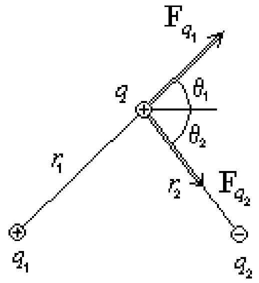
Problems for Chapter 6.

Revision:

$$F = \mathrm{k}_e \frac{q_1 q_2}{r^2} \qquad F = \mathrm{G}\frac{m_1 m_2}{r^2} \qquad F = \frac{mv^2}{r}$$



Force on q is found using

$$F_{q1} = \mathrm{k}_e \frac{qq_1}{r_1^2} \quad \text{and} \quad F_{q2} = \mathrm{k}_e \frac{qq_2}{r_2^2}$$

$$F_x = F_{q1}\cos\theta_1 + F_{q2}\cos\theta_2$$

$$F_y = F_{q1}\sin\theta_1 - F_{q2}\sin\theta_2$$

1.*A comic character (Obelix) once threw a javelin so fast that it swung around the earth and returned to where it was thrown. Now it is 40 000 km around the earth (this was how the metre was first defined), this in turn tells us that the radius of the earth is 6 400 km. How long does it take for a satellite to orbit the earth at (or just above) the surface? See page 59 of the notes for the constant G and page 61 for the mass and radius of the earth.

2. Just how high above the earths surface is a satellite that has a circular orbit of exactly 90 minutes? See page 59 of the notes for the constant G and page 61 for the mass and radius of the earth.

3.* A geo-stationary satellite orbits with the same angular speed as the earth so that the satellite remains directly above a fixed point at the earths equator. Obviously the period of this satellite is 24 hr, change this to seconds and find the height of a geo-stationary satellite in kilometres.

4. What is the speed of the geo-stationary satellite of question 3.?

5.* Imagine two electrons to be 0.20 nm (2.0×10^{-10} m) apart. Compare their gravitational attraction to their electrostatic repulsion. The charge of an electron is $q_e = -1.60\times10^{-19}$ C and the mass of an electron is $m_e = 9.1\times10^{-31}$ kg.

6. Imagine two protons are 1.0×10^{-15} m apart. Compare their gravitational attraction to their electrostatic repulsion. The charge of a proton is $q_p = +1.6\times10^{-19}$ C and their mass is 1.7×10^{-27} kg.

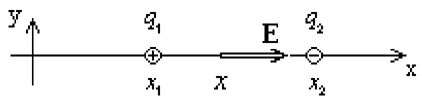
7.* The radius of an hydrogen atom is 0.053 nm. Consider the hydrogen atom to be a large stationary proton of charge $q_p = 1.60\times10^{-19}$ C, while the electron that orbits the proton has a charge of $q_e = -1.60\times10^{-19}$ C and a mass of $m_e = 9.1\times10^{-31}$ kg. Use this information to determine (really to estimate) the speed at which the electron orbits the proton, the attraction is of course electric. What are the period and frequency of rotation?

8. In larger atoms the radius of an orbiting electron will increase to, say 2.0×10^{-9} m. While such an atom will have many electrons and protons around the nucleus we could also suppose that a single "valence" electron with the increased radius orbit is attracted to the nucleus by a charge of $q_n = +\,3.2\times10^{-18}$ C. Do these electrons travel with a greater speed than the electrons in a hydrogen atom (as described in question 7.).

9.* What is the kinetic energy of a 1000 kg satellite that orbits the earth at a height of 110 km? Try the same problem for the satellite at a height of 1100 km, is the kinetic energy proportional to $\dfrac{1}{R_e + h}$?

10. What is the kinetic energy of a 500 kg satellite that orbits the earth at a height of 100 km? Can you use the result that the kinetic energy is proportional to $\dfrac{1}{R_e + h}$, to find the kinetic energy of this satellite when it orbits the earth at a height of 300 km?

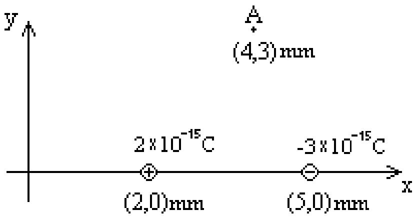
11.* If we calculate the electric field from two charges that are placed along, say an x-axis, we only need to calculate the field for points along the axis, we have reduced the calculation to a one dimensional calculation.



For the above situation we have $E_x = \mathrm{k}_e\left(\dfrac{q_1}{(x-x_1)^2} - \dfrac{q_2}{(x-x_2)^2}\right)$ If $q_1 = 2.0\times10^{-15}$ C and $x_1 = 2.0\times10^{-3}$ m, and $q_2 = -3.0\times10^{-15}$ C and $x_2 = 5.0\times10^{-3}$ m, try and find the value of x where $E_x = 0$. For this problem you will end up solving a quadratic equation and there will be two values of x, ask a tutor which is the correct one.

12. Repeat problem 11. for the case where $q_2 = +3.0\times10^{-15}$ C. the correct answer will be the other value of x that you discarded before.

13.* Use the configuration of question 11. also shown below, to calculate the x- and y- components of the electric field at the point A, (4.0,3.0) mm above the x-axis.



14. Repeat question 13. for the case when both charges are positive.