Physics 1008: Long Answer Revision Questions & Solutions Part 1

B1 Consider the arrangement shown in the diagram. The distance from point A to point C is 9.06 cm, and the distance from point B to point C is 3.01 cm. A proton is fixed in place at point C. An electron is released from rest at point A.

(a) Calculate the potential difference from A to B, due to the proton, and indicate which location is at the higher potential. (4 marks)

(a) Calculate the potential difference from A to B, due to the proton, and indicate which location is at higher electric potential.

$$V = \frac{kq}{r}$$

$$V_B - V_A = \frac{kq}{r_B} - \frac{kq}{r_A}$$

	3.19×10^{-8} V
point of higher potential: (circle your choice)	A : (B)

$$V_B - V_A = kq\left(\frac{1}{r_B} - \frac{1}{r_A}\right) = (8.99 \times 10^9\ N\cdot m^2/C^2)(1.60 \times 10^{-19}\ C)\left(\frac{1}{0.0301\ m} - \frac{1}{0.0906\ m}\right)$$

$$V_B - V_A = 3.19 \times 10^{-8}\ V \quad (+ve,\ so\ V_B > V_A)$$

(b) Calculate the kinetic energy of the electron as it passes by point B. You may answer in either Joules or eV. (4 marks)

Energy is conserved.

3.19×10^{-8} eV

$$E_B = E_A$$

$$KE_B + EPE_B = KE_A + EPE_A$$

(starts from rest at A)

$$KE_B = KE_A + EPE_A - EPE_B = 0 + q_0(V_A - V_B) = -e(V_A - V_B)$$

$$KE_B = e(V_B - V_A) = e(3.19 \times 10^{-8}\ V) = 3.19 \times 10^{-8}\ eV$$

(c) Calculate the speed of the electron just as it passes point B. (2 marks)

$$KE_B = \frac{1}{2} m v_B^2$$

$$\boxed{106\ m/s}$$

$$v_B = \sqrt{\frac{2KE_B}{m_e}} = \left(\frac{2(3.19\times10^{-8})(1.60\times10^{-19}C)V}{9.11\times10^{-31}\ kg}\right)^{1/2}$$

$$v_B = 106\ m/s$$

B2 An electron is orbiting in a constant magnetic field, doing uniform circular motion. The plane of the motion is perpendicular to the magnetic field. The diameter of the circle is 9.60 cm. The mass of the electron = 9.11×10^{-31} kg. The speed of the electron is 5.00×10^{6} m/s, and the charge is -1.60×10^{-19} C

(a) What is the centripetal force comprised of? (1 mark)

The magnetic force on a moving charged particle

(b) Derive an expression for the magnetic field in terms of the radius of the orbit R, the mass m, the charge on the electron, and the speed v (5 marks).

The magnetic force must be equal to the centripetal force so:

$$F_B = qvBsin\theta = \frac{mv^2}{r}$$

Now the magnetic field and velocity vector are perpendicular to each other, so $\vartheta = 90^o$ and $\sin 90^o = 1$

$$qvB = \frac{mv^2}{r}$$

Cancel one of the v terms, and divide by q

$$B = \frac{mv}{qr}$$

(c) Calculate the magnetic field in Tesla (1 mark)

$$B = \frac{mv}{qr} = \frac{(9.11 \times 10^{-31} kg)(5.00 \times 10^{6} m/s)}{(1.60 \times 10^{-19} C)(9.60 \times 10^{-2}\ C)/2}$$

Remember you were given the diameter…

$$B = \frac{mv}{qr} = \frac{(9.11 \times 10^{-31} kg)(5.00 \times 10^{6} m/s)}{(1.60 \times 10^{-19} C)(9.60 \times 10^{-2}\ C)/2} = 5.93 \times 10^{-4} T$$

(d) Calculate the kinetic energy of the electron in eV (3 marks)

$$K = \frac{1}{2} mv^2 = \frac{1}{2}(9.11 \times 10^{-31} kg)(5.00 \times 10^{6})^2 = 1.14 \times 10^{-17} J$$

Convert to eV using the conversion factor 1 eV = 1.60×10^{-19}J

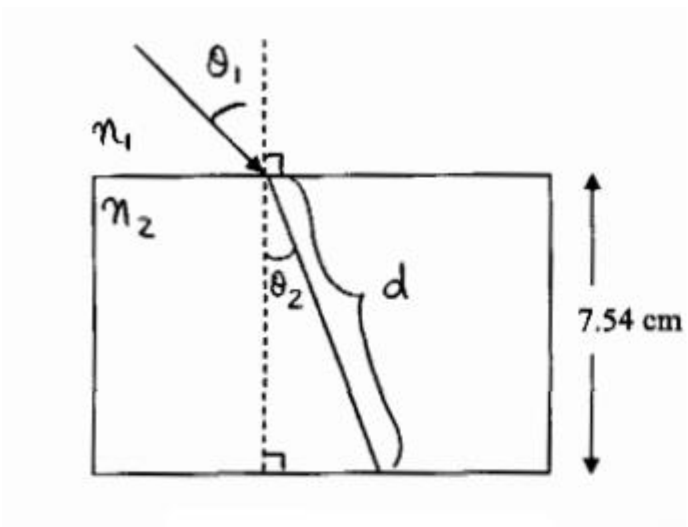
$$K = \frac{1.14 \times 10^{-17} J}{1.60 \times 10^{-19} J/eV} = 71.2\ eV$$

If you every have any doubts about converting Joules to eV, remember that the eV is supposed to be a more convenient and hence larger unit than Joules, when dealing with atomic and nuclear particles

B3 A beam of light strikes a glass block at an angle of $\theta_1 = 35.6^{\circ}$ as shown in the diagram below. The refractive index of the glass is 1.63, and the refractive index of the air = 1.00. The light has a wavelength of 589 nm in air.

(a) Calculate the distance d (5 marks)

(b) Calculate the wavelength of the light while in the glass (5 marks)



(a) To find the distance d, we need to find the angle of refraction θ_2.

$$cos\,\theta_2 = \frac{7.54\ cm}{d}$$

We use Snell's Law to find the angle of refraction

$$n_1\, sin\,\theta_1 = n_2\, sin\,\theta_2$$

$$\frac{n_1}{n_2} sin\,\theta_1 = sin\,\theta_2$$

$$sin^{-1}\left(\frac{n_1}{n_2} sin\,\theta_1\right) = \theta_2 = sin^{-1}\left(\frac{1.00}{1.63} sin\,35.6^o\right) = 20.92°$$

Now calculate the value for d

$$d = \frac{7.54\ cm}{cos\,20.92°} = 8.07°$$

Sanity check: the value for d must be greater than the thickness of the glass.

(b) The wavelength of the light changes when in the glass, but the frequency remains the same

Starting from the definition of refractive index for glass

$$n = \frac{c}{v_g}$$

We can write the speed of light in the glass v_g as

$$v_g = f\lambda_g$$

$$n = \frac{c}{f\lambda_g}$$

$$\lambda_g = \frac{c}{nf}$$

The frequency is the same in both air and glass, so

$$c = f\lambda_a$$

$$\lambda_g = \frac{f\lambda_a}{nf} = \frac{\lambda_a}{n} = \frac{589\ nm}{1.63} = 361\ nm$$

This is in the UV region (<400 nm)