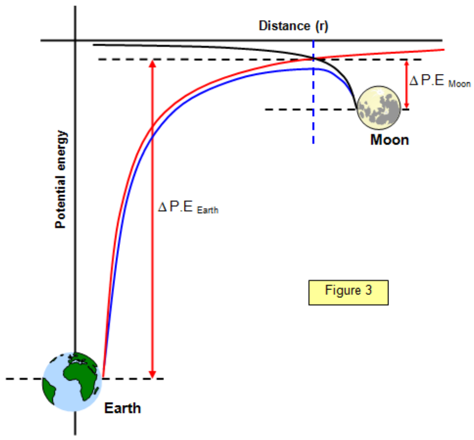
10 Fields review answers

Part A: Gravitational field, potential and energy and orbital motion

Mass of Earth = $6x10^{24}$kg, Mass of Moon = $7.3x10^{22}$kg

1. A satellite is in orbit 42,000 km above the centre of the Earth.
    a. Calculate the gravitational potential at this orbit height explaining why it is negative.
    $V = -GM/r = -6.67x10^{-11}$ x $6x10^{24}$ / 4.2 x 10^7 = - 9.5 x 10^6 J/kg. It is negative because it is a measurement of how much work is done to bring the object from infinity to this point.
    b. If the satellite has a mass of 150kg calculate its gravitational potential energy.
    = 150kg x - 9.5 x 10^6 J/kg = $1.4x10^9$ J
    c. Calculate the gravitational field strength at this point and hence state the centripetal acceleration the satellite undergoes.
    $g = F/m = GM/r^2 = 6.67x10^{-11}$ x $6x10^{24}$ / $(4.2 \times 10^7)^2$ = 0.23 Nkg^{-1} (0.227)
    d. Hence calculate the orbit period of this satellite in days.
    $g = a = 4\pi^2 r/T^2$ so $T^2 = 4\pi^2 r/g$ = 4x π^2x4.2 x 10^7/0.227 = $7.21x10^9$
    T = $8.5x10^4$s = 1 day (A geostationary satellite)
2. Derivation of the formula for escape velocity for a planet of mass M, radius r:
    a. State the energy transfer involved as an object moves completely away from a planet due only to its velocity.
    Kinetic Energy ➔ Gravitational Potential Energy
    b. State the total energy an object has when infinitely far from any other mass and when travelling at an infinitesimal velocity.
    Zero
    c. State the total energy the object must have just after launch.
    Zero
    d. Hence derive the formula for escape velocity.
    $E_p + E_k = 0$, $E_p = mV = -GMm/r$
    $-GMm/r + 1/2mv^2=0$ ➔ $v^2 = 2GM/r$ ➔ therefore $v = \sqrt{(2GM/r)}$
3. The distance from the Earth to the moon is **$3.8x10^8$m**. A point r at a distance of $3.8x10^7$m from the moon in a direction directly towards the Earth is shown on the potential energy diagram opposite:



    a. From the graph alone state the approximate value of the gravitational field strength at this point.
    $g = -\Delta V/\Delta r$ = gradient of graph = 0
    b. Calculate the gravitational potential due to the moon and the Earth combined at this point.
    Distance to earth re = **$3.8x10^8$-$3.8x10^7$m**
    $-GM_e/r_e-GM_m/r_m$
    $-G(M_e/r_e+GM_m/r_m)$
    $-6.67x10^{-11}(6x10^{24}/3.42x10^8+7.3x10^{22}kg/3.8x10^7)$
    $-1.3x10^6$ Jkg^{-1}.

c. Calculate the flight velocity required for an object, whose rockets will stop working at a distance of 7000km from the centre of the Earth to reach, this point in space.

Effect of moon is insignificant at this distance:

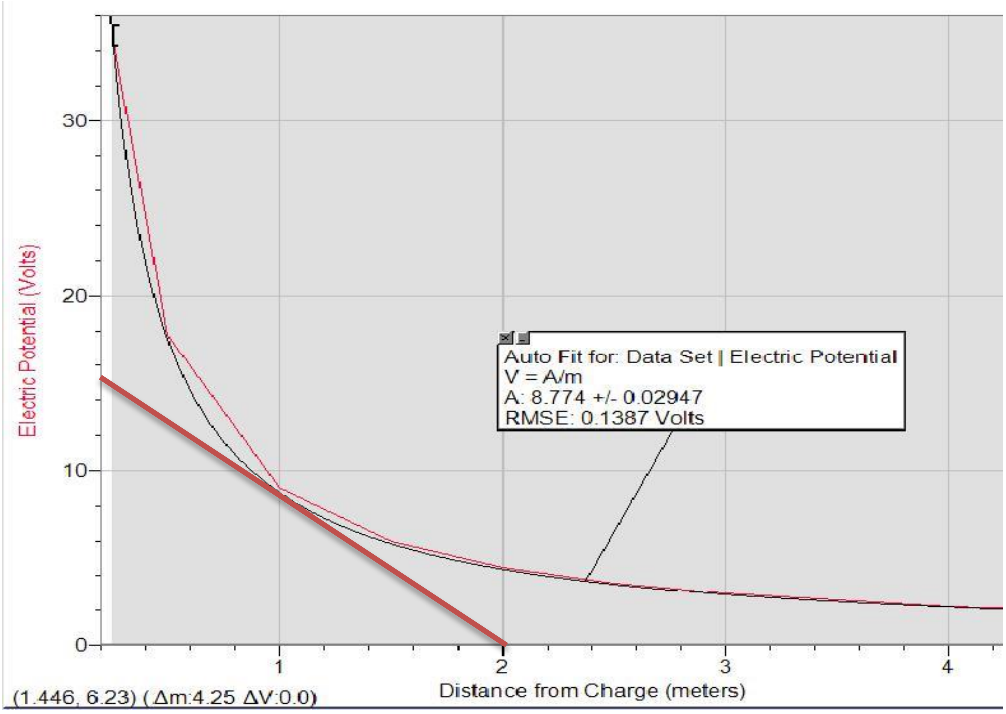
Potential at 7000km from Earth = -GM/r = $-6.67\times10^{-11}\times6\times10^{24} / 7\times10^{6} = -5.72\times10^{7}$ Jkg-1

