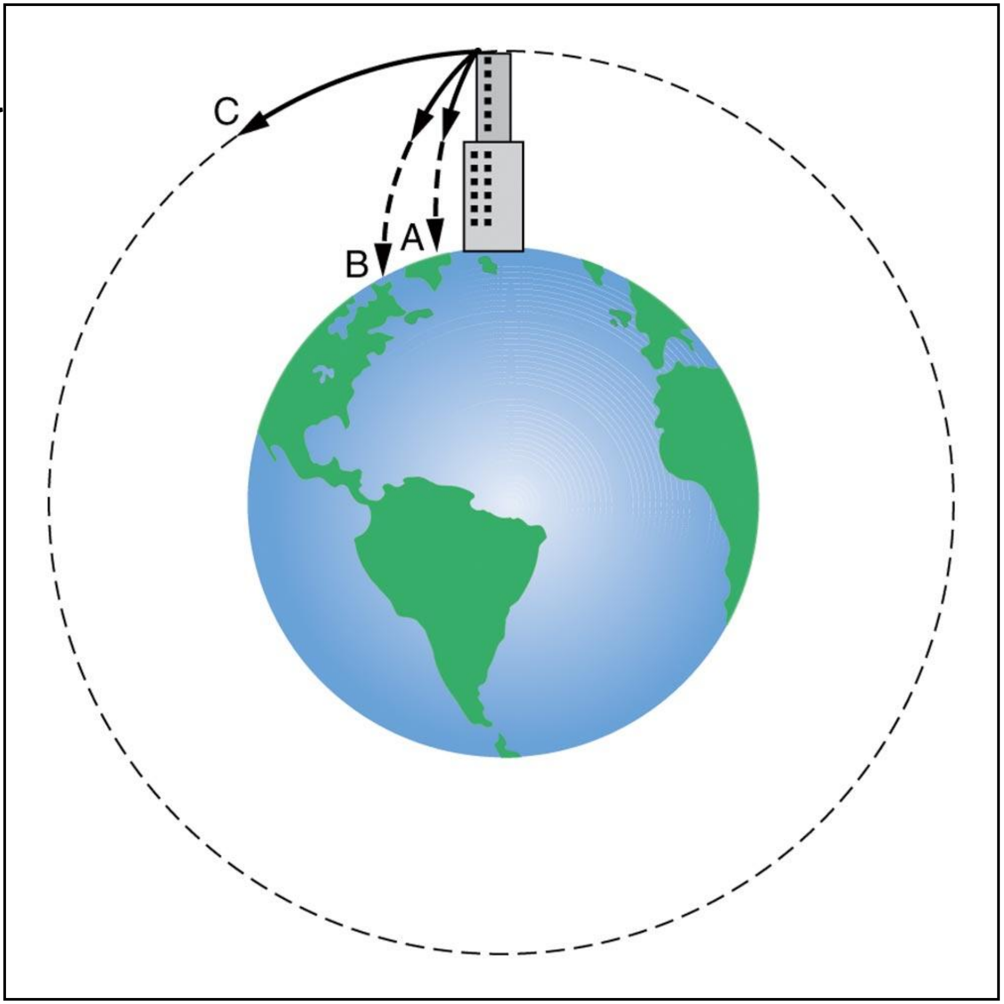
Earth Orbit – Centripetal Force

1) Proper Tangential Velocity
2) Centripetal Force

$F_c = ma_c = mv^2/r$

(since $a_c = v^2/r$)

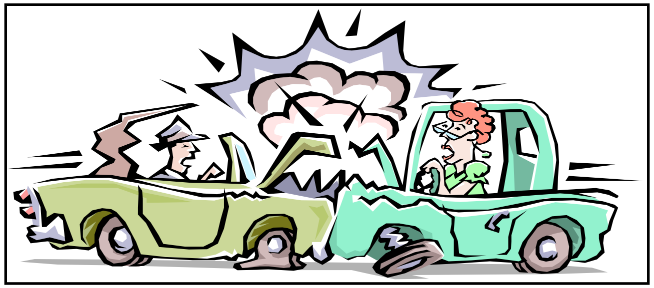
The proper combination will keep the moon or an artificial satellite in stable orbit



"Weightlessness" in space is the result of both the astronaut and the spacecraft 'falling' to Earth as the same rate

