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Today – Exam #1 Review

- Exam #1 is Thursday Feb. 7 in this room, BPS 1410
- The exam is 40 multiple choice questions. There are a few questions where you will have to use a formula.
- Bring your student ID
- You will have the full 80 minutes for the exam.
- You can bring one sheet of notes (front and back)

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Einstein Equation

$$R_{ij} - \frac{1}{2} R g_{ij} - \lambda g_{ij} = \frac{8\pi G}{c^4} T_{ij}$$

• A tensor equation that describes how space-time is influenced by mass.

•The left side is the curvature and motion of space and the right side is the location and motion of mass and energy.

• Rij is the Ricci tensor, g is the metric of space-time, G is the gravitational constant, Tij is the stress-energy tensor.

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Program for Today

- We will read through the review sheet.
- I will give some sample problems.
- Some of the exam problems will be very close to homework problems.
- A couple of the samples we will use as clicker problems

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The Scientific Method

- Science – No theory can ever be proven true. We are always looking for theories that work better.
- Pseudoscience (not bad, just not science)
  - **The hypothesis is not at risk.** If data does not agree with the hypothesis, then the data is assumed to be wrong.
  - Some facts are ignored.
  - Exploit the controversies and inadequacies in a competing theory.
  - Portrayed as an underdog being punished by the scientific establishment.
  - Reliance on fear and other emotions, or reliance on a lack of knowledge
  - People who do pseudoscience usually do not publish in normal scientific journals.

Vector Problem

- Which of the following is not a vector:
  A. Position
  B. Velocity
  C. Mass
  D. Force
  E. Momentum

  The correct answer is C.

Vectors have a magnitude (60 mph) and direction (East). Scalars have only a value (4 kg).

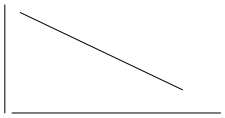
Motion

- Velocity is the rate of change of position
- Acceleration if the rate of change of velocity
- Force is the rate of change of momentum
- Momentum = mass x velocity

Example: If the mass of an object is large, it can take a large force to change its velocity.

It's all in the slopes

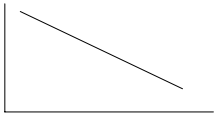
position



time

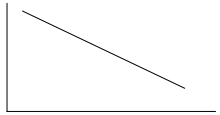
→ **Velocity**
Rate of change of position

velocity



momentum time

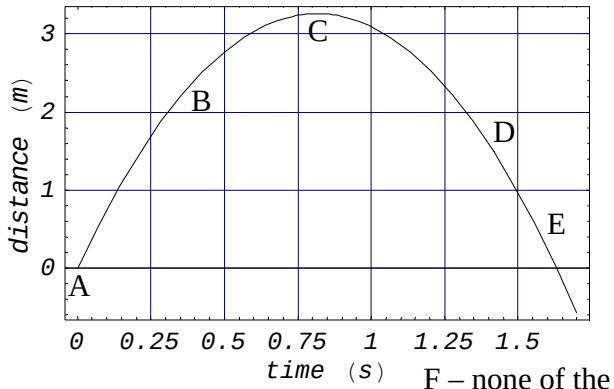
→ **Acceleration**
Rate of change of velocity



time

→ **Force**
Rate of change of momentum

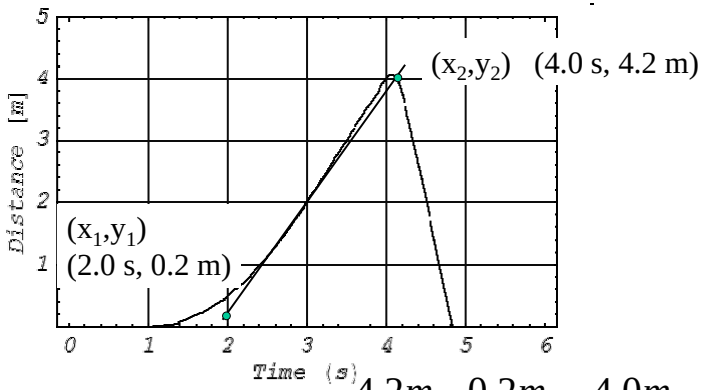
Picture of the flight of a ball



F – none of the choices

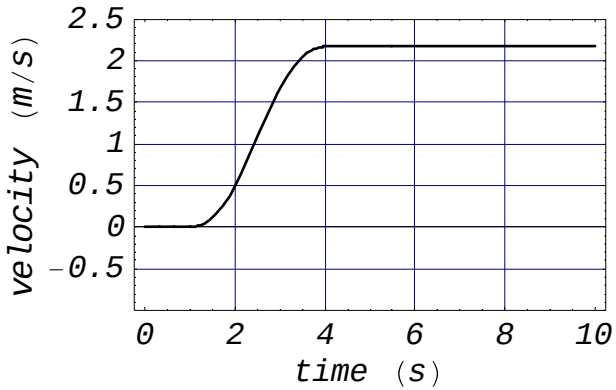
Where is the acceleration 0?
Where is speed the smallest?