½ v^2 must equal the potential difference

½ v^2 ==$-5.72\times10^{7}+1.3\times10^{6} = 5.59\times10^{7}$ ➔ $v = 1.1\times10^{4}$ ms^{-1}.

Part B: Electric field, potential and energy

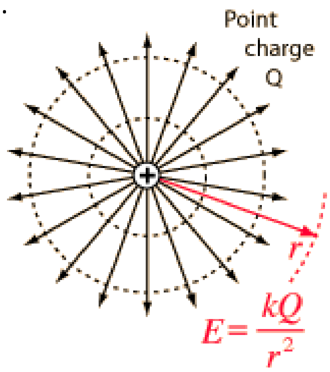
1. How much work is done to bring a charge of 1C to within 1×10^{-6}m of a charge of 10C?
   V = kq/r = $8.99\times10^{9}\times10/1\times10^{-6} = 9.0\times10^{16}$JC-1 so 9.0×10^{16}J of worm is done.
2. How much work is done to bring a charge of 1C to within 1×10^{-6}m of a charge of -10C?
   -9.0×10^{16}J of work is done
3. The graph below shows the variation of electric potential with distance near a point charge.
   a. Use the graph to estimate the field strength at a distance of 1m.
   Field strength E = -ΔV/Δx = -Gradient of this graph = - - 15/2 = 7.5Vm^{-1}.
   b. Hence calculate the size of the charge.
   $E = kq/r^2$
   $q = 7.5 * 1^2 / 8.99\times10^{9} = 8.3\times10^{-10}$C

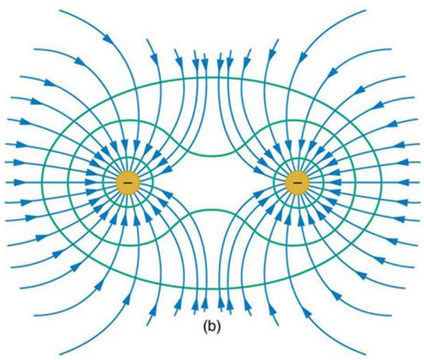


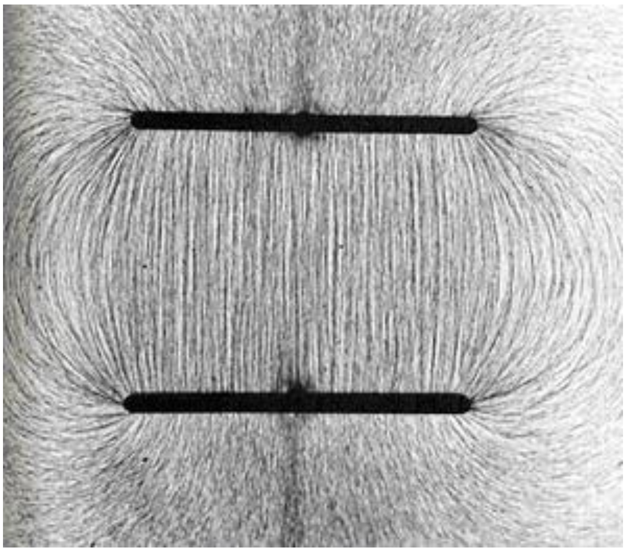
4. Sketch the equipotential surfaces and electric field lines for:

a. A point positive charge b. Two point negative charges separated by a small gap.

a.







5. The image shows electric field lines that are made visible by observing tracks of charged particles moving through a liquid. **4cm separates the plates.**
    a. If the potential difference between the plates is 6V calculate the force experienced by an ion of charge e.
    $E = \Delta V/\Delta x = 6/0.04 = 150Vm^{-1}$.
    $E = F/q$ so $F = Eq = 150e$
    $150 \times 1.6 \times 10^{-19} = 2.4 \times 10^{-17}N$
    b. How much work is done moving the charge all the way from one plate to another?
        i. in electron volts
        6 eV
        ii. in Joules
        6 x 1.6x10-19 = 9.6x10-19J

http://www.physics.upenn.edu/undergraduate/undergraduate-physics-labs/experiments/electric-field-and-electric-potential