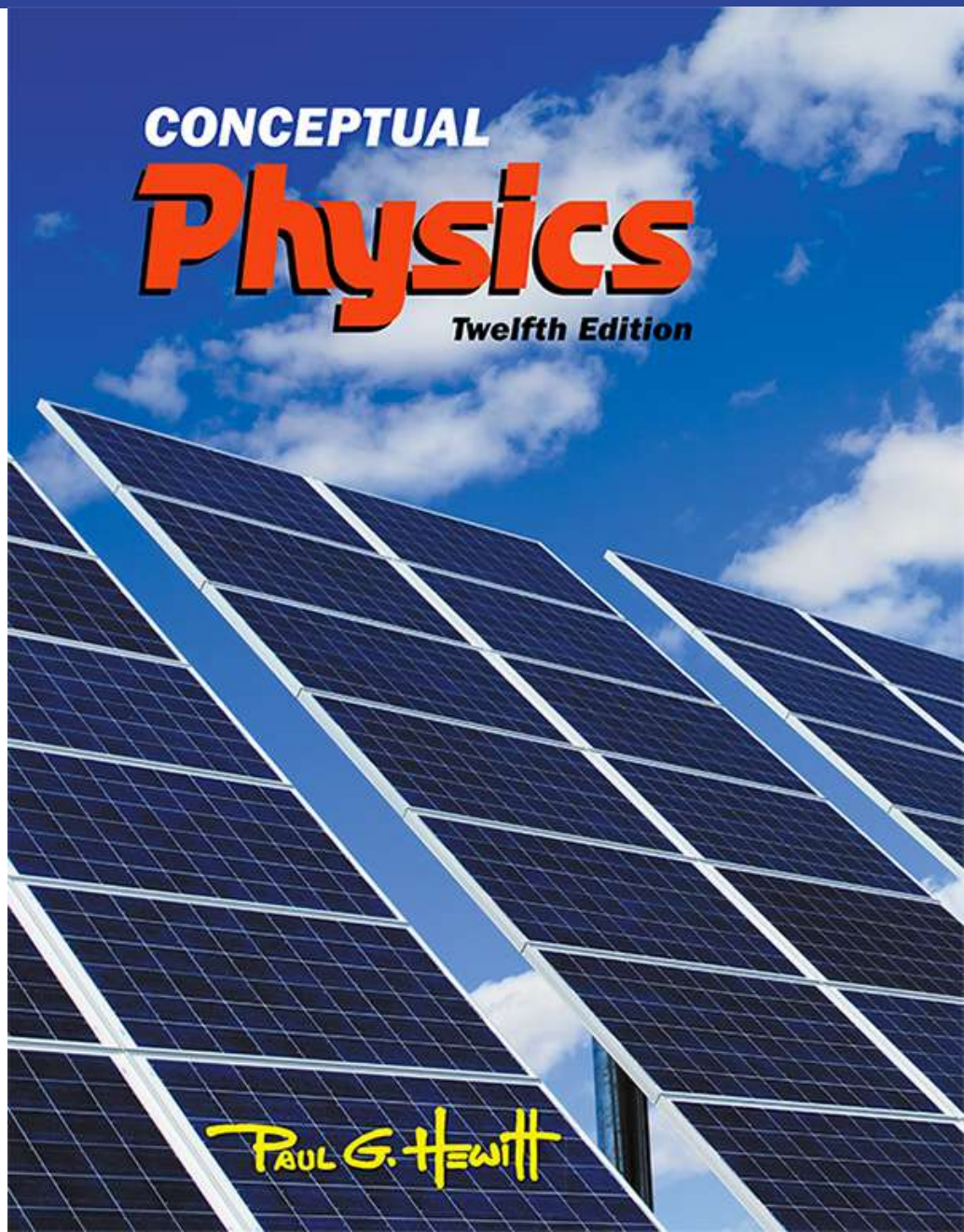
Lecture Outline

Chapter 9: Gravity

Section 5: The Tides

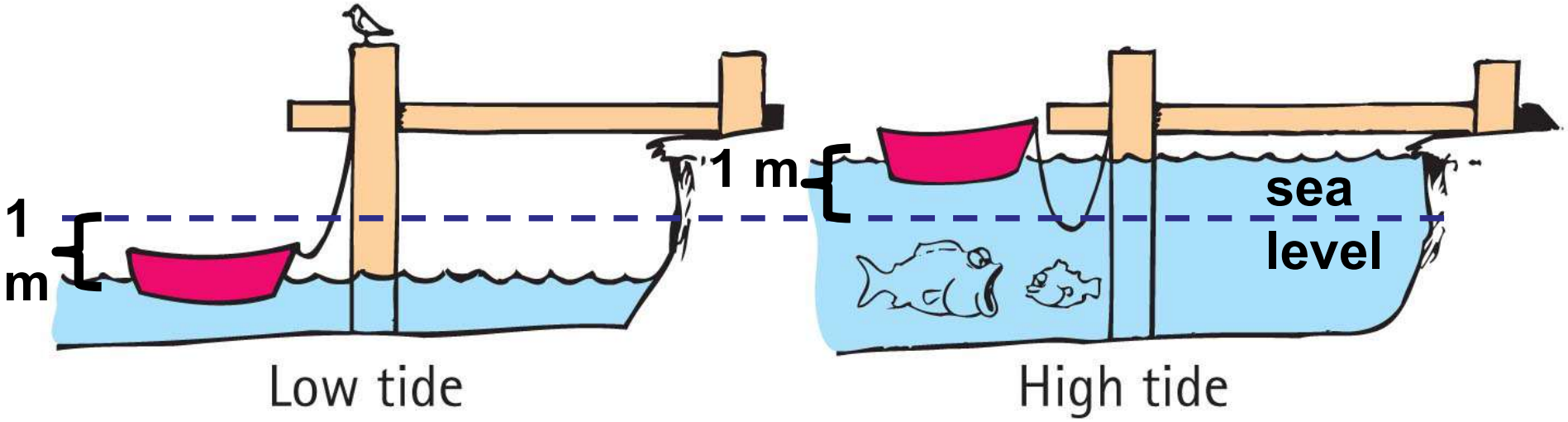


This lecture will help you understand:

- What causes tides.
- Why the moon's tides are greater than those of the sun.
- When tides are greatest and the least.
- Why more earthquakes occur on a full moon.
- Why you never see the other side of the moon.
- Why days are getting longer….

