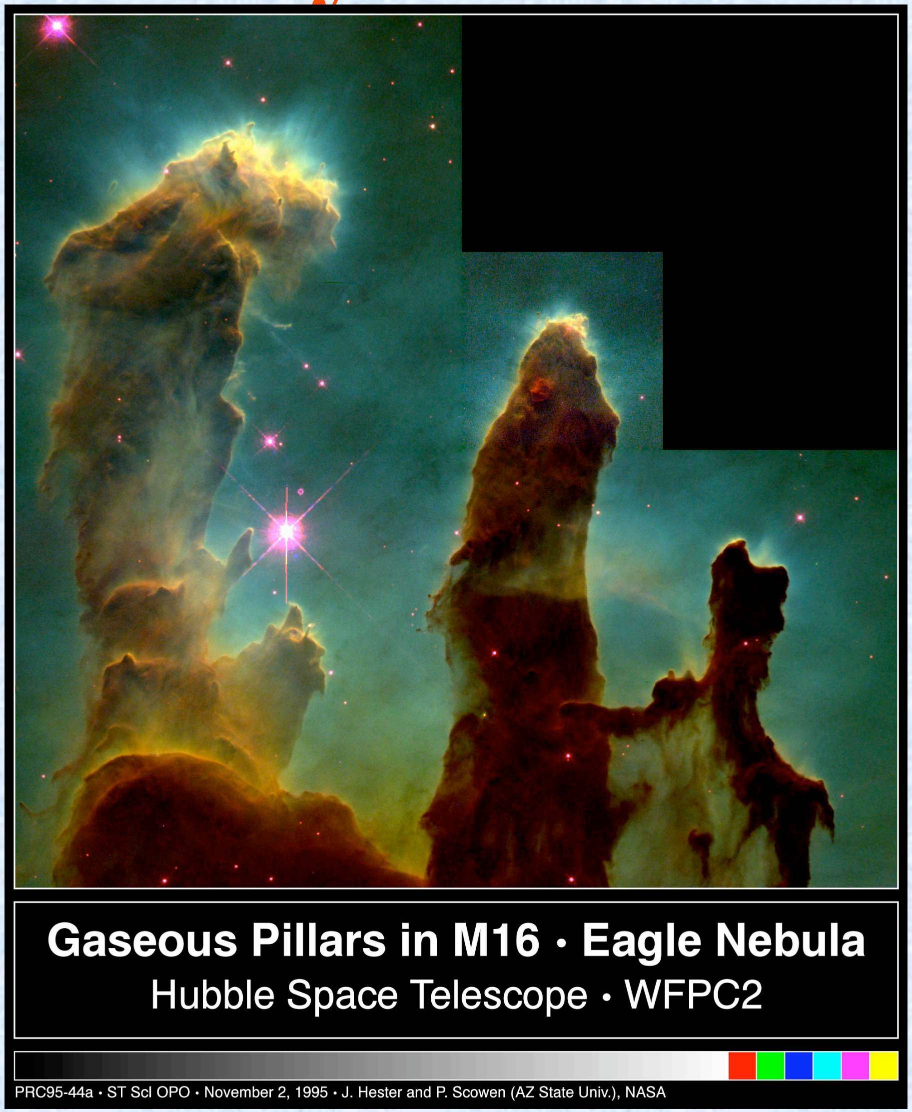
Astronomy 1 – Winter 2011



Lecture 5; January 12 2011

Previously on Astro-1

- Planets appear to move on the sky mostly West to East but occasionally with “retrograde motions”
- The ancients thought that the Earth was at the center of the solar system and that planets moved in spheres around the Earth
  - epicycles explained retrograde motion
- In the modern Heliocentric model, the planets go around the sun (copernican model)
  - What pieces of evidence show that the Geocentric model is false?
- Kepler’s Laws
  - The orbits of planets are ellipses
  - A planet’s speed varies along the orbit
  - The period of the orbit is related to the size of the orbit

Homework – Due 01/19/11

- On your own: answer all the review questions in chapters 4 thru 5
- To TAs: answer questions 4.41, 4.47, 5.30, 5.33, 5.40, 5.41

Today on Astro-1

- Newton's laws of dynamics
- Mass and Weight
- Newton's gravity
- The motion of planets explained by Newton's gravity
- Gravity and tides

Isaac Newton
(1642–1727)
The most influential scientist in history.
Described gravity, explained Kepler's Laws, established that the laws of physics on earth extend up into the heavens, established laws regarding the conservation of momentum, invented calculus, split light into a spectrum, invented the reflecting telescope, made many mathematical advances.

Figure 4-18
Universe, Eighth Edition

Epitaph by Alexander Pope:
Nature and nature's laws lay hid in night;
God said "Let Newton be" and all was light.

Newton in a letter to Robert Hooke: "If I have seen further it is by standing on the shoulders of giants"

Newton’s First Law

An object remains at rest or moves in a straight line at a constant speed unless acted upon by a net outside force.

(Inertia)

Figure 4-18
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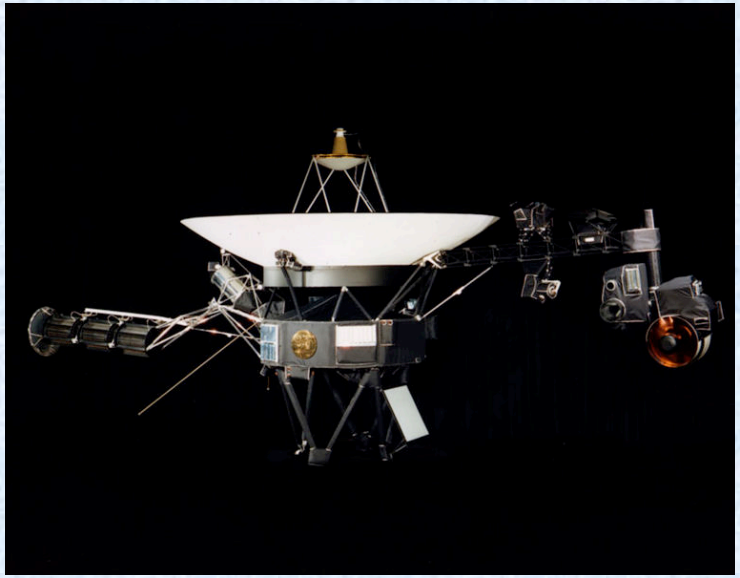
Example: Voyager 1 -- launched in 1977, it is now on its way out of the solar system, forever traveling in a straight line (unless it encounters something).



Newton's Second Law

$F = ma$

F = net outside force on a object

m = mass of object

a = acceleration of object

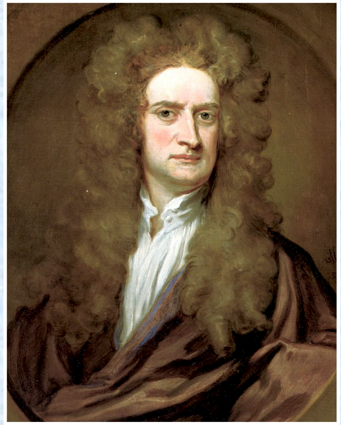


Figure 4-18
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$a=F/m$ – it requires more force to accelerate more massive objects

Or

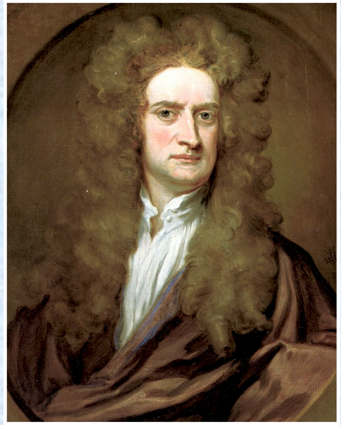
If you push two objects of different masses with the same force, the less massive object will accelerate more

Question 5.1 (iclickers!)

- Acceleration of a body is the rate of change of
  - A) Position with time
  - B) Kinetic energy with time
  - C) Mass with time
  - D) Velocity with time

Newton's Third Law

Whenever one object exerts a force on a second object, the second object exerts and equal and opposite force on the first object.



