NYU Physics I—Problem Set 11

Due Tuesday (yes, Tuesday) 2016 November 29 at the beginning of lecture.

Problem 1: *(a)* Draw a free-body diagram for a package orbiting the Earth on a circular orbit at radius a, outside the atmosphere. Ignore all gravitational forces other than that from Earth.

(b) At what speed v and orbital period T must the package move such that its orbit will be circular?

(c) What is the orbital time at the surface of the Earth, and at the altitude of the orbit of the International Space Station?

(d) What is the orbital radius of a satellite in geostationary orbit? Compute it, and then check it by looking it up on the internets.

(e) Look up Kepler's laws and see if your answers to *(c)* and *(d)* are consistent with all of them.

Problem 2: *(a)* What is the total mechanical energy of a package of mass $m = 1$ kg sitting on the surface of the Earth on the equator? Take as the zero of potential energy a motionless package at infinity, and don't forget to include the kinetic energy from the fact that the package is sitting on the rotating Earth. Give your answer both in symbols (you will need to have symbols for the radius of the Earth, mass of the Earth, and period of rotation of the Earth) and also in J.

(b) To get the package from sitting on the Earth into orbit most easily, should you launch it to the north, south, east or west? Explain your reasoning.

(c) What is the total mechanical energy of the package orbiting just above the surface of the Earth? Again, symbols and also in J.

(d) What is the total energy of the package in geostationary orbit? Once again, both symbols and J.

(e) How fast (that is, at what "muzzle velocity") must you launch the package (that is sitting on the ground at the equator), and in what direction, if you want it to leave the gravitational field of the Earth entirely? Here just give your answer in $\mathrm{km\,s^{-1}}$.

Problem 3: *(a)* Find some combination of Newton's constant G, the speed of light c, and some (arbitrary) mass M, that has units of *length*.

(b) Evaluate your expression for the mass of the Sun (you will have to look it up); that is, find the characteristic length associated with that mass. Give your answer in units of km. What is the physical meaning of this length (approximately)?

Extra Problem (will not be graded for credit): Consider the moment when the Sun, Moon, and Earth are (close to) aligned, with the Moon between the Sun and the Earth. Compute the force on the Moon from the Earth, and then compute the force on the Moon from the Sun. Why is the Moon not falling into the Sun? Why was it that you were permitted to ignore the force on the Moon from the Sun in Problem 1, above? It isn't because the force on the Moon from the Sun is small!

Extra Problem (will not be graded for credit): Given what you thought about in Problem 2 above, why do launches of space vehicles start with the rocket pointing straight up? Why not point at an angle? There are two important reasons!

Extra Problem (will not be graded for credit): Would it take more or less energy to get a package to escape velocity at the North Pole relative to what you calculated at the Equator? Make your argument for a spherical Earth. Now notice that the Earth isn't exactly spherical. Will that fact increase or decrease the difference?