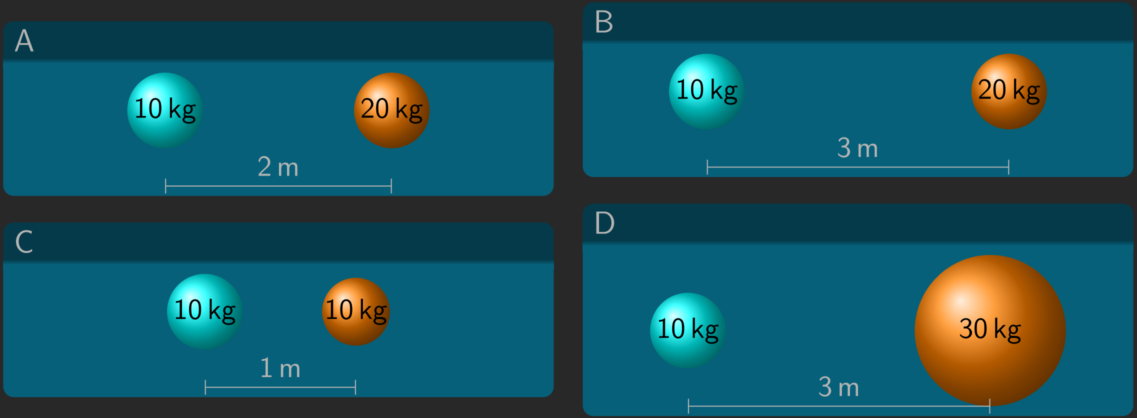
Announcements

- WebWorK due on Friday!
- Starting Ch 4 content today
- I'll be aiming to start posting weekly grade reports starting this weekend
- Polling: rembold-class.ddns.net

Review Question

In which of the following situations would the gravitational force between the two masses be greatest?



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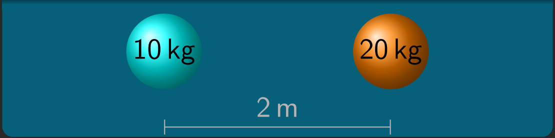
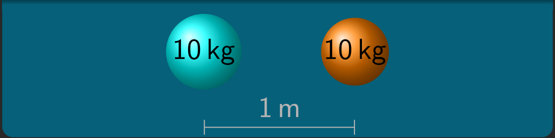
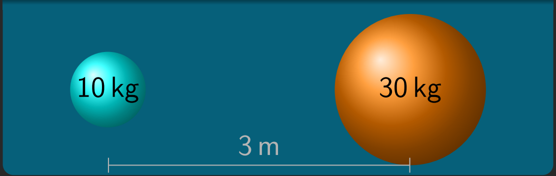


B

C



D



The Fine Art of Throwing Things

- Say you throw a ball sideways

The Fine Art of Throwing Things

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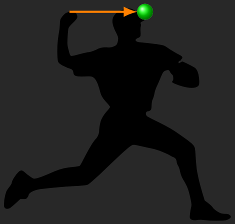
  - You force the ball (using your arm) up to some speed



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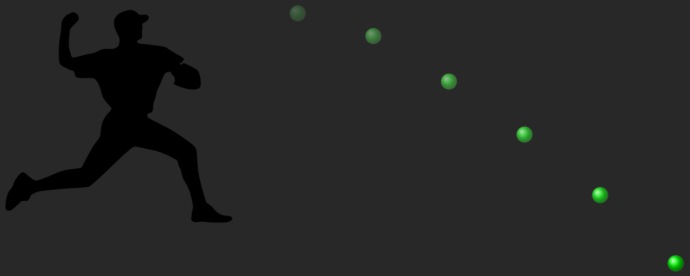
The Fine Art of Throwing Things

- Say you throw a ball sideways
  - You force the ball (using your arm) up to some speed
  - Inertia keeps the ball moving forward at that speed
  - Gravity drags the ball down

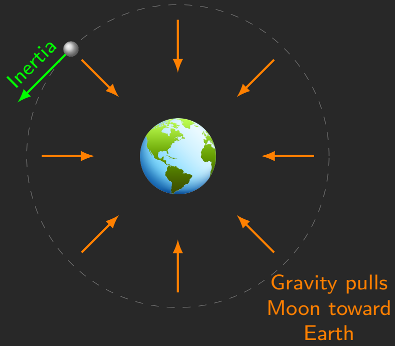


One Powerful Arm. . .