Ocean Tides

- The differences between ocean levels at different times of the day are called *tides*.



- On average, ≈1 m above/below average sea level
- There are typically **two** high tides and **two** low tides each day.

Ocean Tides, Continued

- Ocean tides are caused due to the *difference* in the gravitational attraction of the Moon on either side of Earth.
- Unequal tugs on Earth's oceans causes a stretching effect that produces a pair of ocean bulges.

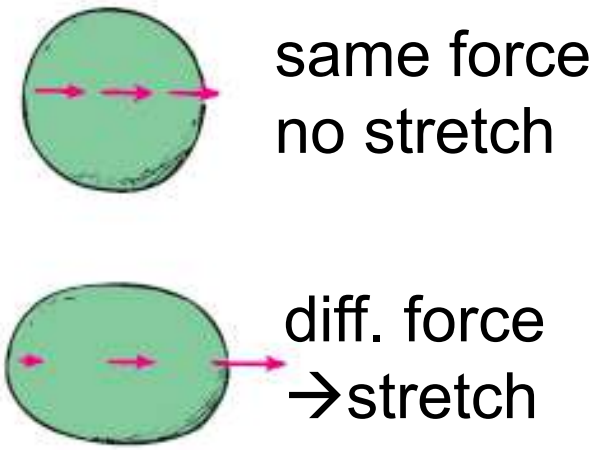
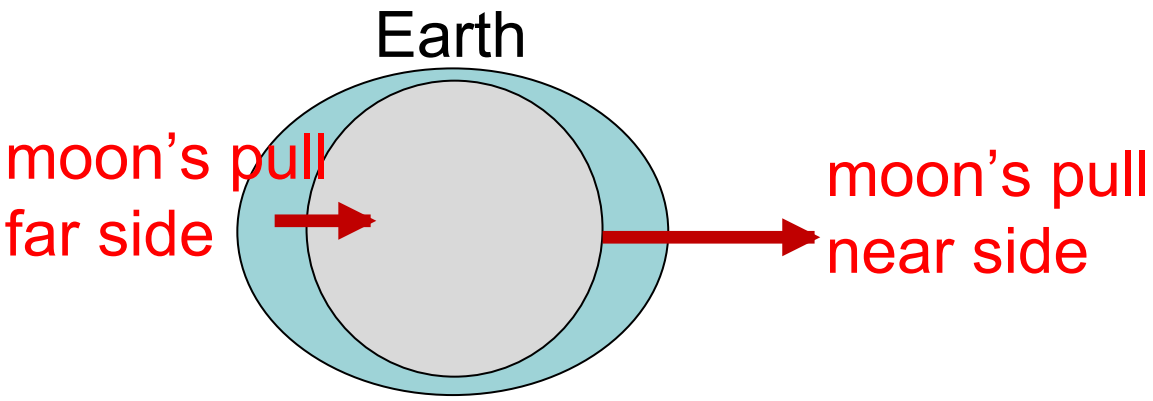


FIGURE 9.14
A ball of Jell-O stays spherical when all parts are pulled equally in the same direction. When one side is pulled more than the other, the ball is elongated.



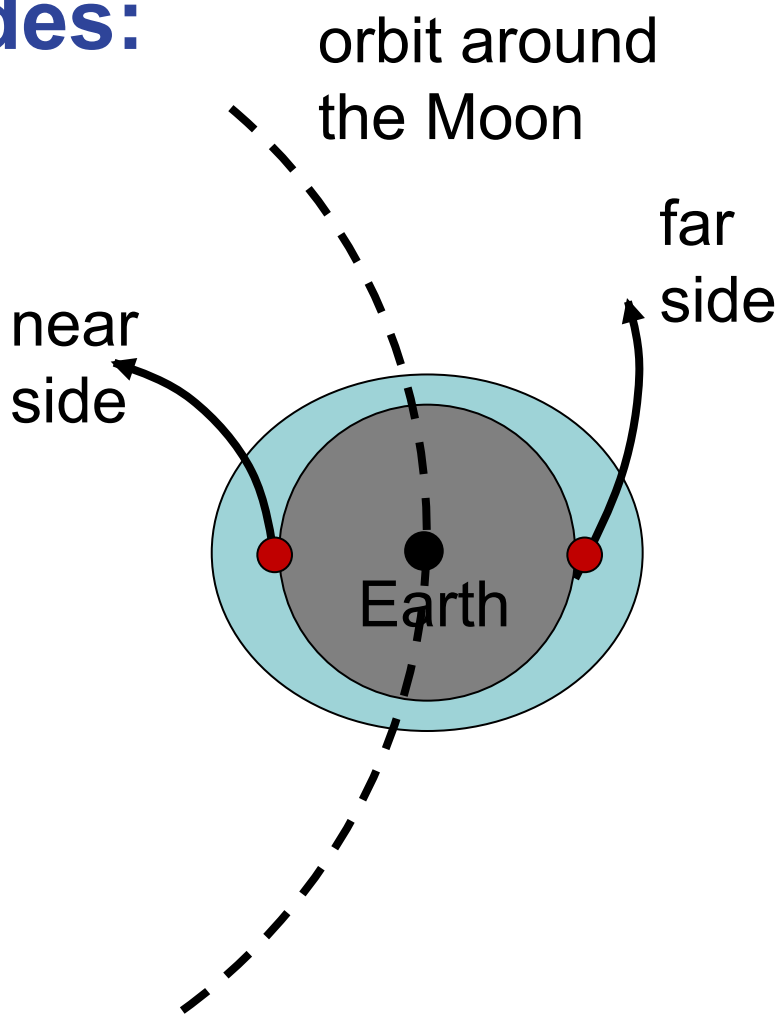
Another way to look at tides:

The center of Earth travels an almost circular orbit around the Moon.