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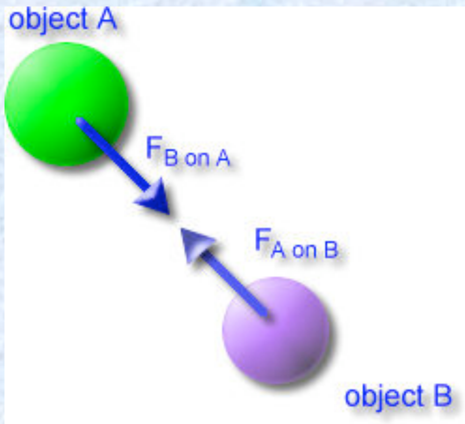
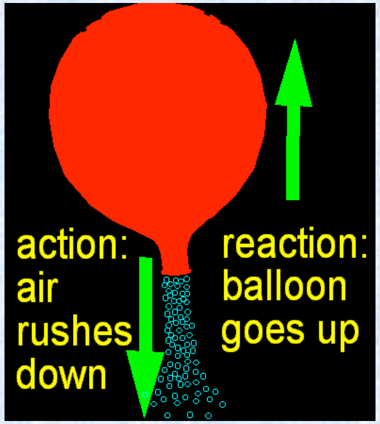
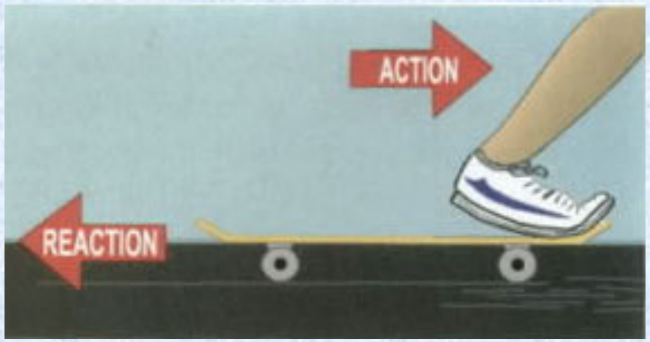
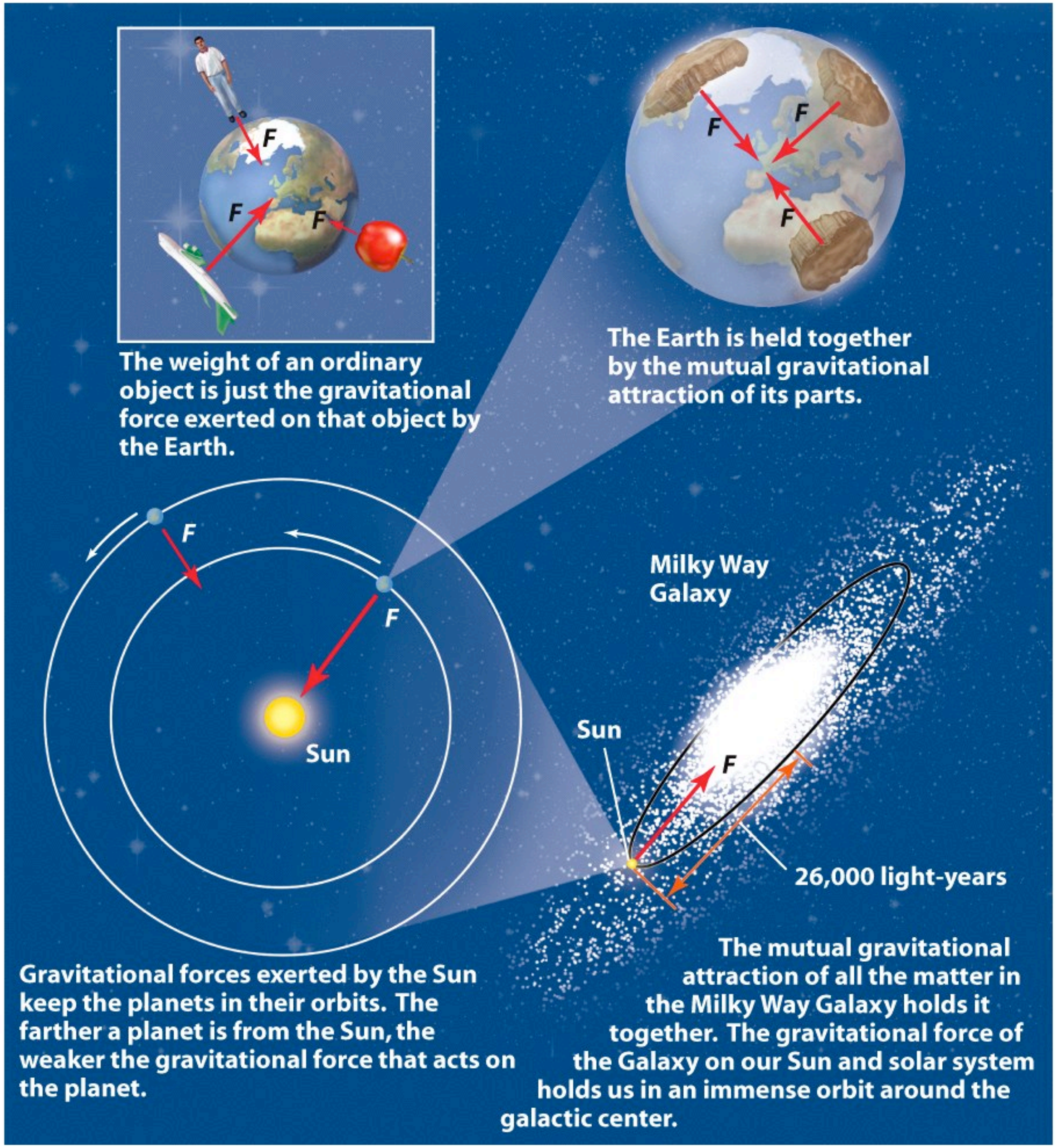






Newtonian Gravity


Sir Isaac Newton's Apple



Cosmic Connections 4-1

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The Law of Universal Gravitation

Two objects attract each other with a force that is directly proportional to the mass of each object and inversely proportional to the square of the distance between them.

Figure 4-18
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$F=Gm_1m_2/R^2$

F = gravitational force between two objects
m_1 = mass of first object
m_2 = mass of second object
r = distance between objects
G = universal constant of gravitation
$G = 6.67\times10^{-11}$ newton•m^2/kg^2

Difference between weight and mass

- Mass describes how much matter is in an object (measured in kg)

- Weight is a force that describes how gravity affects a mass (measured in Newtons: $1 \text{ N} = 1 \text{ kg m/s}^2$)
  - 1 Kg on the surface of the Earth weighs 9.8 N

Question 5.2 (iclickers!)

- If you were to be on the Moon, which of your physical properties would be altered noticeably?
  - A) Weight
  - B) Height
  - C) Mass
  - D) Volume

$F = Gm_1m_2/R^2$

F = gravitational force between two objects
m_1 = mass of first object
m_2 = mass of second object
r = distance between objects
G = universal constant of gravitation
$G = 6.67\times10^{-11}$ newton•m^2/kg^2

Example: If the Earth were the same mass, but twice the radius, what would a 100 kg person weigh?

$m_e = 5.97\times10^{24}$ kg
$m_p = 100$ kg
r = 2 × radus of Earth = $2\times6.38\times10^{6}$ m = 1.28×10^{7}m

