5.2 Ubiquitous Inverse Square Relationship:

When things spread out in three dimensions from their source – like light, sound, or shrapnel from a cluster bomb –intensity often drops like the inverse of the distance *squared*: $Intensity \propto \frac{1}{r^2} = r^{-2}$.

Why is that? When things come from a point source, they spread out in *spherical symmetry*, so they are spread out over the surface of a sphere that gets bigger as it expands in time, because the area of a sphere = $4\pi r^2$, proportional to the *square* of the distance. So, if you double your distance to a lightbulb, the light from the bulb is spread out over 4 times the surface area, and the intensity of light in the new space is ¼ as great as before:

If $R \Rightarrow \mathbf{2}R_o, I \Rightarrow \mathbf{\frac{1}{4}}R_o$.

This may be better seen from the diagram at right, where if light travels through a window of a sphere at distance R_o, the same light would need 4 windows to pass through a sphere at distance $4R_o$: 2 windows wide, and 2 windows high.

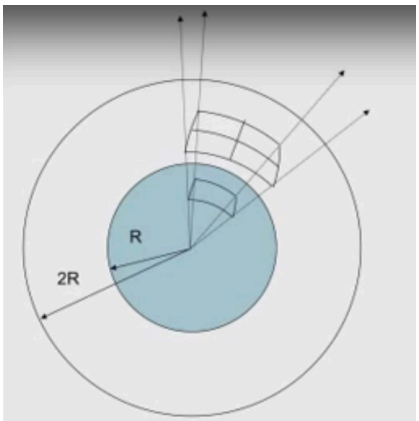

Fig.1 Light propagates equally in all directions from a point source in the middle. The flux of power that escapes through the smaller sphere must also pass through the larger sphere. Because the same flux is spread over a larger surface at the larger sphere, the intensity of light is weaker at the larger distance.

Thus, while we love the fact that Cavendish measured the relationship between mass, distance and gravitational attraction, we might have expected the gravitational force to drop off according to the inverse square relationship.

Exercise 1: The distance between the centers of the earth and moon is about 385,000 km and where the radius of the earth is about 6,400 km.

a) If the moon were to stop moving, what about what would be the moon's acceleration toward the earth? It may help to know that the acceleration from gravity one earth radius away from the earth's center is 10 m/s^2.
b) What would cause that acceleration?
c) But the moon *is* moving! In this case, should its acceleration be the same as in "a" above? Why or why not?
d) From your answers above, estimate the speed of the moon in its orbit around the earth.
e) From your answer above, estimate the period of the moon… is it close to a month?
f) Please calculate the mass of the earth.

Exercise 2 In 1930, it was discovered that a beta decay:

$n \Rightarrow p^+ + e^-$

didn't conserve energy, momentum or *angular momentum*. Wolfgang Pauli postulated the existence of a new particle, the *neutrino* that has the correct angular momentum to conserve angular momentum in the process. We now estimate that 65 billion neutrinos from the sun pass through each square centimeter on earth, *per second*. The earth is about 150 billion meters from the sun and Venus is about 108 billion, or about 0.72 of the earth's distance.

a) How fast does the sun produce neutrinos?

b) How many pass through you during this class?

c) How about if you were on Venus?