The near side of Earth is “too close” and falls towards the Moon.

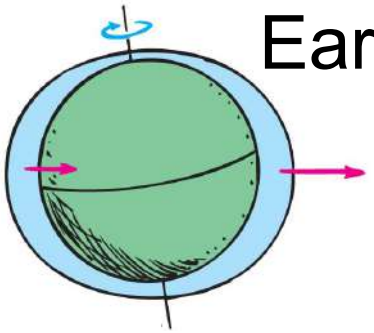
The far side of Earth is “too far” and tends to go off on a tangent.

The result is that Earth (and its oceans) are stretched out.



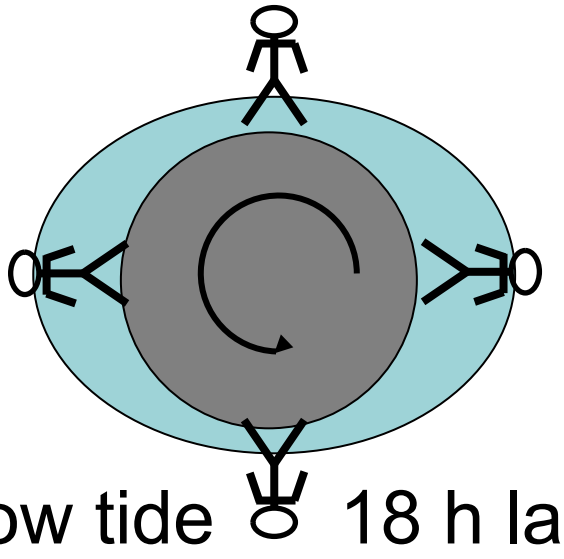
How often are high tides?

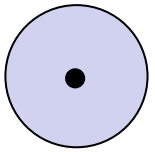
Earth takes 24 hours to rotate once. Because the two bulges are on opposite sides, high tides occur every 12 hours.



moon

Top view:



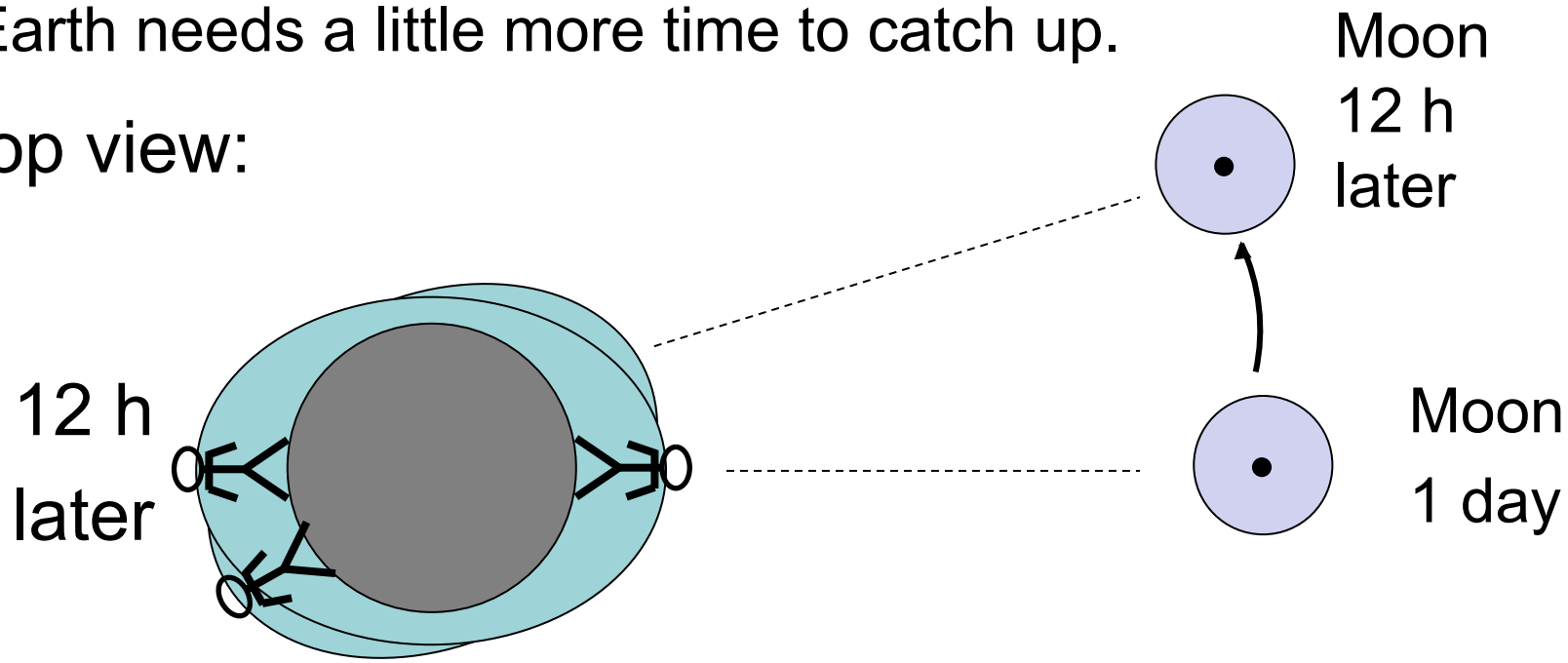


Moon

High tides are not exact 12 h apart:

The Moon revolves around Earth.
As it does, it drags the tidal bulges with it.
Earth needs a little more time to catch up.

Top view:



high tide is
>12h later

Tides due to the Sun?

