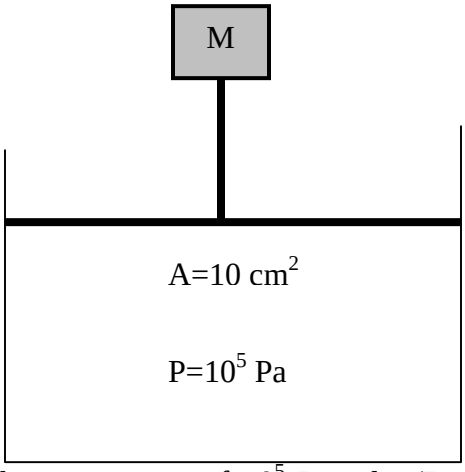
Physics 206a

Homework Assignment XI
due March 30, 2007

1. Using Newton's law of gravitation, derive the acceleration due to gravity experienced by an object of mass *m* at the surface of the Earth. Show that this acceleration is independent of the mass of the object.
2. If the radius of the earth changed and became ½ of its current value (but the mass stayed the same), what answer would you get for the previous problem?
3. Determine the acceleration due to gravity for an object on the surface of the Moon.
4. The "Clarke orbit" is named for science fiction writer Arthur C. Clarke. In 1945, Clarke suggested that there was an altitude above the surface of the earth at which satellites would have the same angular speed as the earth (*Wireless World*, October 1945, pages 305-308). Thus, a satellite placed in such an orbit would be "geosynchronous." That is, it would stay suspended over a single point on the globe. By setting the force of gravity equal to the centripetal force, find the radius of such an orbit. (Careful: Don't confuse the distance from the surface of the earth with the radius of the orbit! They differ by the radius of the earth.) There are currently over 300 satellites occupying such orbits!
5. Generalize the result you found in the previous problem: By using gravity as the thing providing an orbiting object with its needed centripetal acceleration, prove Kepler's third law. What is the constant of proportionality? I.e., Kepler's third law says that $T^2 = kR^3$ where *T* is the period of the orbit, *R* is the mean radius of the orbit, and *k* is some constant. Find *k*. You should assume the orbit is circular.
6. Some years ago, a (crackpot) theory circulated which predicted doom for the Earth due to the gravitational effect of the planets all lining up. This effect was known as "The Jupiter Effect"—which was the title of the book in which this prediction was made. The Earth did not, in fact, suffer any of the ill effects predicted. Calculate the force of gravity exerted by Jupiter on a person on the surface of the Earth when the two are closest. Jupiter's mean distance from the Sun is $7.79\times10^{11}\,m$ and its mass is $1.9\times10^{24}\,kg$. The Earth's mean distance from the sun is $1.49\times10^{11}\,m$. What mass of object would have a weight on the surface of the Earth equivalent to the force of gravity of Jupiter on this person?

7. What is the difference in the force experienced by a cubic meter of water due to the Moon's gravitational pull when the Moon is on the same side of the Earth as the water and when the Moon is on the opposite side of the Earth as the water? (I.e., about 12 hours later.) What is the force of the Earth's gravity on that quantity of water (i.e., its weight)?
8. A space shuttle has a mass of 80,000 kg. What is the difference in the rotational kinetic energy that needs to be given to the shuttle if it is launched from a point on the equator or the north pole in order to get it into a circular orbit? Assume the height of the orbit is 700 km above the surface of the earth.
9. It is frequently stated that astronauts are in "zero g" when in orbit around the earth. What is the net force of gravity on an 80 kg astronaut in a 700 km orbit? Why does the astronaut float?



10. A sample of gas has a pressure of 10^5 Pascals. (By the way: The atmospheric pressure at sea level is 101,325 Pascals.) If this gas is held in a cylinder that is capped with a piston with an area of 10 cm^2, as shown, what mass can be placed on the piston so that it is just supported by the gas? (Assume that the piston and cylinder are housed in a vacuum—i.e., ignore the pressure of surrounding air.)
11. Now, again consider the system in the previous question. Take the pressure of the surrounding air to be 101,325 Pa. If the mass to be supported is 13 kg, what pressure of gas must be used to fill the cylinder?