We have learned in class that the gravitational force between two bodies is proportional to the mass of the two objects and inversely proportional to the square of the distance between them. This can be express mathematically as:

$$\mathrm{F}_{\mathrm{Gravity}} \propto \frac{M_1 M_2}{d^2}$$

If you wanted to figure out the ratio between the force of gravity the Earth feels from the Sun to that of the Moon, you only need to do a little simple algebra:

$$\mathrm{F}_{\mathrm{Gravity}}(\mathrm{Sun}) \propto \frac{M_{Sun} M_{Earth}}{(d_{Sun})^2} \qquad \mathrm{F}_{\mathrm{Gravity}}(\mathrm{Moon}) \propto \frac{M_{Moon} M_{Earth}}{(d_{Moon})^2}$$

$$\frac{\mathrm{F}_{\mathrm{Gravity}}(\mathrm{Sun})}{\mathrm{F}_{\mathrm{Gravity}}(\mathrm{Moon})} = \frac{M_{Sun} M_{Earth}}{(d_{Sun})^2} \times \frac{(d_{Moon})^2}{M_{Moon} M_{Earth}} = \frac{M_{Sun} (d_{Moon})^2}{M_{Moon} (d_{Sun})^2}$$

Now if you plug the number from the box on the right into the above equation you will find that the gravitational force of the Sun on the Earth is **176** times that of the Moon.

$\mathrm{M}_{Sun} = 2.0 \times 10^{30}$ kg
$\mathrm{M}_{Moon} = 7.4 \times 10^{22}$ kg
$\mathrm{d}_{Sun} = 1.5 \times 10^{8}$ km
$\mathrm{d}_{Moon} = 3.8 \times 10^{5}$ km

Tidal Forces

Tidal forces operate slightly differently from gravitational forces. The tidal force from a perturbing body is proportional to the mass of that body and inversely proportional to the **cube** of the distance. Mathematically, this is:

$$\mathrm{F}_{\mathrm{Tidal}} \propto \frac{Mm}{d^3}$$

1. Write down the equation that would allow you to figure out the ratio between the tidal forces the Earth feels from the Sun to that of the Moon.

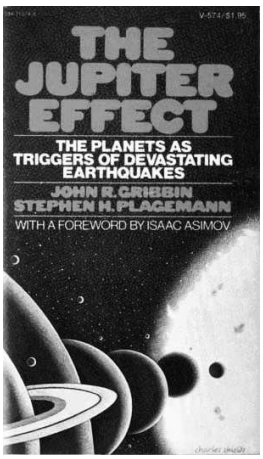
2. Plug in the numbers from the box on the other side of this sheet. Does the Earth feel a stronger tidal force from the Sun or the Moon? What is the ratio?

3. Jupiter's moon Io feels a tidal force from Jupiter in much the same way our Moon feels a tidal force from the Earth.

Using the data in the table to the right, figure out the ratio of the tidal force Io feels from Jupiter to the tidal force the Moon feels from Earth. [We will assume that the Moon and Io have the same mass. This is a pretty good assumption.]

$M_{Jupiter} = 1.9 \times 10^{27}$ kg
$M_{Earth} = 6.0 \times 10^{24}$ kg
$d_{Jupiter-Io} = 4.2 \times 10^{5}$ km
$d_{Earth-Moon} = 3.8 \times 10^{5}$ km

The Jupiter Effect



In early 1974 a strange little book was published called *The Jupiter Effect* that got a good deal of play in the media at the time. The central premise of the book was that the Earth was going to suffer devastating consequences on March 13th, 1982 due to the fact that all of the outer planets were aligned (roughly) on one side of the Sun. The combined tidal forces from these planets would cause massive earthquakes on the Earth, especially in southern California. Of course this did not happen, but occasionally a variation of this "effect" get knocked around on the more alternative outposts of the Internet. Random aside - This book was one of the first "science" books I ever read as a little nerd in 1975. Even then I did not believe it.

We now have all of the tools need to find out just really how much of a "Jupiter Effect" there really is. Let us just line up all of the outer planets on one side of the Sun (just like the cover of the book). This will give the largest effect. The table on the right shows the masses and distances from the Earth for the outer planets and the Moon.

Planet	Mass [kg]	Dist [km]
Moon	7.4×10^{22}	3.8×10^{5}
Mars	6.4×10^{23}	0.8×10^{8}
Jupiter	1.9×10^{27}	6.3×10^{8}
Saturn	5.7×10^{26}	12.8×10^{8}
Uranus	8.7×10^{25}	27.2×10^{8}
Neptune	1.0×10^{26}	43.5×10^{8}

Now crank-up your calculators or excel spreadsheets and figure out the ratio of the tidal force on the Earth due to the Moon and each of the outer planets (this is just like you did in problem#2). If you do use a spreadsheet for this problem, hand-in a printout to your TA. In any case show your work below.

Mars / Moon:

Jupiter / Moon:

Saturn / Moon:

Uranus / Moon:

Neptune / Moon:

Now, add-up all of those ratios and see how the "Jupiter Effect" compares to the tidal forces caused by the Moon alone. Should you be worried about the "Jupiter Effect"?