F = 245 Newtons = ¼ 980 Newtons

The fall of bodies in a gravitational field does not depend on their mass

The orbits of planets

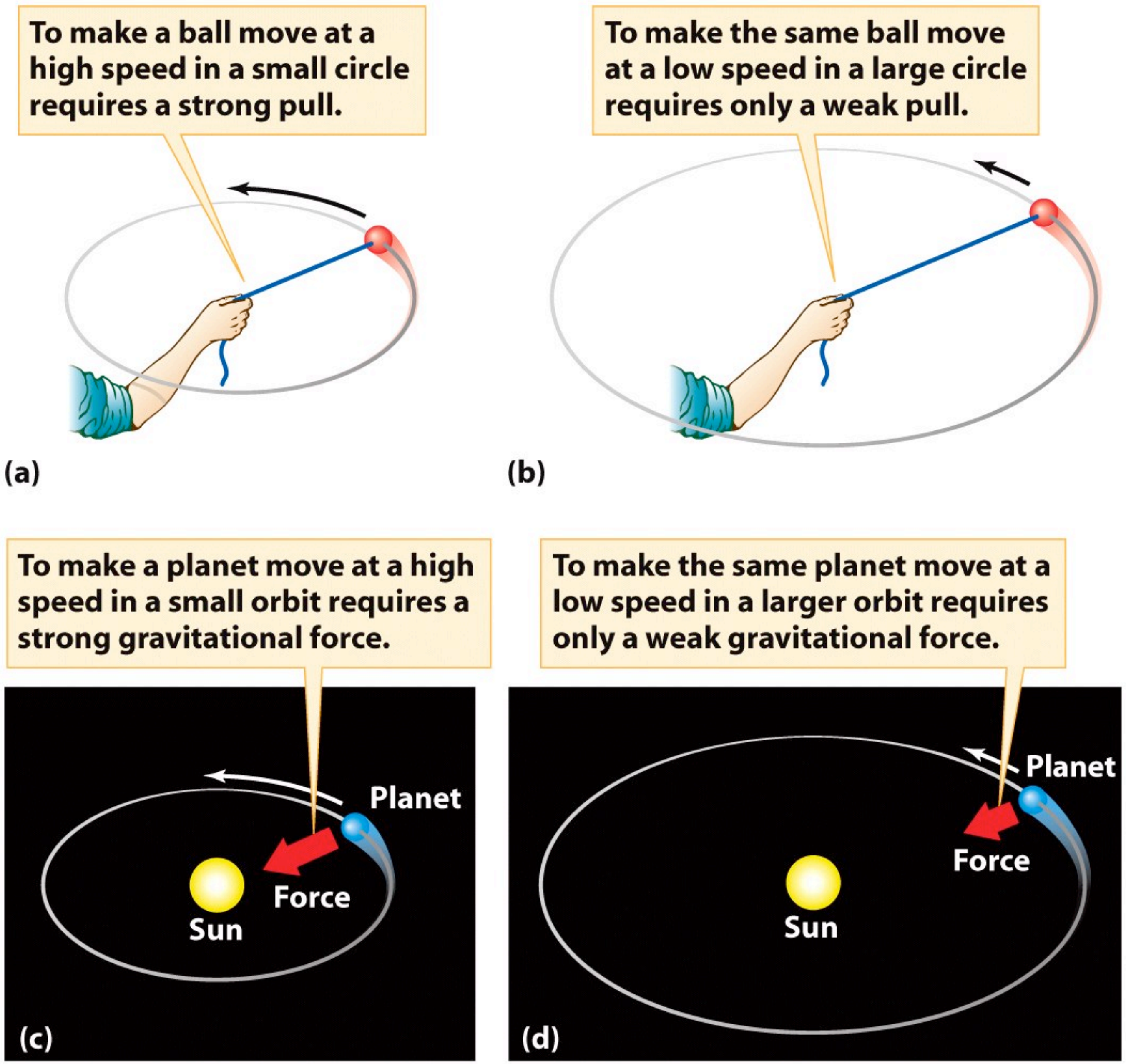

Figure 4-19
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Newton’s form of Kepler’s Third Law

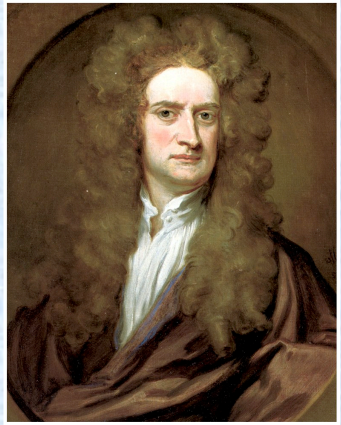

Figure 4-18
Universe, Eighth Edition

$$P^2 = \left[\frac{4\pi^2}{G(m_1 + m_2)}\right]a^3$$

P = period of orbit, in seconds
m_1 = mass of first object, in kg
m_2 = mass of second object, in kg
a = semimajor axis of orbit, in meters
G = universal constant of gravitation
G = 6.67×10^{-11} newton•m^2/kg^2

Note that Kepler’s form is only valid for objects orbiting the sun. Newton’s form can be applied to any two objects in the universe.

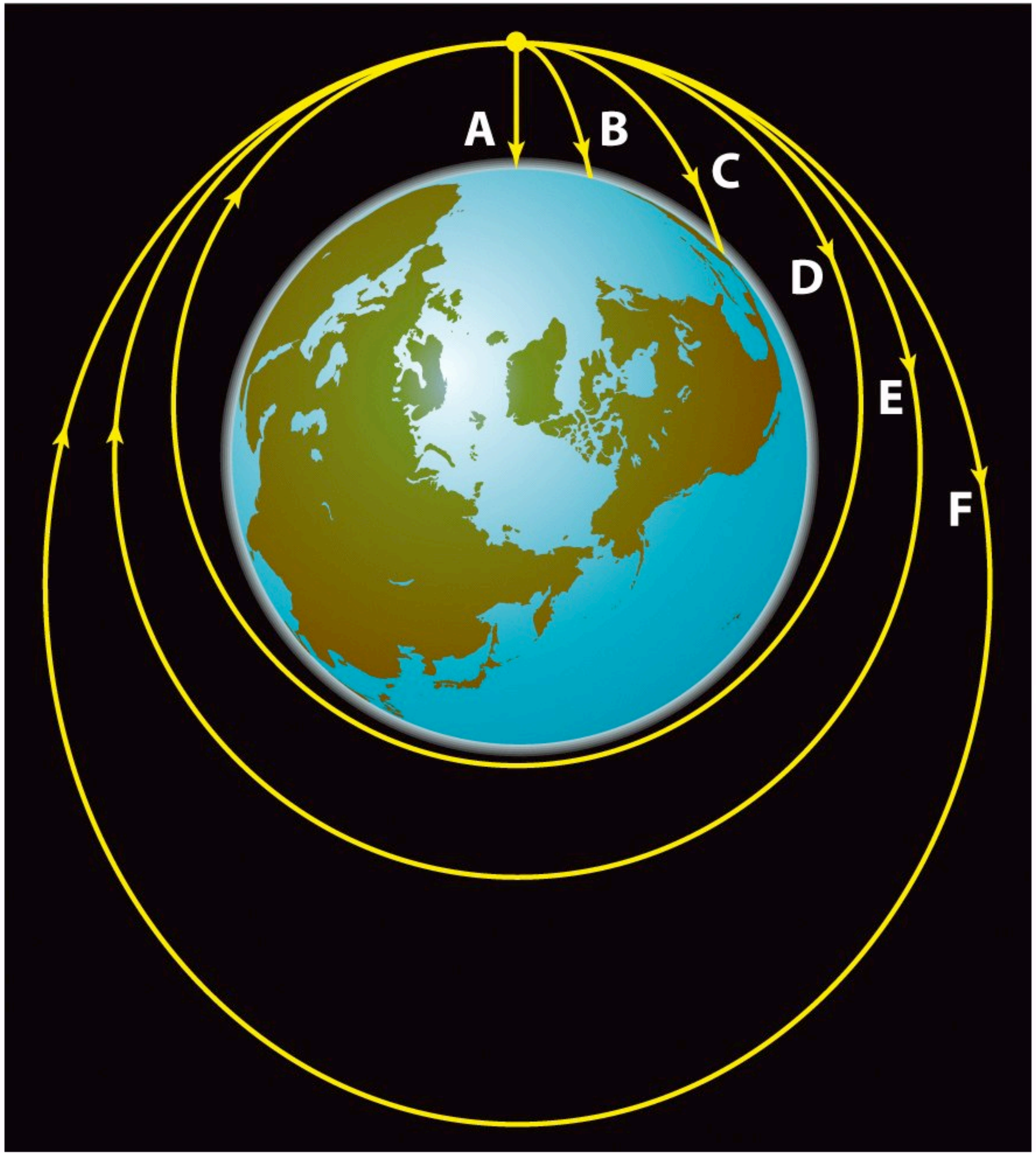

Figure 4-20
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The first American in space, Alan Shepard, did not orbit the Earth, because his Redstone rocket (a ballistic missile) was not powerful enough. John Glenn would later orbit Earth after being launched from an Atlas rocket.