Linear Momentum

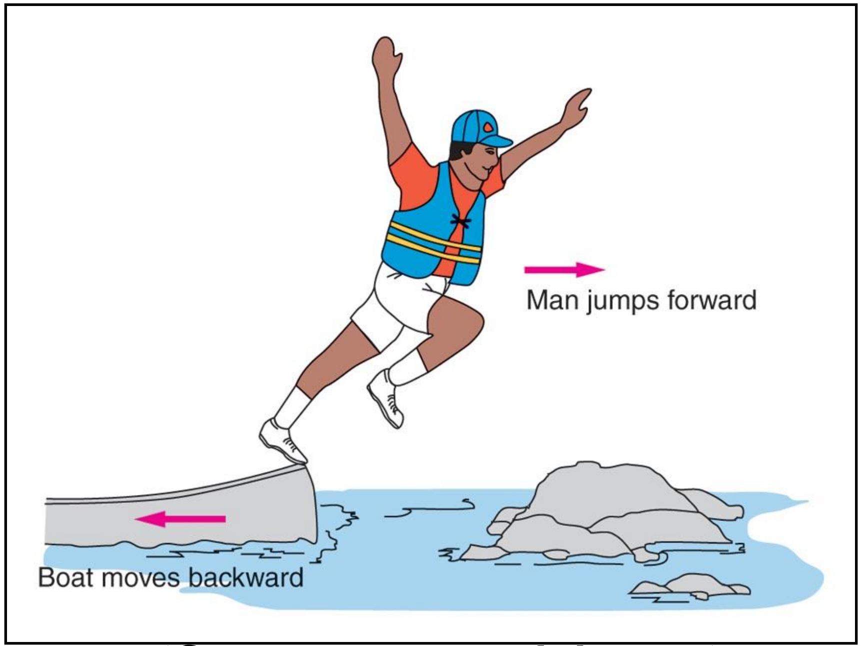
- Linear momentum = mass x velocity
- p= *mv*
- If we have a system of masses, the linear momentum is the sum of all individual momentum vectors.
- $P_f = P_i$ (final = initial)
- P = ❒$_1$ + ❒$_2$ + ❒$_3$ + … (sum of the individual momentum vectors)



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)

Conservation of Linear and Impulse

- How Newton's three laws, momentum and impulse have to do with a car accident?
- What can we learn from a raw egg?

Conservation of Linear momentum and Impulse

- First, I need to explain what impulse is:
- Start with Newton's Second Law
- $F = m a$
- but $a = v/t$
- Hence, $F = m (v/t)$ what happens if we mult. by t
- $F * \Delta t = m * v$
- Well, in physics $F * \Delta t$ = Impulse
- and $m * \Delta v$ = momentum
- Therefore: change impulse = change momentum

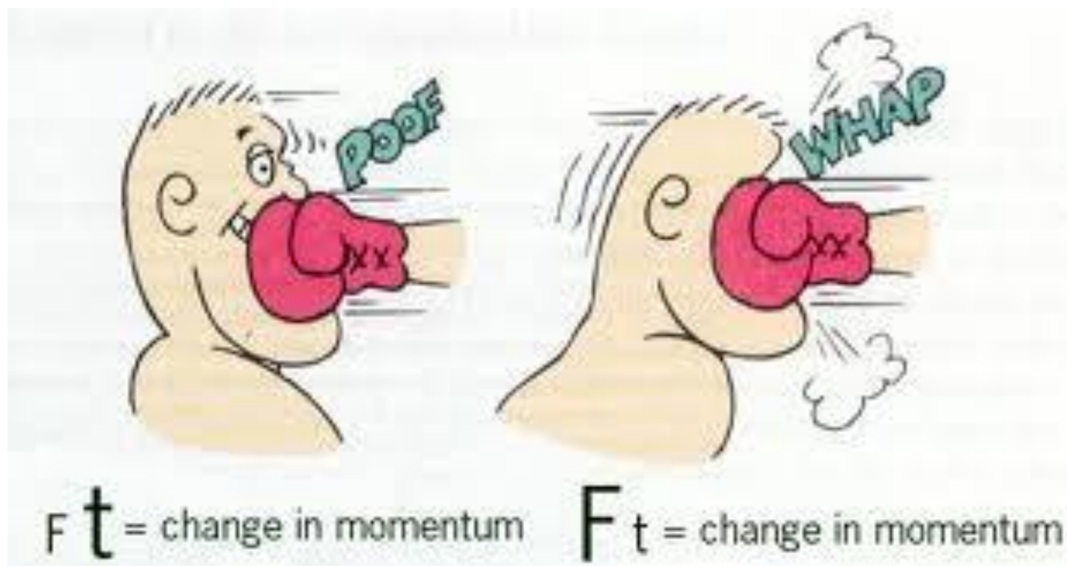
What is impulse

Extend time of collision

$$Impulse = F_{average}\Delta t = m\,\Delta v$$

Reduce average impact force

For a given change in momentum, the impulse stays constant.



Demonstration

- Egg

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)
- $G = 6.67 \times 10^{-11}$ $N\text{–}m^2/kg^2$ (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)
- *Impulse* $= F * \Delta t =$ *change in momentum*