Notes

- Reminder: course syllabus and schedule + my replies to questions students have asked by email or in person:
  - http://scs.gmu.edu/~rweigel/F2006

Outline for 14 September (Thursday)

- **Review topics from Lecture 5 (Chapter 4 of text).**
  (~ 30 minutes)
- **Newton's Giant Leap (Chapter 4 of text)**
  (~ 45 minutes)

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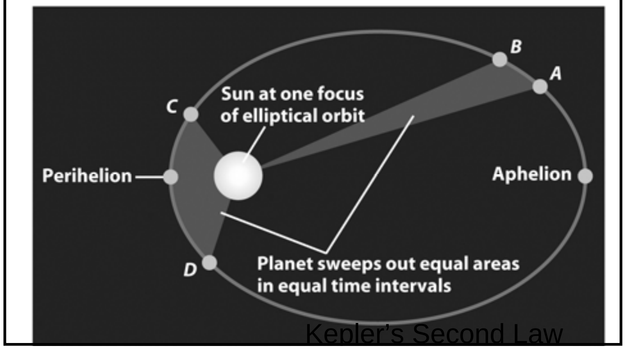
Quiz Chapter 4, #20

- A planet moving in an ellipse with the Sun at one focus will have a speed which is
  1. highest when it is farthest from the Sun.
  2. constant along the orbit, as required by Kepler's law.
  3. highest when it is closest to the Sun.

Takes equal time to go from A to B as from C to D
C to D is much longer distance –
so it must be moving faster in C-D interval
(velocity = distance/time)



Kepler's Second Law

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Chapter 4 Quiz #2

- As observed from Earth, the motion of a planet known as direct motion refers to
  1. a slow westward motion against the background stars.
  2. a slow eastward motion against the background stars.
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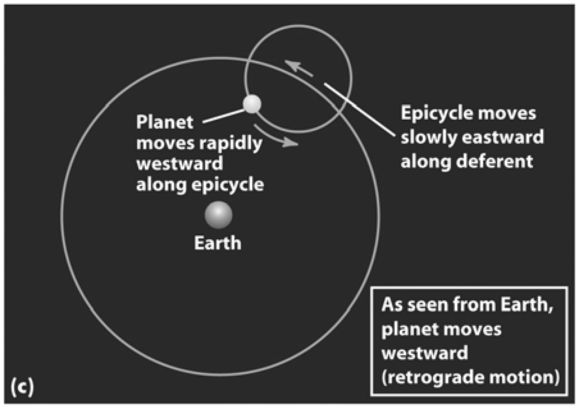
If you forget, here is how you can figure it out:

- direct and retrograde were used to describe motion of planet in Ptolemic model
- Think about what you would see from Earth



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  1. in small circles, the centers of which were moving around the Earth more slowly in larger circles.
  2. in circles around the Earth, the planes of which were precessing slowly around a direction perpendicular to the ecliptic plane
  3. in ellipses, with their respective foci at the center of Earth.

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Key Words

- Newton's laws (of motion)
- tidal forces
- universal constant of gravitation
- weight vs. mass
- Force
- acceleration
- gravity

Lingering questions

- Kepler's laws are not so "clean"
- Need to explain
  - Why orbits of planets are elliptical
  - Why distance from Sun is related to orbital period
  - Why planet velocity changes during orbit

- Also want a recipe that gives good predictions of when eclipses will occur, where the planets will be in the future.

Lingering questions

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  - Why orbits of planets are elliptical
  - Why distance from Sun is related to orbital period
  - Why planet velocity changes during orbit
  - Why people on the south pole don't fall into space …

- Also want a recipe that gives good predictions of when eclipses will occur, where the planets will be in the future.

iSaac Newton

Isaac developed three principles, called the laws of motion, that apply to the motions of objects on Earth as well as in space

Newt's "Principles" (Laws of Motion)

1. The law of inertia: a body remains at rest, or moves in a straight line at a constant speed, unless acted upon by a net outside force
2. F = m *x* a: the force on an object is directly proportional to its mass and acceleration, provided the mass does not change
3. The principle of action and reaction: whenever one body exerts a force on a second body, the second body exerts an equal and opposite force on the first body

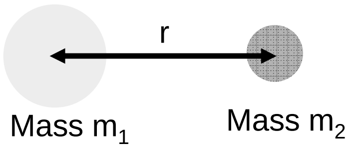
Group Question

- An object at rest tends to stay at rest. An object in motion tends to stay in motion.
  - –What is wrong with this statement?
  - –Why don't we observe "objects in motion tending to stay in motion" more often?