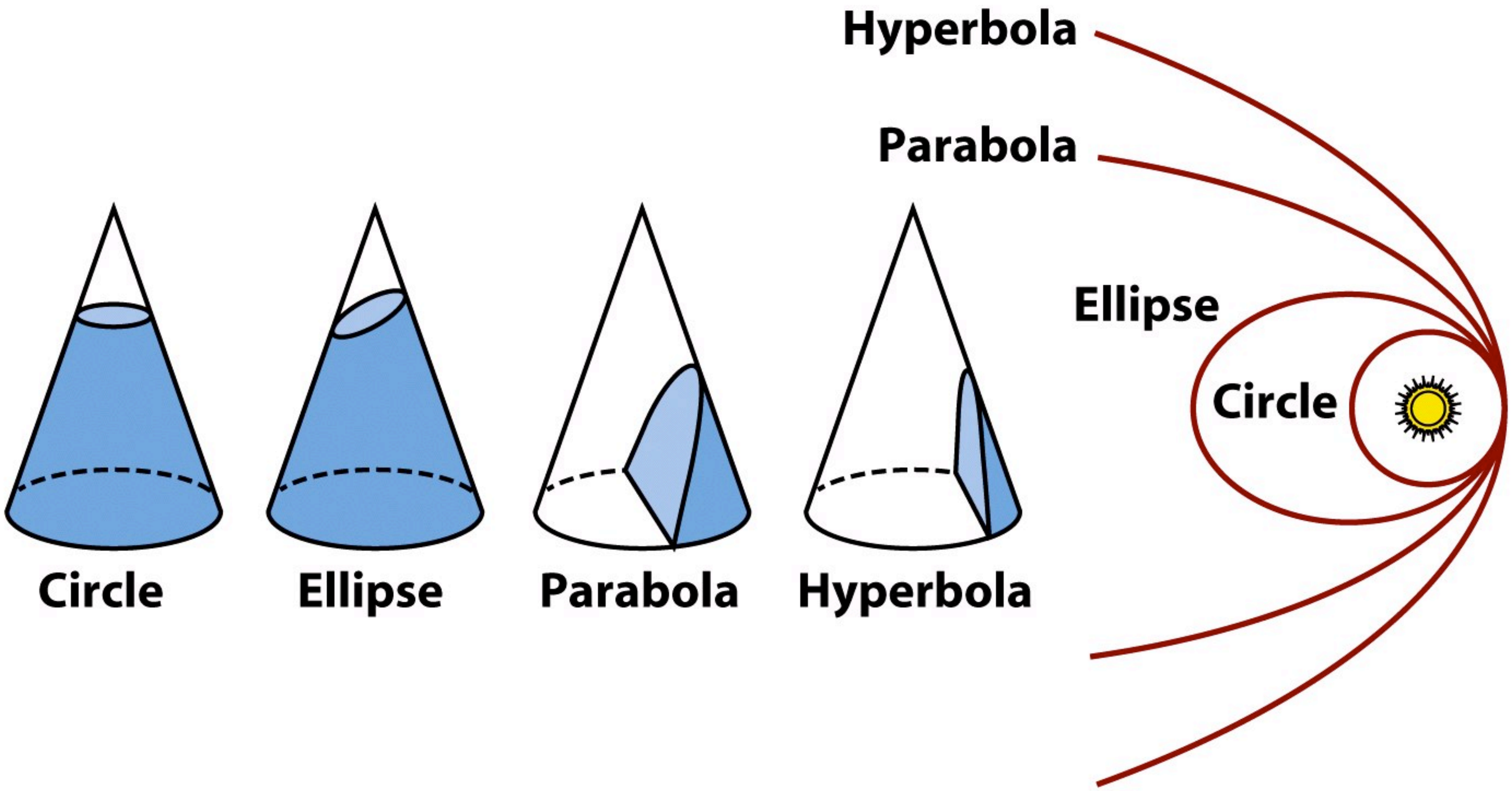

Figure 4-22
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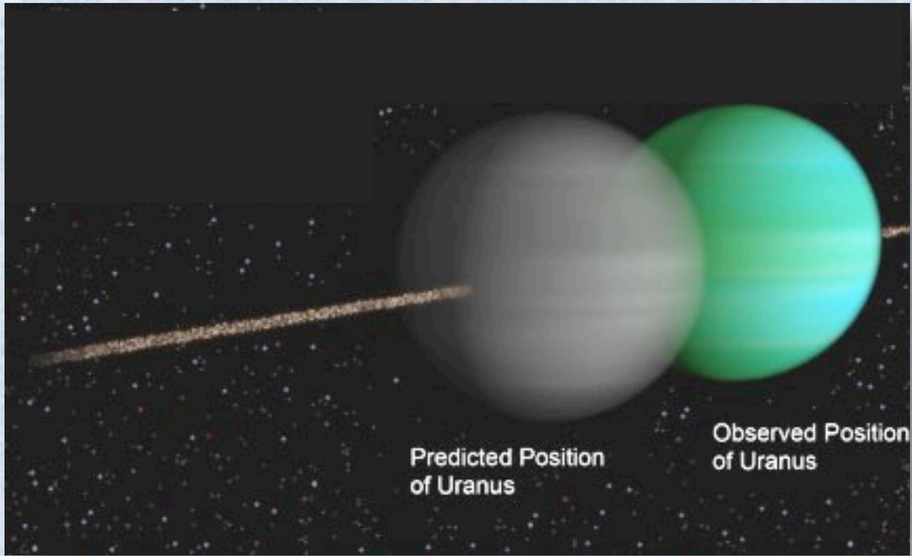
Discovery of Neptune



Le Verrier 1846 noticed Uranus was not in the right place. Predicted the existence of Neptune. Neptune was found where predicted to within one degree!

Question 5.3 (iclickers!)

- Suppose two asteroids are located at the same distance from the sun. One asteroid has twice the mass of the other. According to Newton's law of gravitation (and ignoring all forces except those from the sun)?
  - A) the more massive asteroid feels half the force that the other does
  - B) neither feel any force because they are weightless in space
  - C) the more massive asteroid feels twice the force of that on the less massive
  - D) both asteroids feel the same force, because gravity acts equally on all objects