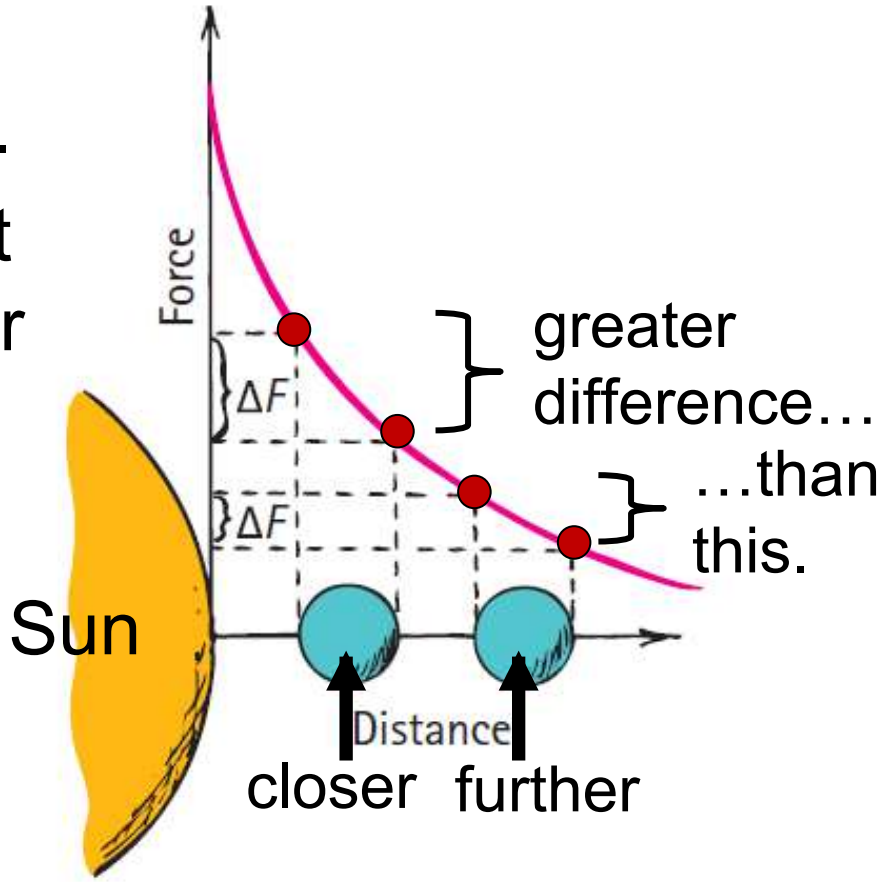
The Sun's pull is 180x greater than the Moon's.

Why are solar tides weaker than lunar tides?

Tides are due to *differences* in pull on either side of Earth.

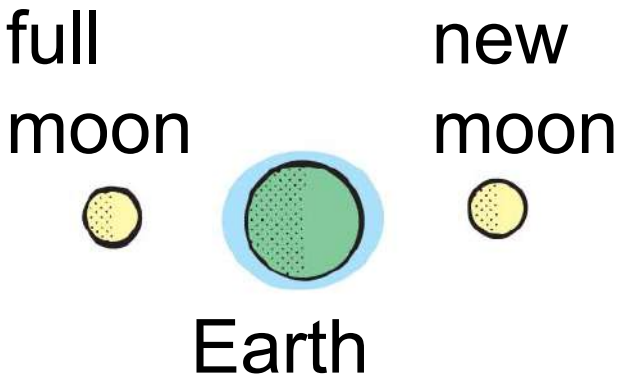
The Sun is so far away, that the difference in pull on either side of Earth is *less* than the difference in pull from the Moon.

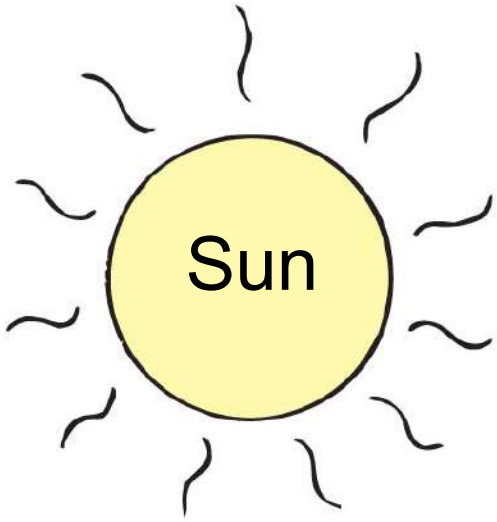
Solar tides ≈ ½ lunar tides



Spring Tides

- During the new Moon or full Moon, the effects of Moon and Sun add up, causing most pronounced **spring tides.** This has nothing to do with spring time!





→ High tides are higher and low tides are lower.

Neap Tides

- When the Moon is halfway between a new and full Moon, the tides due to Sun and Moon partly cancel each other, causing least pronounced **neap tides.**

- → High tides are lower and low tides are higher.

Tides are complicated!

Your local tides depend on:

1. the tilt of the axis

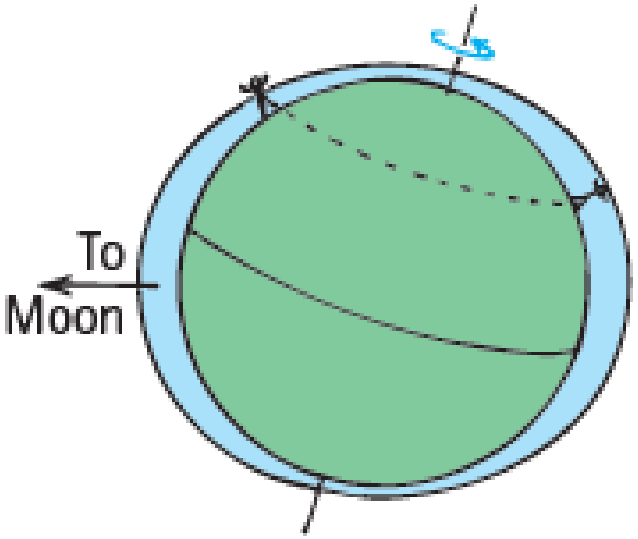
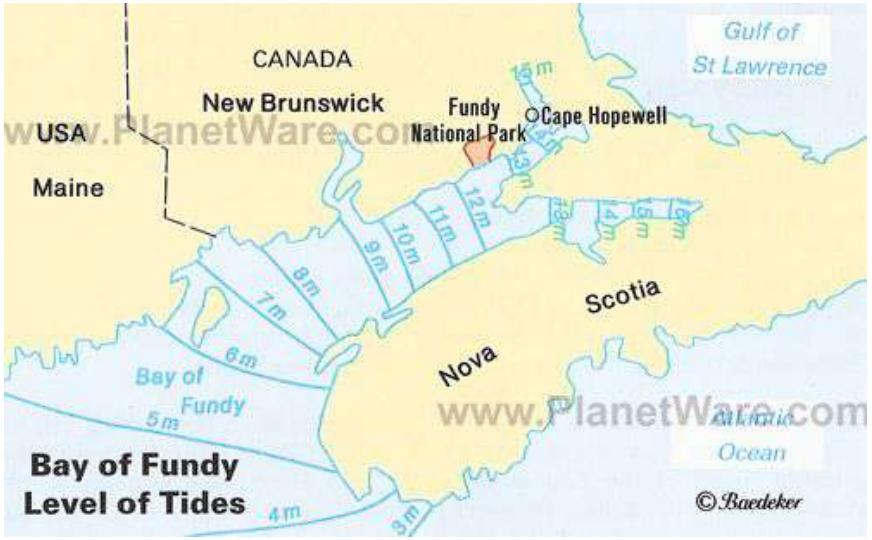