Newton's Law of Universal Gravitation

A number (T.B.D.)

$$Force = G\left(\frac{m_1 m_2}{r^2}\right)$$



- ***Mass and Weight are not the same***
  - –Mass refers to how much stuff is in an object (atoms, molecules, etc).
  - –Weight refers to how much that stuff will push down on a scale. This depends on what planet you are on.

Newton's Law of Universal Gravitation

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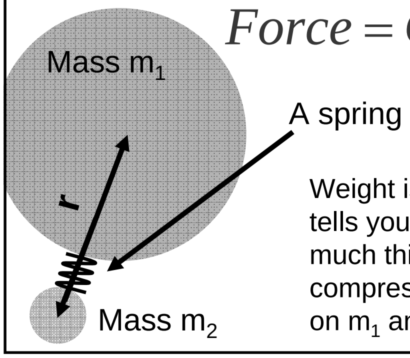

Weight is a number that tells you about how much this spring will compress. It depends on m_1 and r.

How to get Weight = mass x gravity

$$Force = G\left(\frac{m_1 m_2}{r^2}\right)$$

Mass of Earth

$$Force = m_2 \underbrace{\left(\frac{Gm_1}{r^2}\right)}_{g = 9.8 \text{ m/s}^2} = m_2 g$$

Radius of Earth

What about Bob Beamon?

- The law of universal gravitation accounts for planets not falling into the Sun nor the Moon crashing into the Earth

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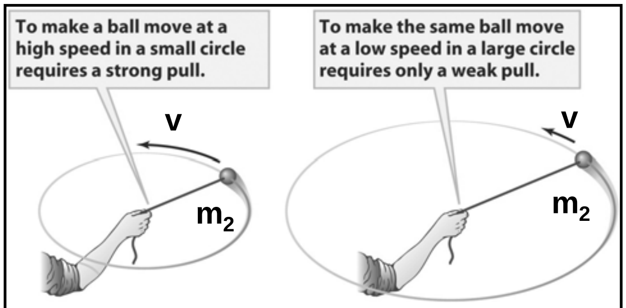
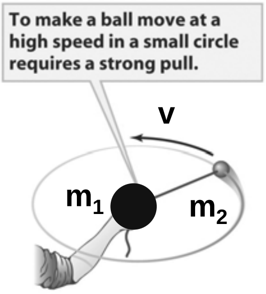

To make a ball move at a high speed in a small circle requires a strong pull.

To make the same ball move at a low speed in a large circle requires only a weak pull.

$$Force = \left(\frac{m_2 v^2}{r}\right)$$

(You will need to take my word on this equation)


To make a ball move at a high speed in a small circle requires a strong pull.

$$Force = \left(\frac{m_2 v^2}{r}\right)$$

Now suppose Earth provides “pull” instead of string and arm

$$Force = G\left(\frac{m_1 m_2}{r^2}\right)$$

$$Force = G\left(\frac{m_1 m_2}{r^2}\right)$$

(Force that can be provided)

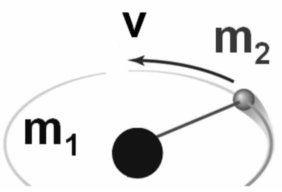
$$Force = \left(\frac{m_2 v^2}{r}\right)$$

(Force needed to keep it in orbit)

$$\left(\frac{m_2 v^2}{r}\right) = G\left(\frac{m_1 m_2}{r^2}\right)$$

$$v^2 = \frac{Gm_1}{r}$$

Is this right?



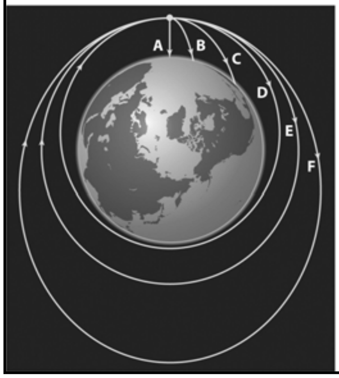
- G = 6.7 x 10^{-11} N·m^2/kg^2
- m_1 = 2 x 10^{30} kg

- Mars
  - Orbital velocity = 24 km/s
  - Distance from Sun = 228 x 10^9 km
- Earth
  - Orbital velocity = 30 km/s
  - Distance from Sun = 150 x 10^9 km