Tides

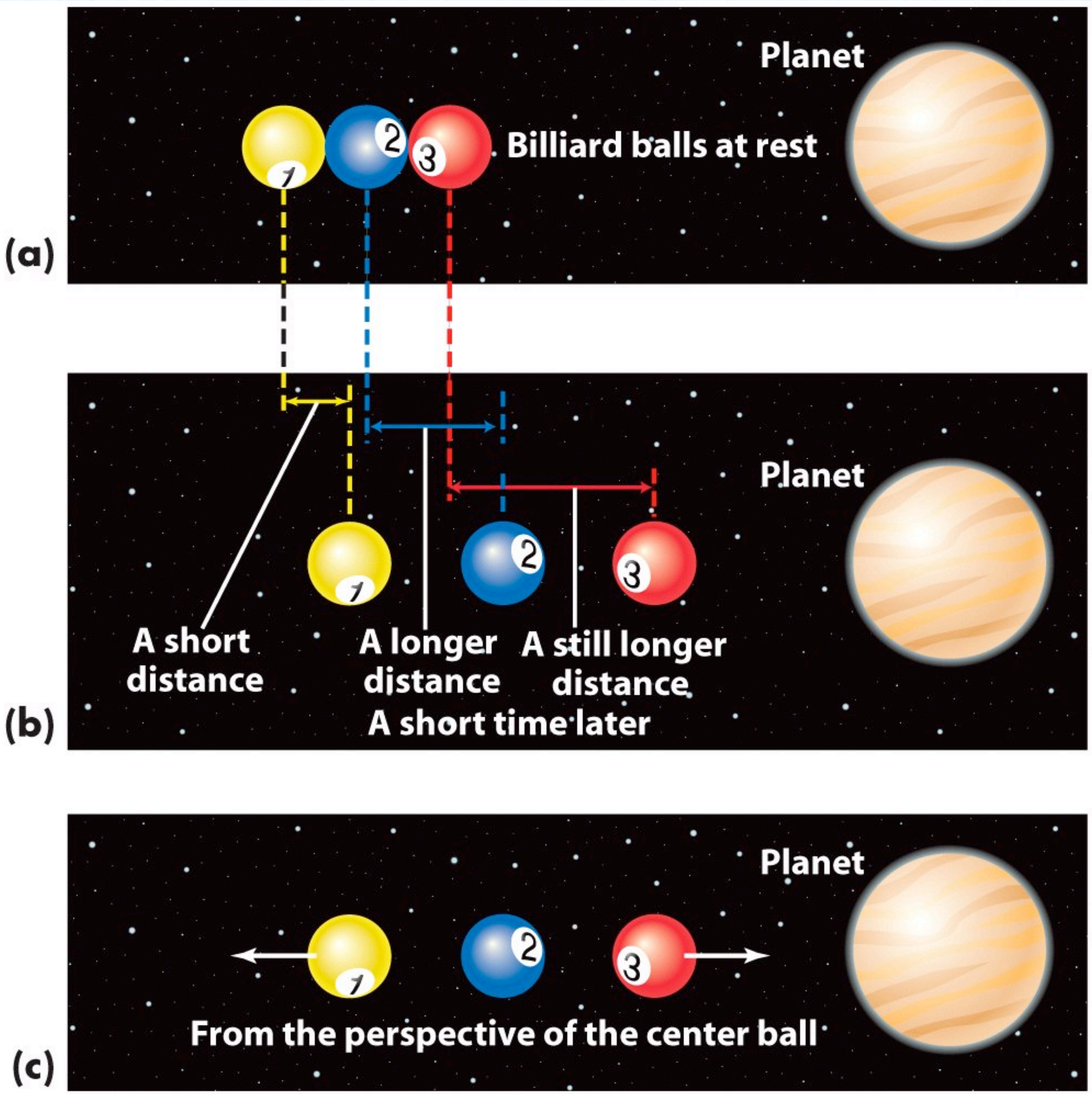


Figure 4-24
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