FIGURE 9.19
The inequality of the two high tides per day. Because of Earth's tilt, a person may find the tide nearest the Moon much lower (or higher) than the tide half a day later. Inequalities of tides vary with the positions of the Moon and the Sun.

2. the shape of the coast
3. the depth of water
4. where Earth and Moon are in their orbits, because their distances from each other change

Bay of Fundy: largest in the world



Some tides come in so quickly that they can be surfed.

What do NOT have tides?

1. Ponds
2. You

Why?

No part of a pond (or you) is significantly closer to the Moon than another part.

→ Holding a melon above your head produces a stronger tide in you than the Moon does.

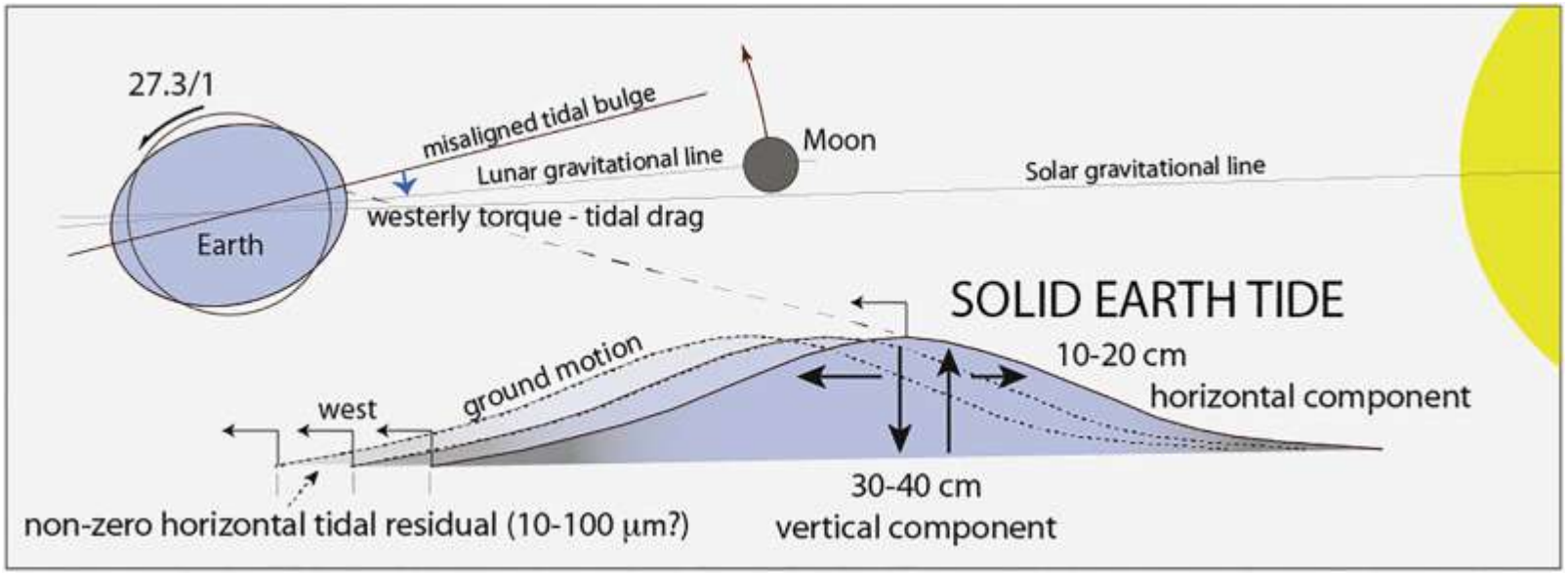
FIGURE 9.20
The tidal force difference due to a 1-kg body 1 m over the head of an average-height person is about 60 trillionths (6×10^{-11}) N/kg. For an overhead Moon, it is about 0.3 trillionth (3×10^{-13}) N/kg. So holding a melon over your head produces about 200 times as much tidal effect in your body as the Moon does.

CHECK POINT

We know that both the Moon and the Sun produce our ocean tides. And we know that the Moon plays the greater role because it is closer. Does the Moon's closeness mean that it pulls on Earth's oceans with a greater gravitational force than the Sun?

