Today's Class: Conservation Laws

- Read about Energy in *Cosmic Perspective*, Section 4.3.
- Homework #1 is due on Wednesday, Sep. 9.
- Complete Daily Health Form

1

Space in the News: Here's what NASA could accomplish if it had the US military's $600 billion budget

Presented by Kidus Abera

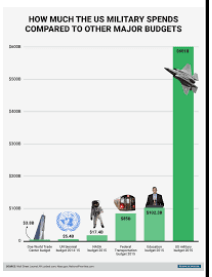
2

Space in the News: Here's what NASA could accomplish if it had the US military's $600 billion budget

By Kidus Abera

What NASA could do with the US Military 's Budget:

- From landing humans on the moon, to exploring alien worlds such as Mars and Saturn's moon Titan, NASA has done a lot of work on a relatively small budget. Ever since Neil Armstrong and Buzz Aldrin returned from their Apollo 11 mission, NASA's percentage of the annual federal budget has shrunk from 4.5% to .05%. Meanwhile the US Military's annual spending budget has swelled from 8.9% to over 54%. If NASA was given the $600 Billion the US Military was given annually, they could easily fund their biggest upcoming projects. Which include sending humans to Mars ($400 Billion) and the completion of the most powerful telescope in history: the James Webb Telescope ($10 Billion). While having hundreds of billions of dollars to spare to invest into other big projects
- Question: In this current day and age, with everything going on, do you think it is best for NASA to get a bigger budget, or should the US invest its extra money into other departments?



3

Last Class

- **How did Newton change our view of the universe?**
  - He discovered laws of motion and gravitation.
  - He realized these same laws of physics were identical in the universe and on Earth.
- **What are Newton's three laws of motion?**
  1. Object moves at constant velocity if no net force is acting.
  2. Force = mass × acceleration
  3. For every force there is an equal and opposite reaction force.

4

Class Exercise: Which of the following describes how a rocket takes off?

a) The rocket exerts a force on the ground, and then the atmosphere, causing it to accelerate upward.
b) The backward momentum of the rocket exhaust is canceled by the forward momentum of the rocket.
c) The escaping rocket exhaust changes the mass of the rocket, giving it upward momentum.
d) The burning rocket fuel heats the air beneath the rocket, causing it to move upward.

5

Which of the following describes how a rocket takes off?

a) The rocket exerts a force on the ground, and then the atmosphere, causing it to accelerate upward.
b) The backward momentum of the rocket exhaust is canceled by the forward momentum of the rocket.
c) The escaping rocket exhaust changes the mass of the rocket, giving it upward momentum.
d) The burning rocket fuel heats the air beneath the rocket, causing it to move upward.

6

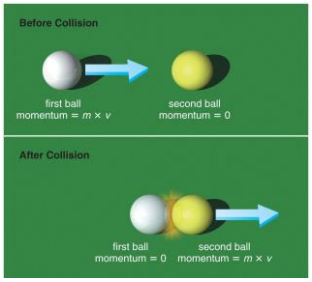
Today's Class

- Why do objects move at constant velocity if no force acts on them?
- What keeps a planet rotating and orbiting the Sun?

7

Why do objects move at constant velocity if no force acts on them?

Objects continue at constant velocity because of Conservation of Momentum.



- The total momentum (p = mv) of interacting objects cannot change unless an external force is acting on them.
- Interacting objects exchange momentum through equal and opposite forces.

8

Conservation of Momentum

- In the absence of external forces:

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = 0$$

- So, $p = \sum_{i=1}^{n} M_i V_i$ = constant.
- Example:

$$M_c V_{initial} + M_b(0) = (M_c + M_b)\, V_{final}$$

9

Conservation of Momentum

- In the absence of external forces:

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = 0$$

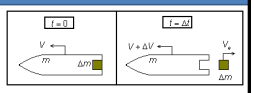
- What should happen below if George Clooney lets loose of tether from Sandra Bullock?

- Initially, $p_1 = p_2 = 0$, so this should not change!

10

Rocket Equation

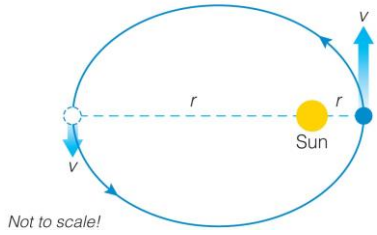
- In space, $F = \frac{\Delta p}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = 0$.



- For the case of a rocket in space where m = rocket mass, Δm is fuel mass, and Δv is change in rocket velocity, one can show using Newton's 2nd Law and a bit of math: M_f = mass fraction = $\frac{\Delta m}{m + \Delta m} = 1\text{-}e^{-\Delta v / v_e}$, where v_e is exhaust velocity.
- Let's do an example: Δv = 9700 m/s (Earth to LEO), v_e = 4500 m/s for chemical propulsion => M_f = .884 or 88.4% of total mass must be devoted to rocket fuel!

11

What keeps a planet rotating and orbiting the Sun?



13

Conservation of Angular Momentum

Angular momentum L = mass × velocity × radius = mvr.

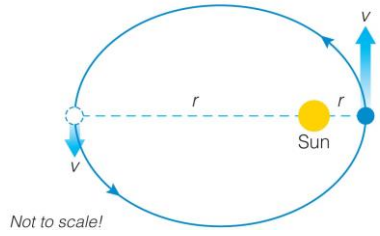
- The angular momentum of an object cannot change unless an external twisting force (torque) is acting on it.
- Earth experiences no twisting force as it orbits the Sun, so its rotation and orbit will continue indefinitely.

14

Angular momentum conservation also explains why objects rotate faster as they shrink in radius

15

What keeps a planet rotating and orbiting the Sun?



16

What have we learned?

- **Why do objects move at constant velocity if no force acts on them?**
  - –Conservation of momentum
- **What keeps a planet rotating and orbiting the Sun?**
  - –Conservation of angular momentum

17