Compare

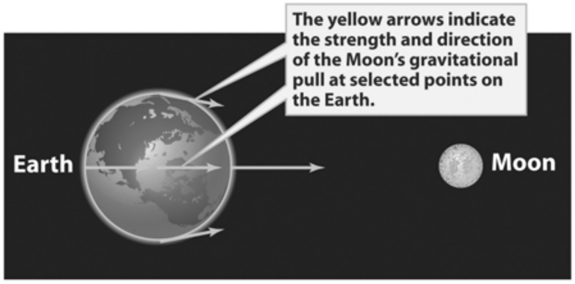
- Kepler’s 3rd law relates orbital speed and radius
- Newton’s law of gravitation was used to derive a relationship between orbital speed and radius
- Both will give the same answer. Which is “better”?

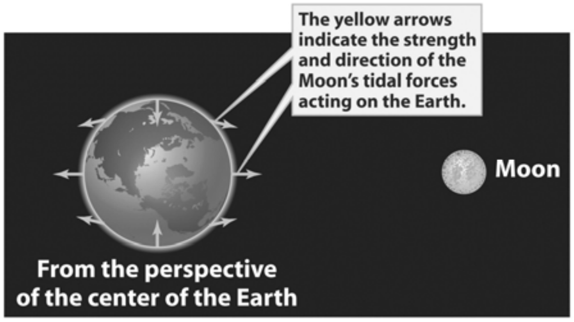
To get something in orbit, you need a special horizontal velocity

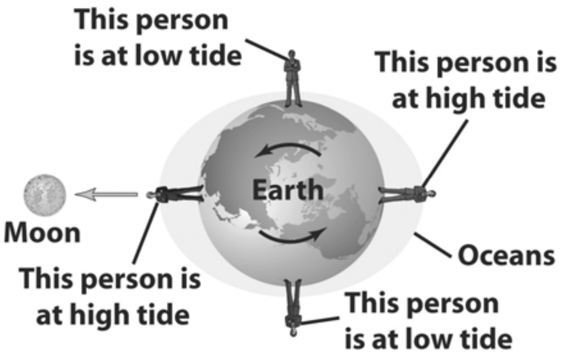


- The law of universal gravitation accounts for planets not falling into the Sun nor the Moon crashing into the Earth
- Paths A, B, and C do not have enough horizontal velocity to escape Earth’s surface whereas Paths D, E, and F do.
- Path E is where the horizontal velocity is exactly what is needed so its orbit matches the circular curve of the Earth

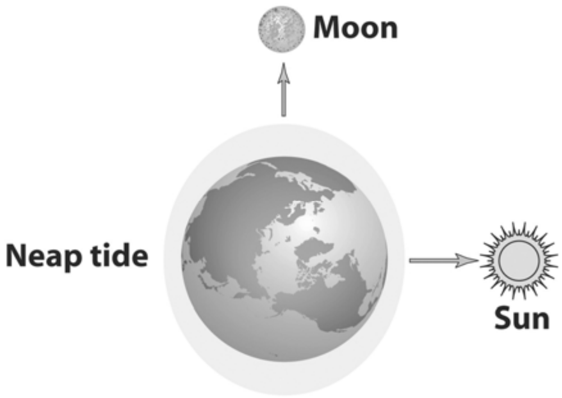
Tides


The yellow arrows indicate the strength and direction of the Moon’s gravitational pull at selected points on the Earth.


The yellow arrows indicate the strength and direction of the Moon’s tidal forces acting on the Earth.



Spring tide



Chapter 4, #24

- How far would you have to go from Earth to be completely beyond the pull of gravity?
- Suppose the Earth was 2x its current radius (with the same mass). How would your mass change? How would your weight change?

Chapter 4, #24

- How far would you have to go from Earth to be completely beyond the pull of gravity? r = infinity

$$Force = G\left(\frac{m_1 m_2}{r^2}\right)$$

- Suppose the Earth was 2x its current radius (with the same mass). How would your mass change? How would your weight change? mass unchanged. r increases to 2r so weight goes down by $1/2^2=1/4$

Chapter 4, #2

- (a) In what direction does a planet move relative to the horizon over the course of one night?
- (b) is the answer to (a) is the same whether the planet is in direct or retrograde motion. What does this tell you about the speed at which planets move on the celestial sphere?

Review Questions

- Textbook Chapter 4: 1, 2, 4, 6, 9, 10, 11, 14, 18, 21, 22, 23, 24, 27, 29, 39, 42.
- CD or Online Quiz for Chapter 4: 29-45, but omit 36, 41, 42.