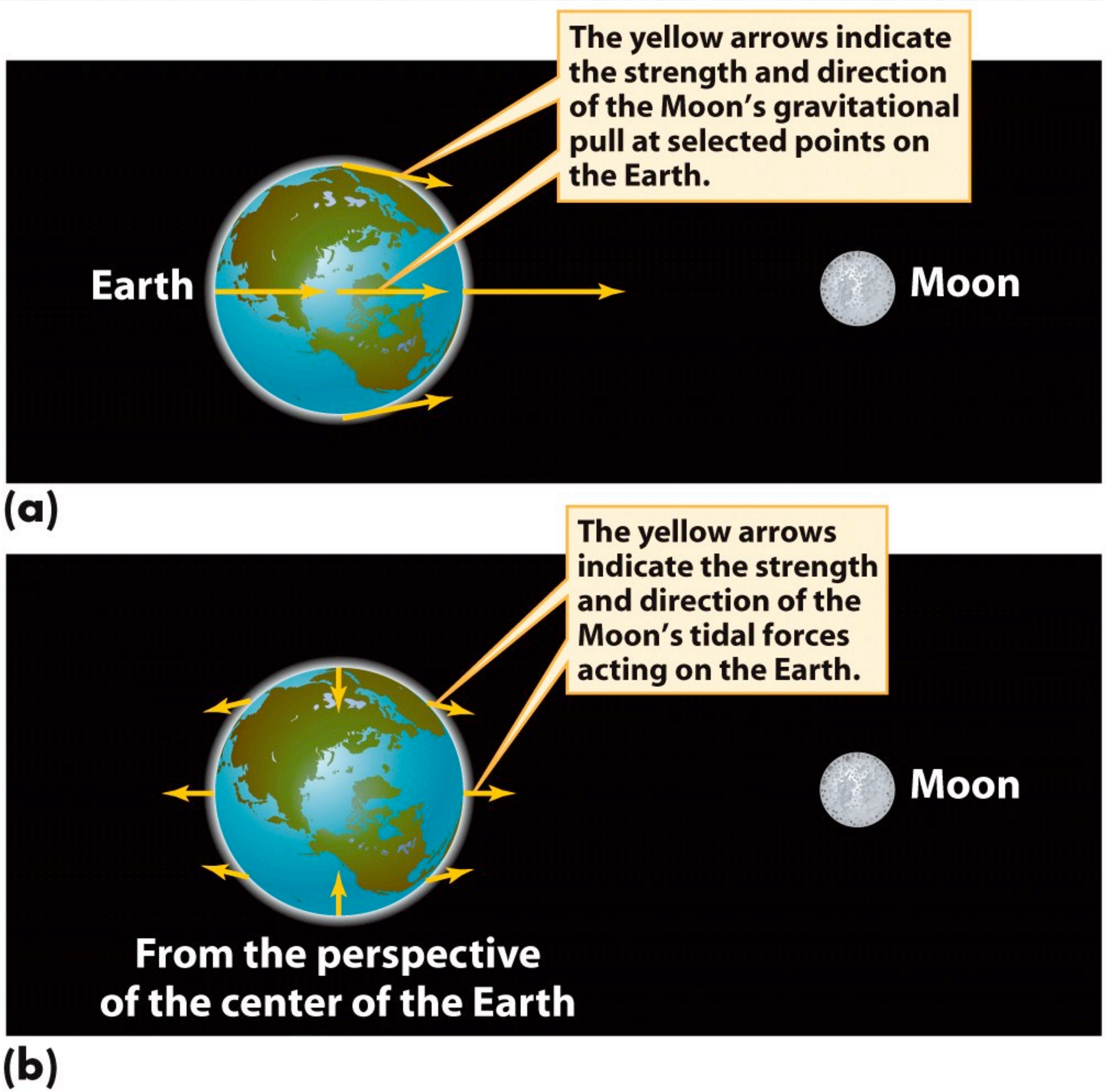
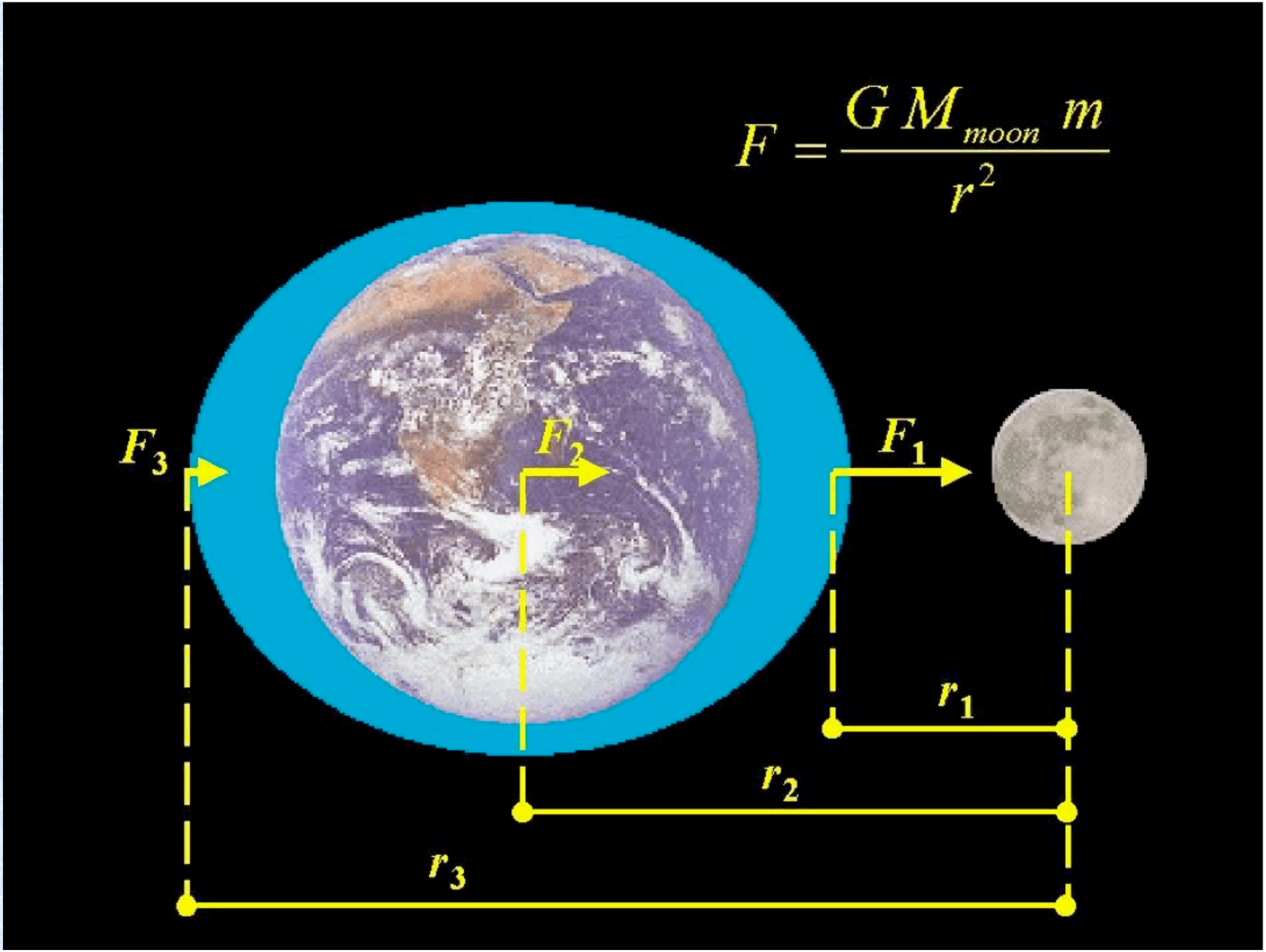
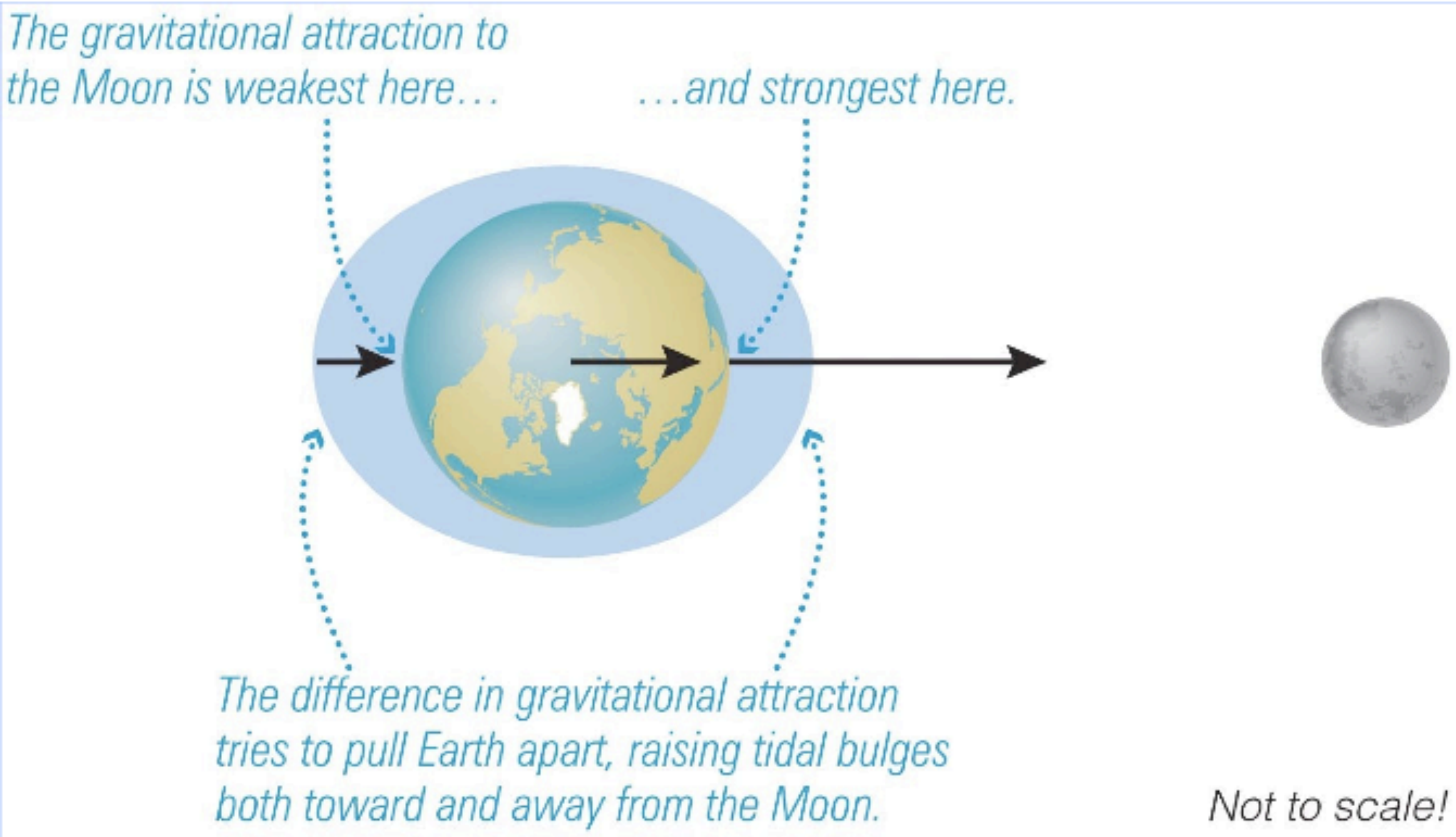