Another Motion Sample



$$speed = \frac{4.2m - 0.2m}{4.0s - 2.0s} = \frac{4.0m}{2s} = 2.0\,m/s$$

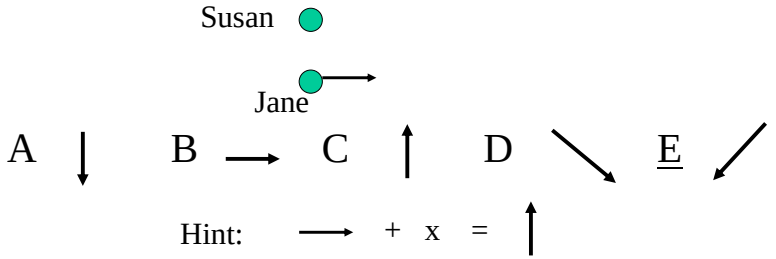
Acceleration is Rate of change of Velocity



What time is the acceleration the largest?
A) 1 s B) 2 s C) 2.5 s D) 6 s E) it is not possible to tell

Vector Problem

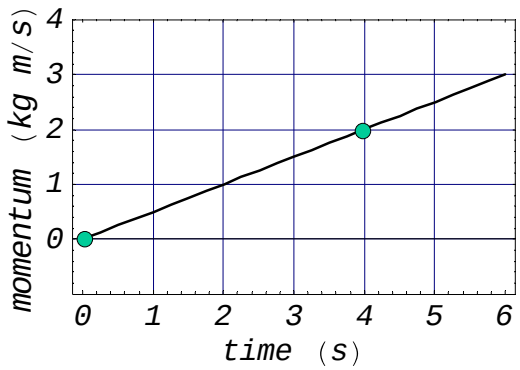
- Jane is running east with a speed of 2 m/s. When she gets directly south of Susan, she throws the ball at 2.8 m/s. What direction should she throw the ball?



Newton's Laws of Motion

- Three laws that define a force
  - If the net force is zero, there is no acceleration
  - F=ma
  - For every force, there is an equal and opposite force
- Force is the rate of change of momentum

Force is the Rate of Change of Momentum



$$F = \frac{p_2 - p_1}{t_2 - t_1}$$

$$F = \frac{2.0_{kg\,m/s} - 0.0_{kg\,m/s}}{4s - 0s}$$

$$F = 0.5\ N$$

What is the direction of the force? A) Right B) Left
What is the magnitude of the force? A) 0 N B) 2 N C) -2 N D) 0.5 N

Newton's Laws Problem

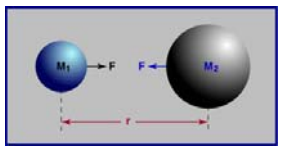
A car is moving in a straight line at a constant speed of 60 mph. What can we say about the force of friction (air and rolling friction) on the car?

A. The force of friction is larger than the force of the tires on the road.
B. The force of friction is equal to the force applied by the tires to the road.
C. Friction must be small.
D. The force of friction must be a little smaller than the force of the tires on the road.
E. None of these statements is correct.

Newton's Universal Law of Gravity

Newton's Universal Law of Gravity:

$$F = \frac{Gm_1m_2}{r^2};\ G = 6.673E-11\ {Nm^2}/{kg^2}$$



Two examples using the Law of Gravity

- More mass more force
- Greater distance, less force
- What would happen if the distance were doubled, but the masses are the same?

$$F_{new} = \frac{Gm_em_p}{(2r_e)^2} = \frac{Gm_em_p}{4(r_e)^2} = \frac{1}{4} \times F_r$$

- What would happen if the distance is half and the mass of the Earth were twice?

$$F_{new} = \frac{Gm_e(2m_p)}{\left(r_e/2\right)^2} = \frac{2Gm_em_p}{1/4\,(r_e)^2} = \frac{8Gm_em_p}{(r_e)^2} = 8 \times F_{old}$$

Gravity on the Moon

- The mass of the Moon is 0.0123 times that of the Earth, and the radius is 0.273 time that of the Earth's radius. What is the force of gravity on the Moon relative to that on Earth?

$$F_{Moon} = \frac{Gmm_{moon}}{r_{moon}^2} = \frac{Gm(0.0123m_{Earth})}{(0.273r_{Earth})^2} = \frac{0.0123}{(0.273)^2} \cdot \frac{Gmm_{Earth}}{r_{Earth}^2}$$

$$\boxed{F_{Moon} = 0.165 \cdot F_{Earth}}$$

Newton's Laws Problem

When the space shuttle is in orbit, what can we say about the force the shuttle exerts on the Earth? Choose the best answer.