- Now, if we hiked up a tall mountain and had a REALLY REALLY strong arm. . .
- Newton's Mountain

Moon Orbits

- So we know that we can get an object into orbit by throwing it really hard in a certain direction
- Whatever process formed the Moon must have thus given it this "initial velocity"
- So our Moon's orbit is a result of:
  - That velocity
  - Inertia
  - and the pull of gravity



Newton meets Kepler's 3rd

- Recall that Kepler had worked out that

$$\frac{a^3}{p^2} = \text{ same value for all planets orbiting Sun}$$

  - This is why we need to use AU and year units, because those describe Earth's a and p!

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$$\frac{a^3}{p^2} = \text{same value for all planets orbiting Sun}$$

  - This is why we need to use AU and year units, because those describe Earth's a and p!
- Newton worked out from theory that two objects held in orbit by gravity would obey:

$$\frac{a^3}{p^2} = \frac{G\left(M_1 + M_2\right)}{4\pi^2}$$

  where

$$\begin{aligned} M_1, M_2 &= \text{masses of objects in \underline{kilograms}} \\ a &= \text{average separation of objects in \underline{meters}} \\ p &= \text{orbital period in \underline{seconds}} \\ G &= \text{gravitational constant in \underline{SI Units}} \end{aligned}$$

A Nicer Newton's Formulation

- Put into more everyday units, Newton's formulation boils down to:

$$\frac{a^3}{p^2} = (M_1 + M_2)$$

  where

$$\begin{aligned} M_1, M_2 = &\ \text{masses of objects in solar masses} \\ a = &\ \text{average separation of objects in AU} \\ p = &\ \text{orbital period in years} \end{aligned}$$

- For the Sun and Earth, $M_1 + M_2 \approx 1$

Newton and Kepler's 3rd Law Example

Example

Suppose our Sun suddenly grew to have 30 times it's current mass. Assuming we stayed the same distance away, how long would our new year be?

- $a = 1\,\mathrm{AU}$
- $M_{earth} + M_{sun} \approx M_{sun} = 1M_{\odot}$

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- $a = 1\,\text{AU}$
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$$
\begin{aligned}
p &= \sqrt{\frac{a^3}{(30M_{\odot})}} \\
&= 0.182\,57\,\text{yrs} \\
&= 66.5\,\text{days}
\end{aligned}
$$

Angular Momentum

- Related to how much rotational inertia an object has
- For an object moving in a circle, the angular momentum is:

$$L = m \times v \times r$$

- The only way to change an objects angular momentum is to apply an angular force (called a torque)

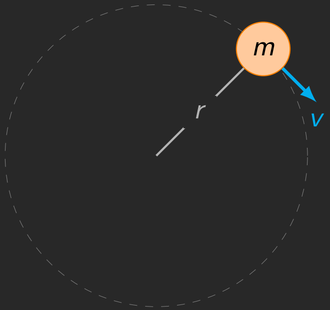

Figure Skating

Summary!

- Force is a measure of how something's motion will change
- The gravitational force increases with mass and decreases rapidly with distance
- Newton refined Kepler's 3rd law to account for the masses of the orbiting objects
- Angular momentum is related to an object's rotational inertia, and is difficult to change
- Decreases in radius will result in a faster rotating object

Concept Question

Seasons are determined by the proximity of Earth to the sun. Summer when we are closer and Winter when we are further away.

A. True

B. False

The Reason for the Season

- Summer in Northern Hemisphere = Winter in Southern
  - Both would be the same if seasons were based on distance

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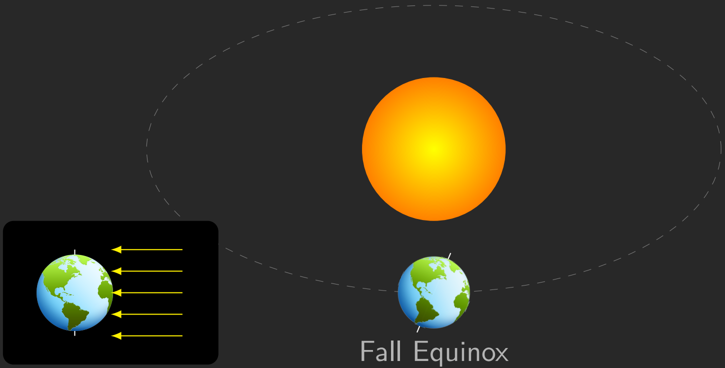
Fact!