Figure 4-25
Universe, Eighth Edition



$F = \frac{G M_{moon} m}{r^2}$
F_3
F_2
F_1
r_1
r_2
r_3

Tides are a difference in gravitational forces over a body of finite size.



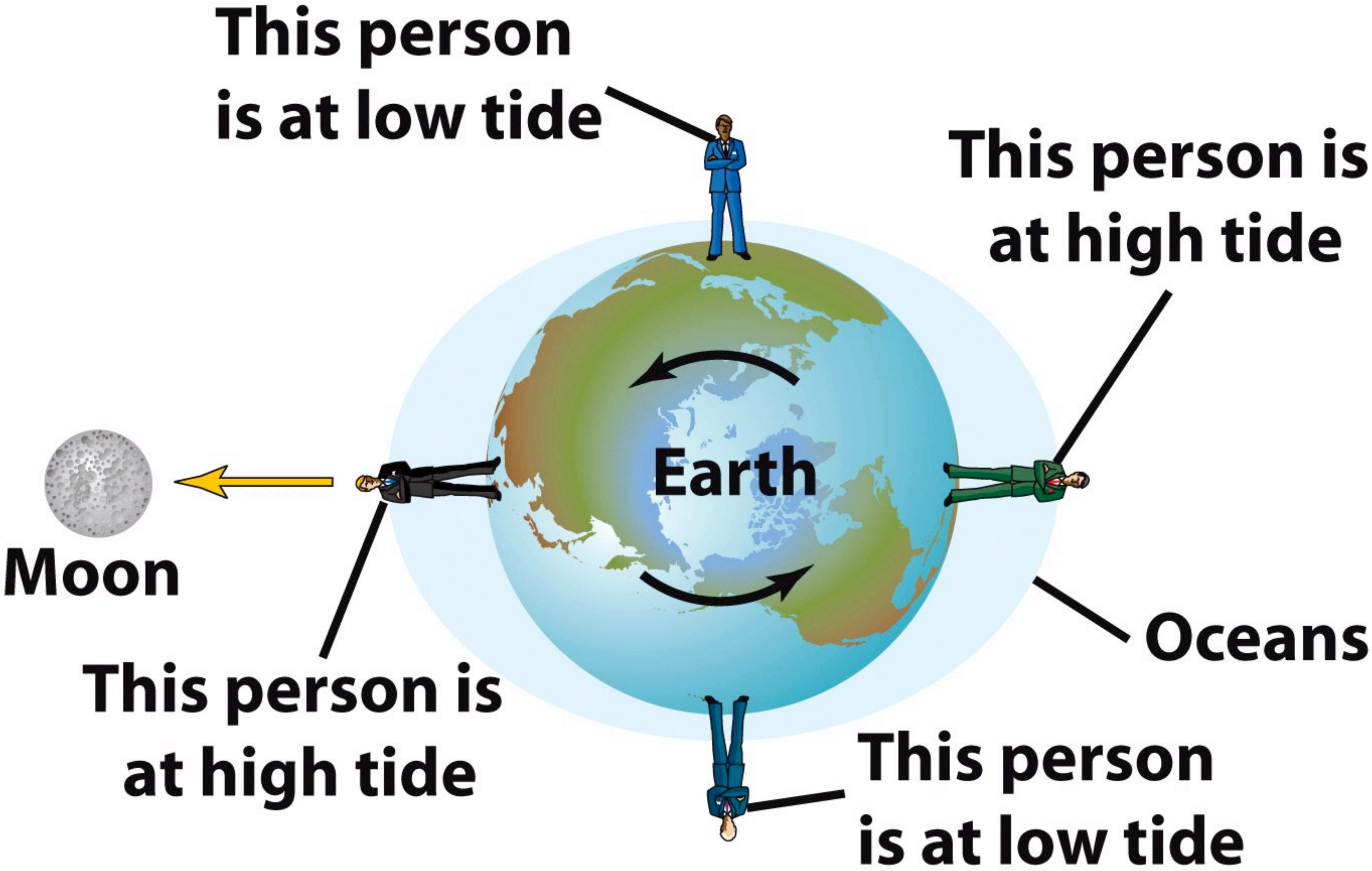


Figure 4-26a
Universe, Eighth Edition

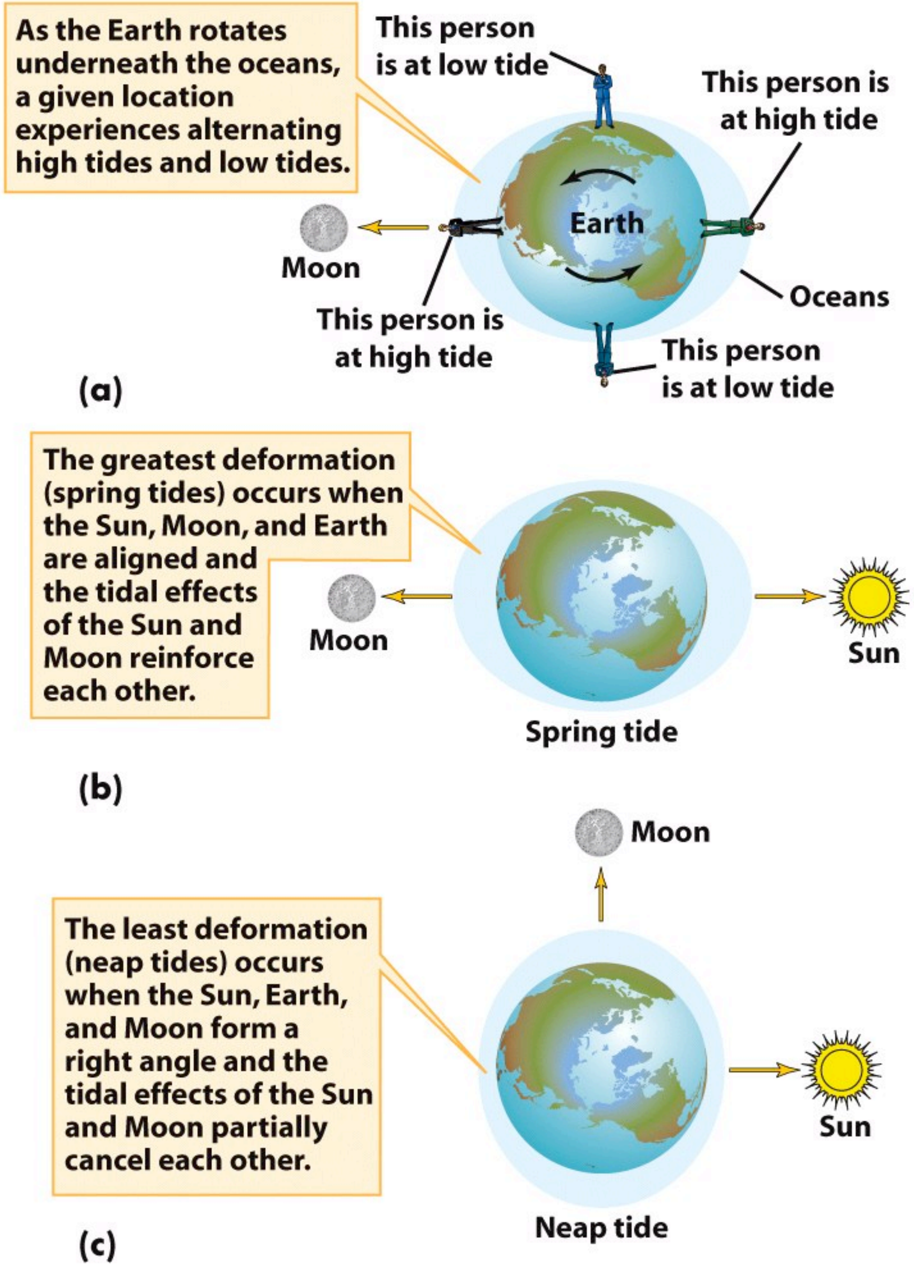


Figure 4-26
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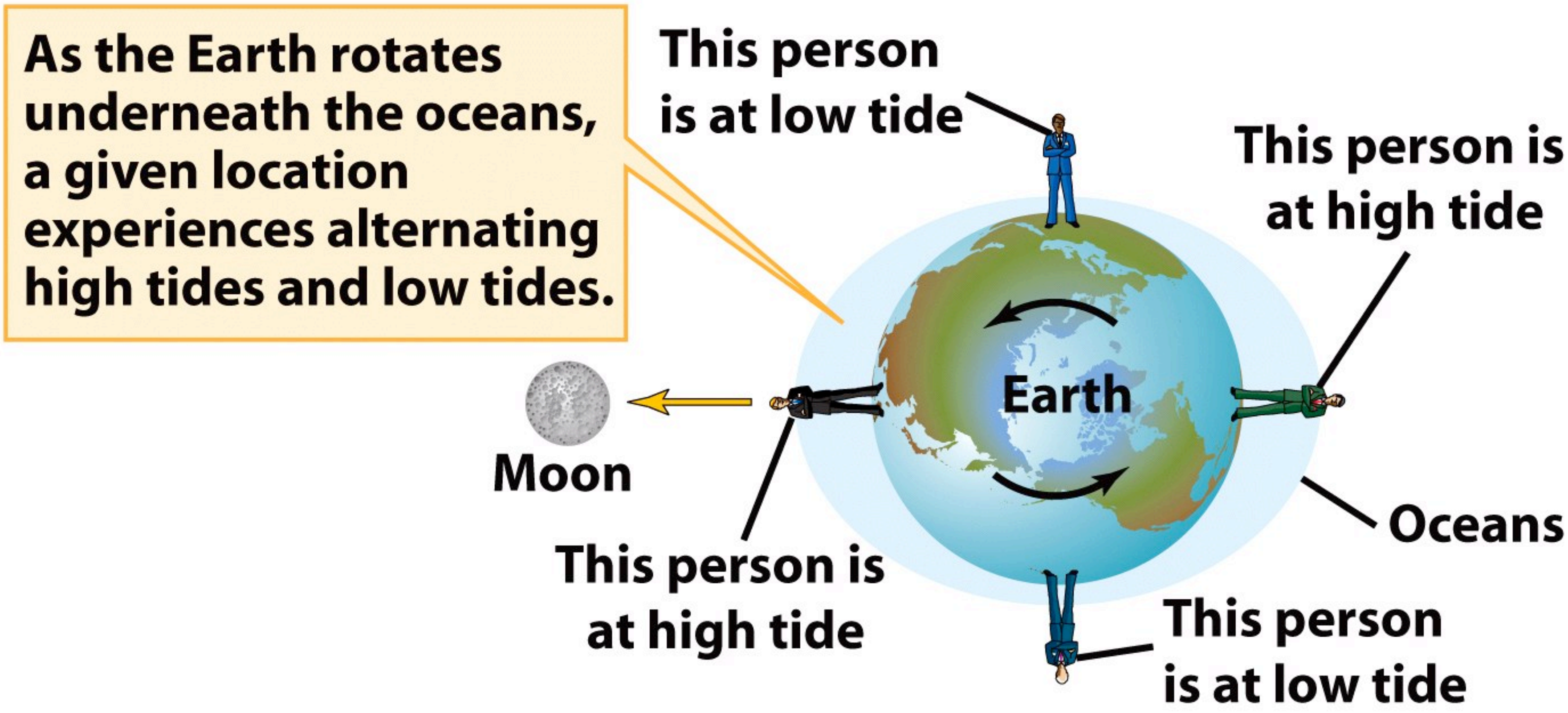

Figure 4-26a
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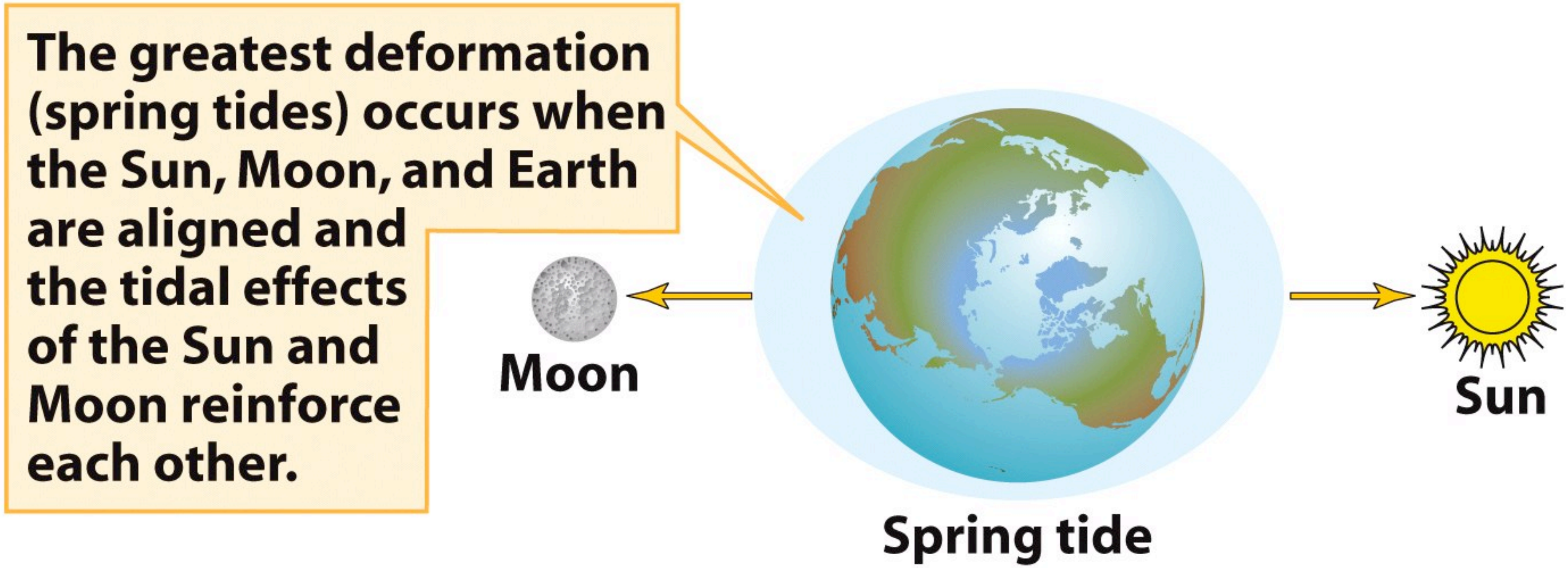

