Tides lesson planning

Key concepts:

1. Gravitational forces from the moon and the sun comprise the first major piece of the tidal force.
2. Inertia (centrifugal) forces from the rotation of the E-M unit and the E-S unit comprise the other major piece of tidal force.
3. Tides significantly affect organisms
4. The rise and fall of water, forced through narrow openings of land, cause tidal currents

Background needed:

- Basic algebra
- General idea of tides rising and falling
- How the phases of the moon relate to the position of the sun and moon

Outline:

1. Notice and Wonder – month's worth of tides with moon phases
2. Discussion about gravity
    a. What is gravity
3. Draw Earth and Moon
    a. Draw gravitational forces
4. What kinds of spin happen in the solar system?
    a. Earth around its own axis
    b. Earth around the sun (E-S unit)
    c. Moon around the Earth (E-M unit)
5. Center of rotation
    a. Go outside and spin around
    b. Where is the center of rotation for each of these:
        i. Self
        ii. Holding a 5lb dive weight
        iii. Holding a cinder block or two
        iv. Holding someone else's hands
    c. Moon doesn't rotate around us, the combined E-M unit rotates around its center of mass
6. Inertia
    a. Spin around a bucket of water on a rope
    b. Spin around with a dive weight, let go
        i. It flies straight
    c. Playing corners in the car
7. Combine gravity and inertia to develop the two tidal bulges
    a. Draw inertial forces on each diagram
    b. Add forces to find resultant vectors
    c. Draw resultant vectors as bulges of water

8. How do we experience these bulges? (looking down on N Pole)
    a. As the Earth rotates on ITS OWN axis it passes through the two bulges
    b. But the E-M unit is also rotating in the same direction
        i. So it takes ~24h 50min to go one full tidal day
9. (Looking at the equator) Tilt the moon up and down, and demonstrate diurnal, semidiurnal and mixed tides
    a. Fun tides to check out at http://www.mobilegeographics.com:81/locations/####
        i. 1656 – Duffus Point, Nova Scotia – totally screwy
        ii. 1632 – Dover, New Brunswick – huge exchanges
        iii. 5115 – Prudhoe Bay, Alaska – no daylight
        iv. 5412 – McMurdo Station, Antarctica – very little exchange
        v. 1028 – Cape Town, South Africa – nearly semidiurnal
        vi. 6749 – Venice, Italy – mixed
        vii. 3503 – Amazon River, Brazil – semidiurnal
        viii. 6011 – Mississippi River, Louisiana – diurnal
    b. Continents get in the way of perfection
        i. Tidal excursions are larger at basin heads than mouths
            1. Bay of Fundy
            2. Puget Sound
10. Bring on the Sun
    a. Ask students to draw the E-M-S in NEW MOON, NEAP and FULL MOON configurations
    b. More gravity
        i. How do you calculate the force of gravity?
        ii. Calculate the gravitational force from the sun and from the moon
            1. $Force \propto \frac{mass}{distance^3}$
            2. Sun's mass is 27 million times greater than moon, but the sun is 390 times farther away from the Earth. $390^3 = 59$ million.
            3. $\frac{27\ million}{59\ million} = 0.46$ so the sun's tidal force is only 46% that of the moon
    c. Ask students to come fill in lunar- and solar-derived bulges
        i. "Spring" and "Neap" tides
11. Tidal currents
    a. How does a tide become a current?
        i. Force a tidal bulge through a narrow passage
12. Challenge questions:
    a. Does the entire world see the same fraction of the moon on the same day?
    b. Does the entire world experience a spring tide at the same time?
    c. What time of day does a full moon rise? New moon?
    d. The moon is closer to the earth at some points of its orbit. True or false: spring tides are their strongest when the moon is closest to the earth. Why true or false?

Snazzy tide trivia:

- Amplitude of gravitational tides in deep mid-ocean: about 1 meter.
- Shoreline tides can be more than 10 times as large as in mid-ocean.
- **Amplitude of tides in the Earth's crust: about 20 cm.**
- The gravitational force of sun on Earth is 178 times as large as the force of moon on Earth.
- Ratio of sun/moon tidal forces on Earth is 0.465.
- **Tidal stretch of human body changes its height by fraction 10^{-16}, an amount 1000 times smaller than the diameter of an atom. By comparison, the stress produced by the body's own weight causes a fractional change in body height of 10^{-2}. [Sawicki]**
- Tidal friction causes Earth days to lengthen 1.6 milliseconds/century. [Sawicki]
- Angular velocity of Earth's axial rotation: 7.29×10^{-5} rad/s.
- Angular velocity of moon's revolution around Earth: 2.67×10^{-6} rad/s.
- Earth polar diameter: 12710 km.
- Earth equatorial diameter: 12756 km.
- Difference between these diameters: 46 km.
- Difference between these radii: 23 km, or 0.4 %.
- Centripetal acceleration at Earth's surface due to Earth's axial rotation: 0.034 m/s^2
- Size of centripetal acceleration at Earth's surface due to Earth's circular motion around the Earth-moon barycenter: 3.3×10^{-5} m/s^2.