Seasons are a result of the Earth's tilt.

The Seasons



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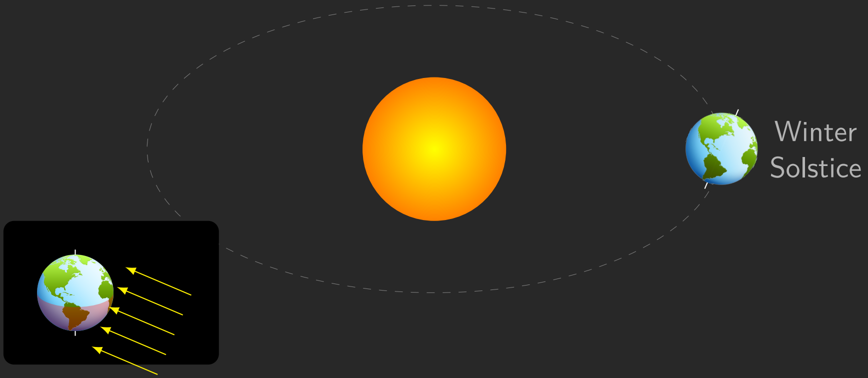

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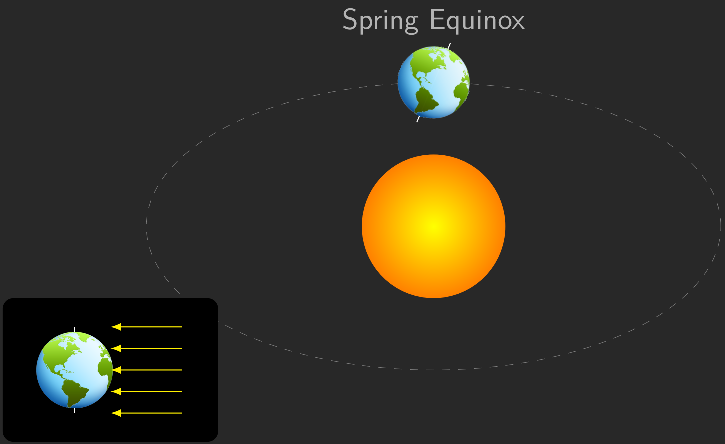

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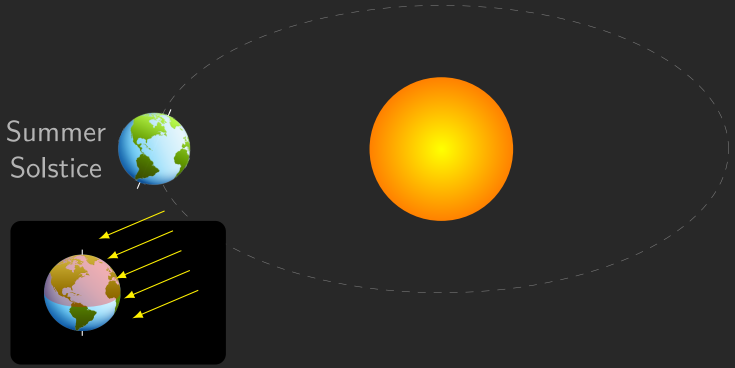

The Seasons

- More direct Sun heats better
- Each position marks the start of our "seasons"
- Sun's position in the local sky changes as well
  - Highest on Summer Solstice
  - Lowest on Winter Solstice
  - Rises *exactly* in the East and sets *exactly* in the West on the Equinox's

Alien Seasons

- Earth's seasons
  - Planet Tilt
  - Orbital variations
  - Distance differences due to tilt
- Pluto's seasons
  - Planet Tilt
  - Orbital variations
  - Distance differences due to tilt
- TrES-4 (1.8x size of Jupiter, 0.05 AU from it's parent star)
  - Planet Tilt
  - Orbital variations
  - Distance differences due to tilt

Our Wobbly Planet

- Just like a spinning top, Earth has a bit of a wobble
- Relative to the celestial sphere, the direction of our North Pole oscillates every 26 000 yrs
- “North Star” changes!