Figure 4-26b
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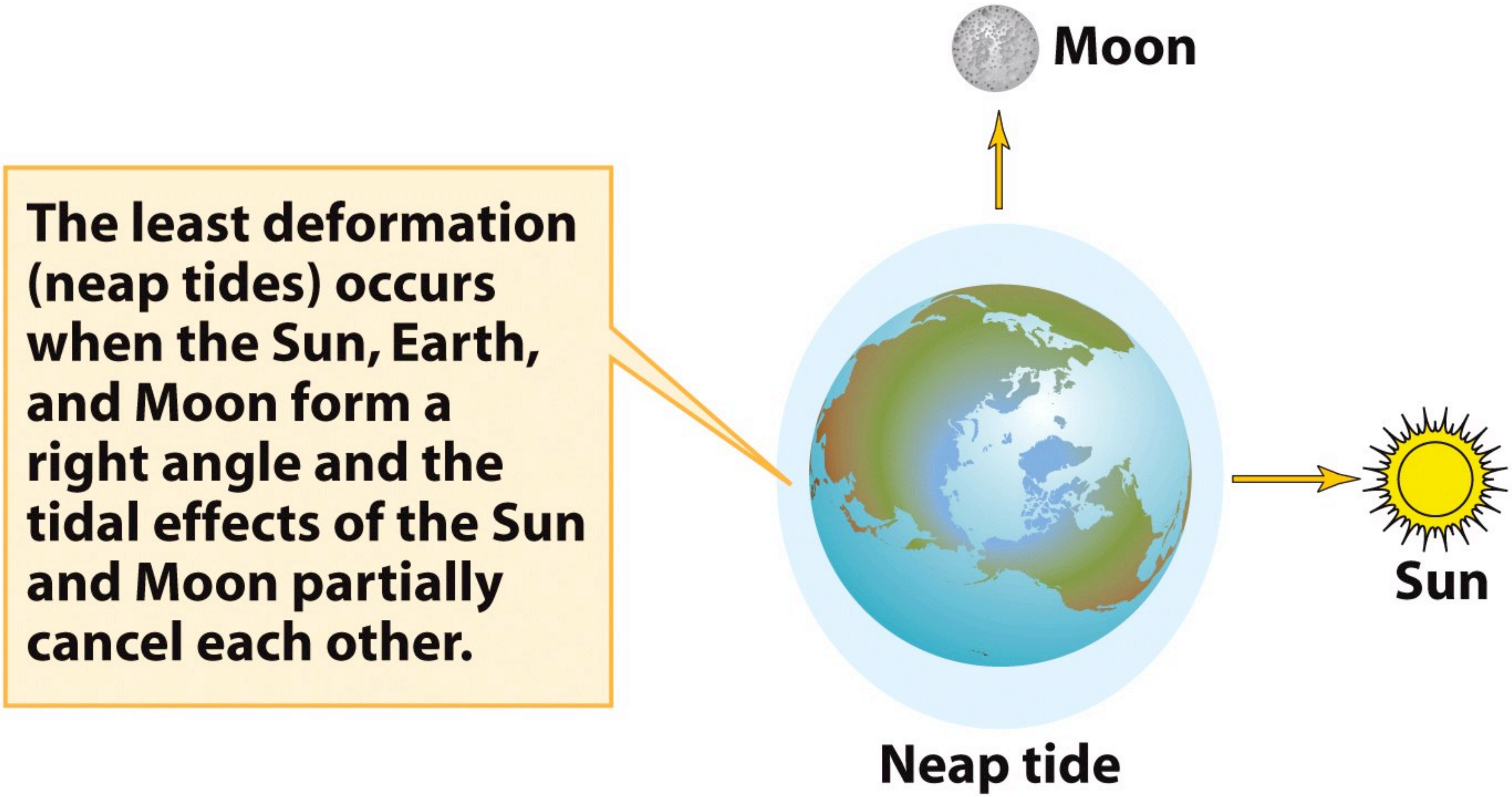

Figure 4-26c
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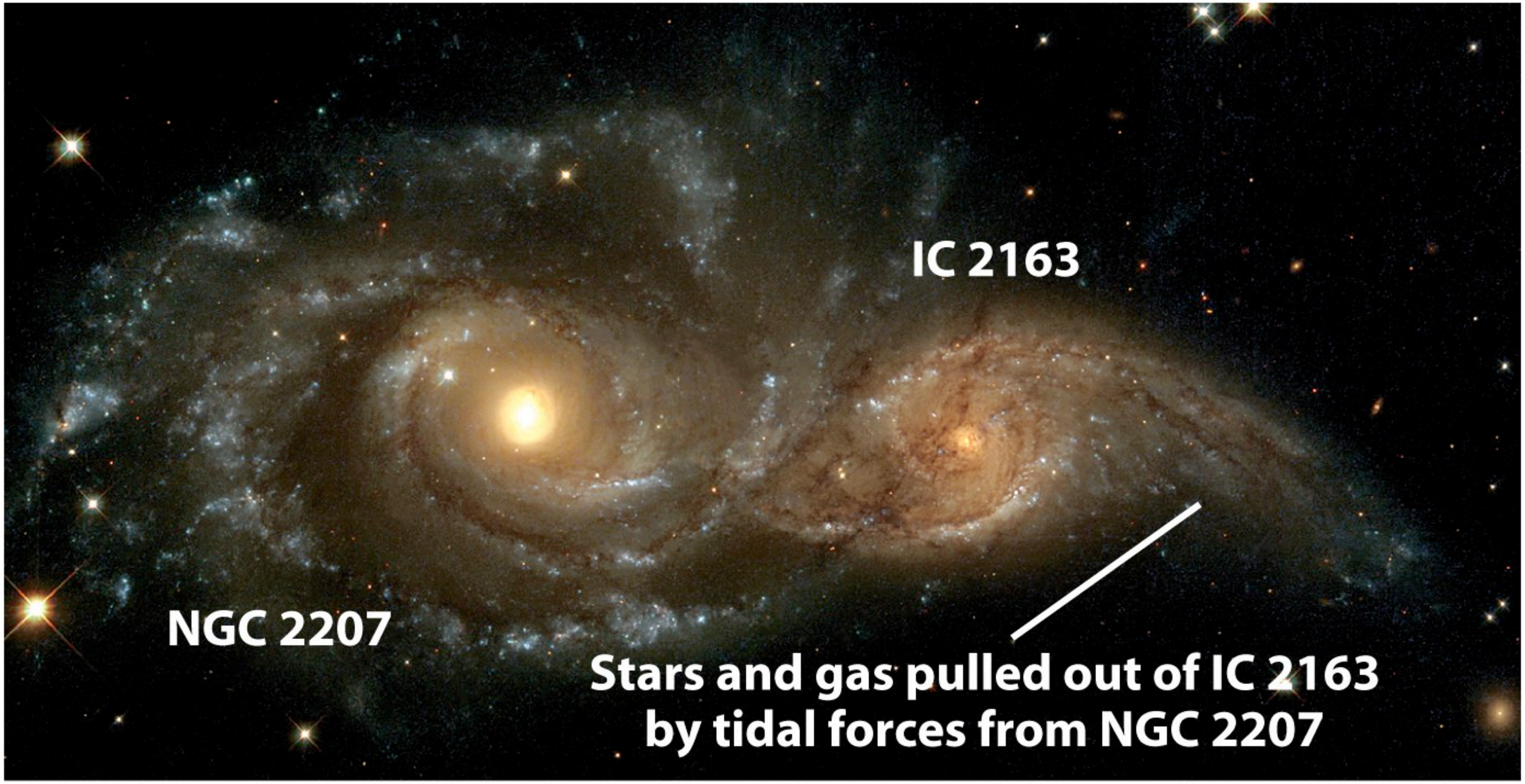

Figure 4-27
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Summary

- Newton's Laws of Motion:
  1. Inertia
  2. Relation between force and acceleration
  3. Action/Reaction
- Inertial and gravitational mass
- Newton's Law of gravity
- The orbits of planets
- Tides

The End

See you on Friday!

Figure 4-23
Universe, Eighth Edition

Comet Halley

Edmund Halley, a friend of Newton's used Newton's math to predict the return of a comet seen at intervals of 76 years.