Tides in the solid Earth

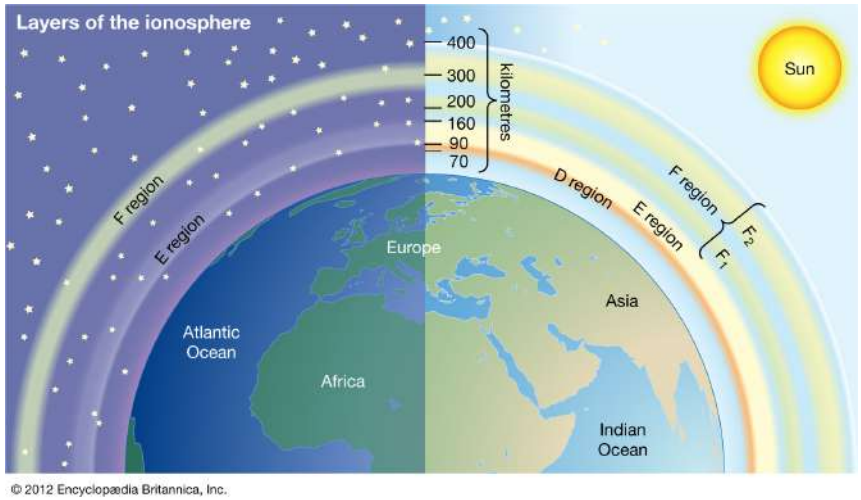
Earth's solid surface also rises and falls like the oceans, but not as much.

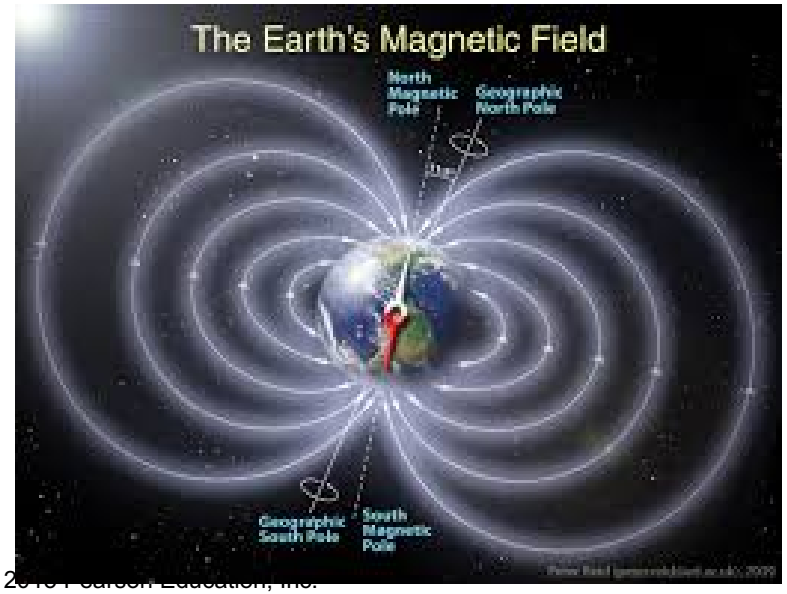


As a result, earthquakes and volcanic eruptions occur slightly more often at new and full moons!

Tides in the Atmosphere

The atmosphere also has tides. The upper part of the atmosphere is made up of ions (charged particles). It is called the *ionosphere*.

