PHYS1221-1231 tutorials

Tutorial 10 Answers

Q1 $\Delta E.\Delta t = h/2\pi$. $E = -\left(\frac{me^4}{8\varepsilon_o^2 h^2}\right)\frac{1}{n^2}$

$\Delta E/E = \frac{h}{2\pi\Delta t.E}$ = 20 parts per billion. 8 significant figures only

Q2 $\Delta E.\Delta t = h/2\pi$. So $\Delta E/E = \frac{h}{2\pi\Delta t.E}$ = 2 parts in 10^{10}.

Q3 The photons must have $\lambda \sim 10$ pm, so they have $E = hc/\lambda = 120$ keV and $p = h/\lambda = 7\ 1 10^{-23}$ kgm.s^{-1}

The binding energy of the hydrogen atom is only 13 eV so interactions with these photons will ionise it.

The momentum of Sommerfeld electrons is $\frac{m}{2\varepsilon_o}\frac{e^2}{nh} = 2\ 10^{-25}$ kgm.s^{-1} << p_{photon} so the collisions would give the electrons large recoil velocities.

Q4 $\Delta f.\Delta t \geq 1/2\pi$. $\Delta f \geq 0.16$ Hz. For the second case, 1.6 Hz.

Answers for musicians: At this pitch, the uncertainty is half a semitone. (In practice, this is only 5 vibrations of the string, and it takes at least a few cycles for the bow to set up periodic Helmholtz motion, so it won't have a clear pitch at all. Musicians know this: in very fast runs in the bass you can get away with a lot: the ear will interpolate.

Serves the composer right for writing low demisemiquavers for the basses – but then Schubert never finished that symphony: Detective we're re-opening the case – I want you to interview all the bassists who were in Vienna on or around the night of 18 November 1828.)

Q5 For electrons, $I d\theta$ would be proportional to the number of electrons detected between the angles θ and $\theta+d\theta$. The integral of I from $\theta = -\pi/2$ to $\pi/2$ would be set equal to N, and this equation would define I_0, the maximum in the electron distribution function.

If you covered one slit, only half as many electrons would pass through. Further, there would be no interference, and only diffraction, so

$$I_{single}(\theta) = \frac{I_0}{2} \cos^2\left(\frac{\sin\alpha}{\alpha}\right)^2$$

Q6 $n_e = \frac{2}{3}\frac{8\sqrt{2}\,\pi\, m_e^{3/2}}{h^3} E_F^{3/2} = 8.5\ 10^{28}$ electrons/m^3.

atom density = density/(atomic mass) = $\frac{(8920\text{ kg.m}^{-3})}{(63.5\text{ kg/kmol} / 6\ 10^{26}\text{ atoms/kmol})} = 8.4\ 10^{28}$ atoms/m^3. So one conduction electron per atom.

$$v = \sqrt{\frac{2K}{m}} \cong \sqrt{\frac{2E}{m}} = \sqrt{\frac{2 * 7.05\text{ eV}}{9.11\ 10^{-31}\text{ kg}}} = 1.6\ 10^3\text{ km/s} = 0.5\%\text{ of c.}$$

For a conductor, $i = nAvq$ so $v = i/nAq = 0.95$ mm/s.

If all moved at 0.5% of c, $i = nAvq \rightarrow 17$ GA