A. It is the same as the force the Earth exerts on the shuttle.

B. The Earth pulls harder on the shuttle.

C. The shuttle pulls harder on the Earth than the Earth does on the shuttle.

D. None of these statements is correct.

E.There is no force on the Earth since the shuttle is in orbit.

Clicker Questions

- Why is an astronaut in orbit weightless?

A). Because they are always in free fall, but constantly miss the Earth.

B). Because gravity from the Earth and moon cancels.

C). Because gravity from the Earth and Sun cancels.

D). Because there is no gravity in space.

History of astronomy

- Ptolomy devised an Earth-centered model of the motion of planets that worked well
- Brahe made detailed measurements that showed deficiencies in the model
- Kepler discarded the previous assumptions and devised his three laws of planetary motion with the Sun at the center
- Newton unified the tree laws with his Universal Law of Gravity

Consequences of Special Relativity

- Clocks in moving systems run more slowly.

$$t = \gamma\, t_0 \quad \gamma = \sqrt{\frac{1}{1-\left(\frac{v^2}{c^2}\right)}} = \sqrt{\frac{1}{1-\beta^2}}$$

  - t_0 is called the "proper" time it is the time measure in the inertial reference frame.
- A clock pendulum has a period of 1 s. What would the period appear to be if the clock was moving at 0.89 c?

$$t = t_0\sqrt{\frac{1}{1-\beta^2}} = 1s\sqrt{\frac{1}{1-0.89^2}} = 2.19s$$

In the ship

- What period would a person traveling with the clock measure?

Answer: 1 s
Time is relative!

Sample question

If Jane flies at the 0.99c for 10 years (according to her). How much older is she when she returns back to the Earth?

Answer: 10 years

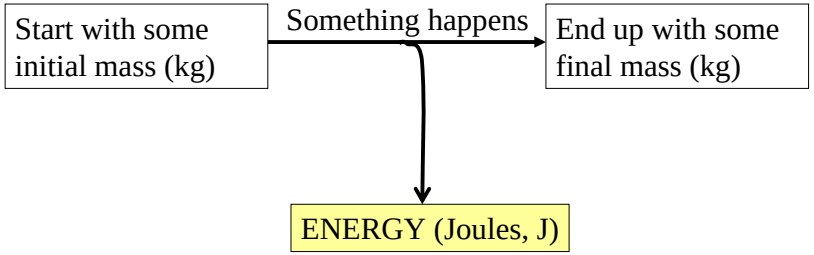
Consequences of Special Relativity

- In a moving system, clock run more slowly
- In a moving system, distance appear smaller
- In a moving system, mass increases

$$\text{reletivistic factor} = \gamma = \sqrt{\frac{1}{1-\left(\frac{v^2}{c^2}\right)}}$$

Picture

The following is a picture of a chemical reaction:



The amount of energy is $E = m_{converted}\, c^2$

$m_{converted}$ = (Mass to start) x fraction

Fraction of Energy Converted

- In a chemical reaction not all the mass can be converted to energy. Actually only a very small fraction (the exact value of the fraction depends on the chemical reaction).

Reaction	Fraction	Example
Matter-Antimatter Annihilation	1	No common example; happens at particle accelerators
Fusion	0.007	Power source of the Sun
Fission	0.001	Nuclear power plant
Chemical	$1x10^{-10}$	Burning coal
Mechanical	$1x10^{-15}$	Compressing a spring

Gravitational Time Dilation

- Mass stretches space, but since space and time are connected (space-time) it also affects time.
- Near a mass, time runs more slowly. On the surface of the Earth this affect is only 10^{-9} s, but near a black hole it could be infinite.
- Why? As you travel through space you travel through time. Where space is stretched, time is stretched.
- Metric equation: $$(\Delta s)^2 = (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 - (c\Delta t)^2$$

The (-) is part of what is called the metric of space time. It is contained in the tensor called the *metric of space time*.

Review of where we are

- The universe behaves in a mathematical way
- We can define quantities like velocity and with laws of motion describe, for example, the motion of the solar system
- The leads us to a deterministic picture of the Universe. However this is not correct.
- What causes the forces of nature like gravity? Why is Newton's law of gravity the correct form?
- Time is a thing that is measured by clocks. However, time is relative. It depends on motion. Einstein's General Relativity says that space and time are connected in space-time.
- Why is the speed of light special? Why is it always constant?