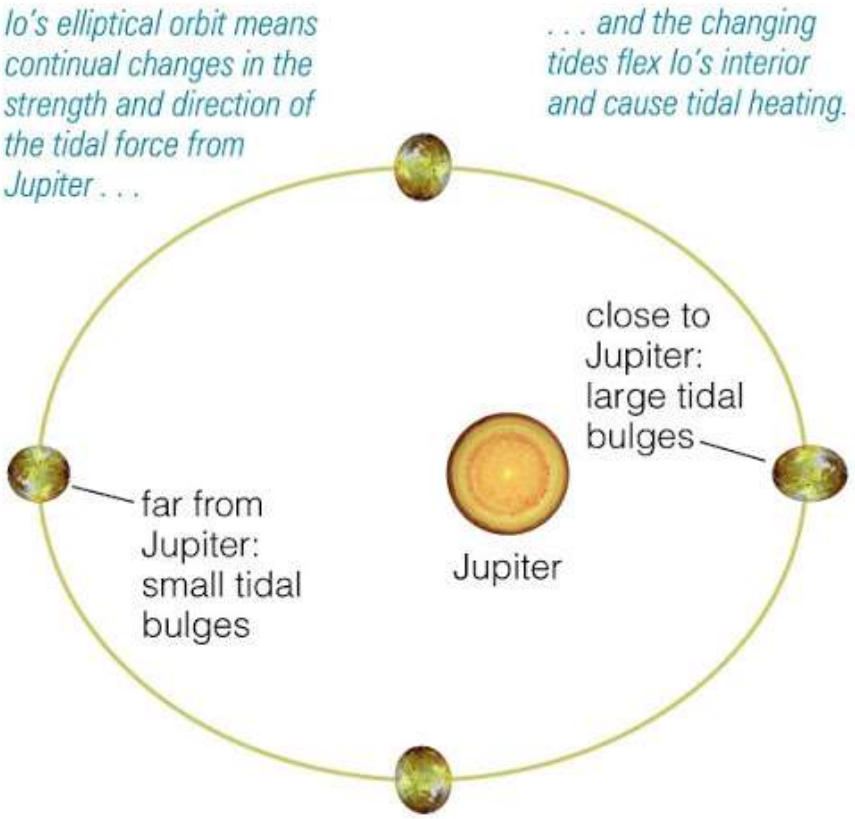




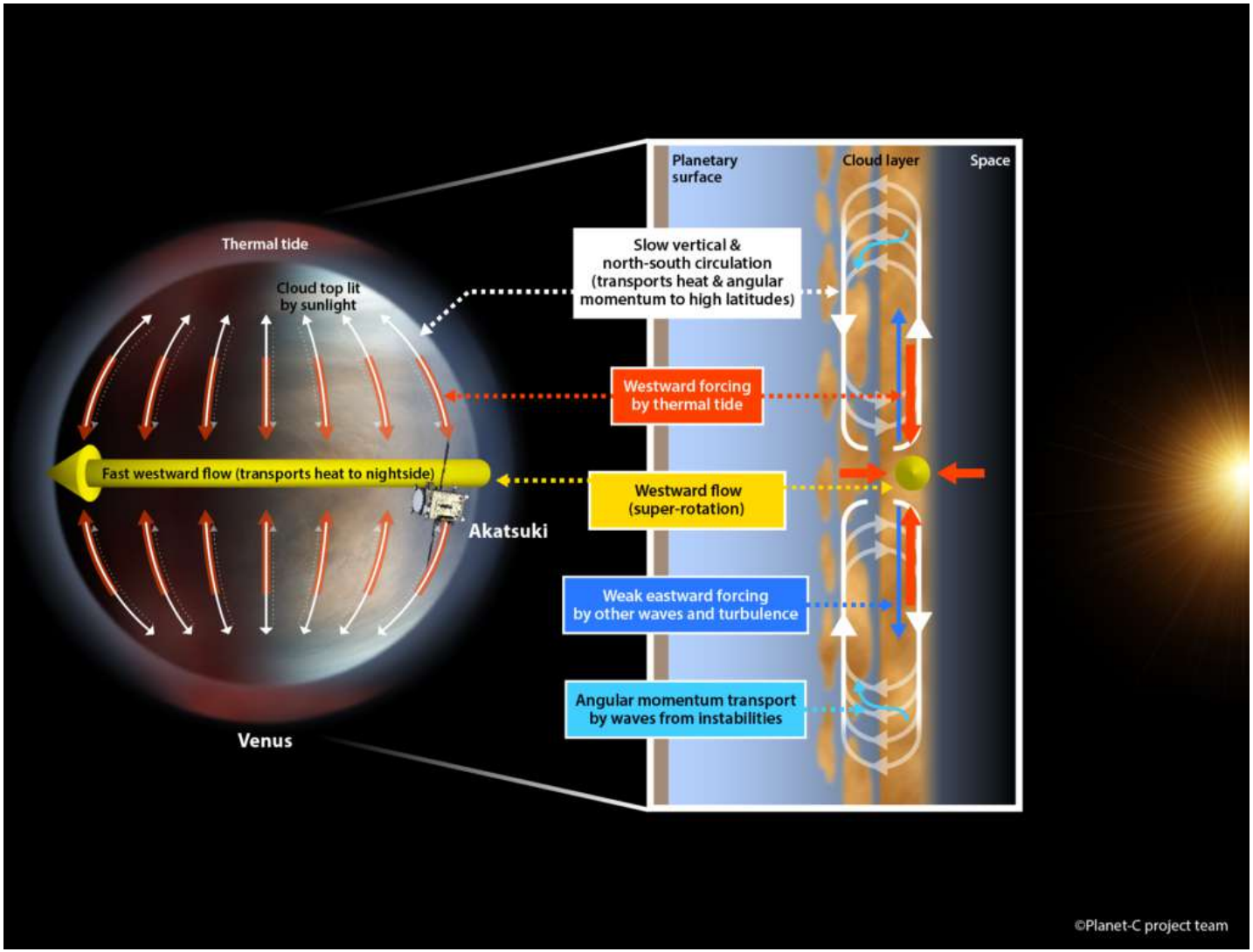
Tides in the ionosphere produce electrical currents. These cause Earth's magnetic field to change. These are *magnetic tides*.

Tidal heating on Io (Jupiter's closest moon)

Because Io is so close to Jupiter, it has huge land tides. This rising and falling heats up the crust and causes volcanoes.



Tides in Venus' atmosphere cause fast winds.



Tidal Bulges on the Moon

Earth's gravity has stretched out the Moon.

Its CM and CG are different.

Gravitational torque on its CG keeps the long axis of Moon facing Earth.

We always see the same side of the Moon!

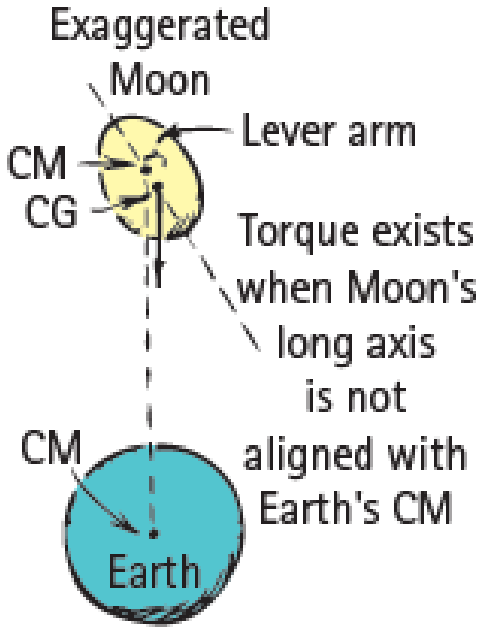


FIGURE 9.21
Earth's pull on the Moon at its center of gravity produces a torque about the Moon's center of mass, which tends to rotate the long axis of the Moon into alignment with Earth's gravitational field (like a compass needle that aligns with a magnetic field). That's why only one side of the Moon faces Earth.

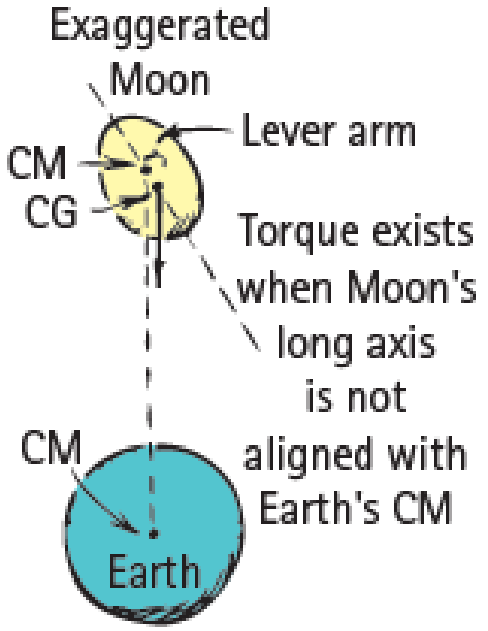
Tidal Bulges on the Moon

And the Moon is doing the same to Earth.

As a result, Earth's rotation is slowing…the days are getting longer.

Eventually Earth will rotate once in the same time it takes the Moon to revolve once.

→The same side of Earth will always face the Moon!



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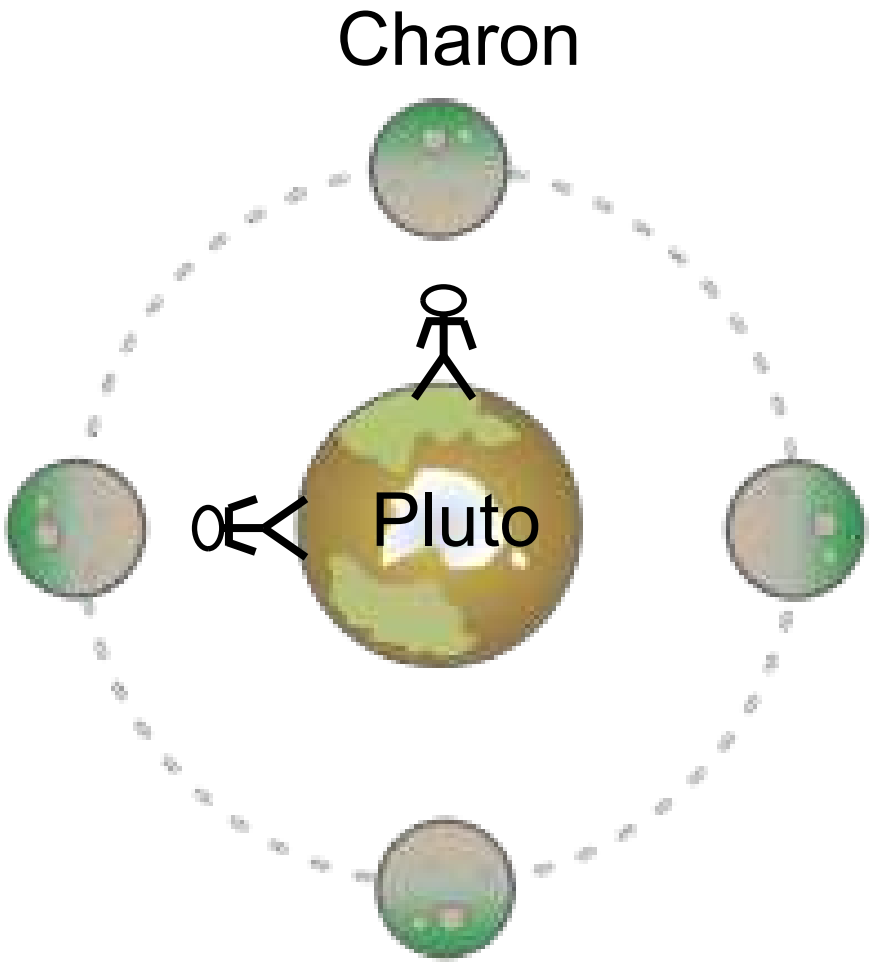
This has already happened for Pluto and its moon Charon. The same sides always face each other:

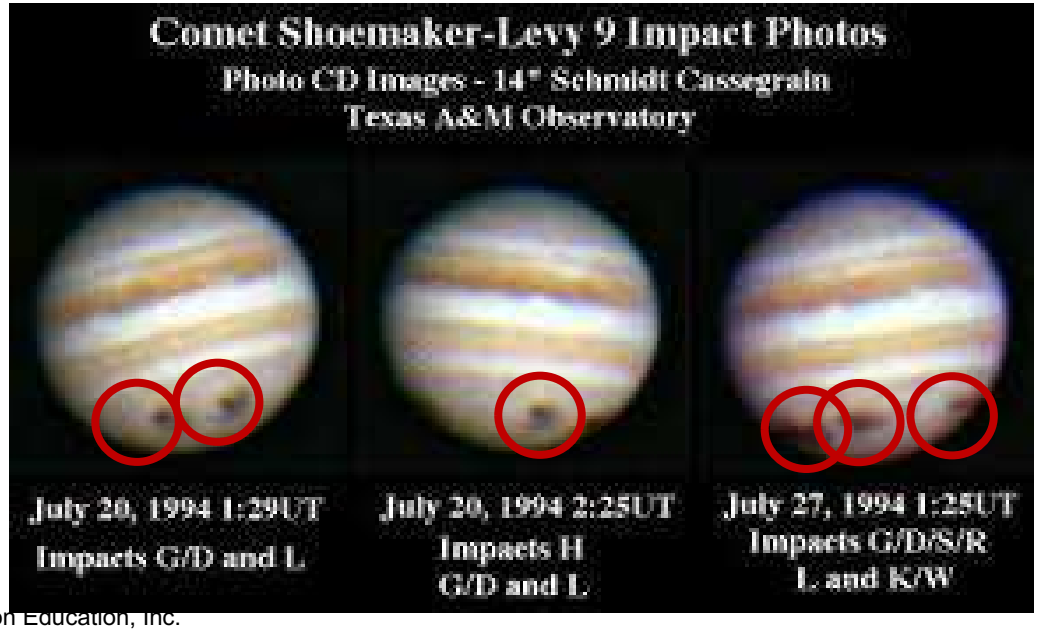
Charon is always in the same place in the sky!



If a moon gets too close to its planet, tidal force will rip it apart:

The distance where this happens is called the *Roche limit.*

Comet Shoemaker-Levy 9 was ripped apart before it crashed into Jupiter:



You can see multiple impact sites as Jupiter rotates around.

Take out a new sheet of paper. Put your name at the top. Write the answers to the following questions on it:

16. Do tides depend more on the strength of gravitational pull or on the *difference* in strengths? Explain.

17. Why do both the Sun and the Moon exert a greater gravitational force on one side of Earth than on the other?

18. Which has the higher tides: *spring tides* or *neap tides*?

19. Do tides occur in the molten interior of Earth for the same reason that tides occur in the oceans?

20. Why are all tides greatest at the time of a full Moon or new Moon?

21. Would a torque on the Moon occur if the Moon were spherical, with both its center of mass and center of gravity in the same location?

Stop.
Take a photo of your answers.
Submit to Teams.
Now.
Due by end of period.