# Problem sheet : 1

*PHY 202; Relativity and quantum physics.*
*IISER, Pune. (Feb, 2009)*

*This is not meant for evaluation and need not be submitted back. However, you are welcome to approach me for any doubts and clarifications. Some of these problems are taken from Beiser's book. You can consult the book for more hints on solution.*

1. Find the de Broglie wavelength of a football of mass 450 gms flying off at a speed of 40 km/hr.

2. Calculate the de Broglie wavelength (in meters) for an electron in $n = 2$ state of hydrogen atom.

3. Power received by the top of earth's atmosphere from the sun is 1.4 kW/m$^2$. Assuming that the earth behaves like a blackbody, find the surface temperature of the earth. (*For a hint, see example problem 9.7 in Beiser's book.*)

4. The temperature of a wall of size 25 sq. m. exposed to sun on a hot summer day is 36$^o$C. Calculate the total power radiated by the wall.

5. A blackbody is maintained at a temperature of 2500 K. Calculate the wavelength in meters for which the emitted radiation is maximum.

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7. The maximum wavelength for photoelectric emission in tungsten is 230 nm. What wavelength of light must be used in order for electrons with a maximum energy of 1.5 eV to be ejected.

8. What is the frequency of an x-ray photon whose momentum is 1.1 x $10^{-23}$ kg. m/s.

9. An x-ray photon of initial frequency 3 x $10^9$ Hz collides with an electron and is scattered through 90 degrees. Find its new frequency.

10. Compare the uncertainties in the velocities of an electron and a proton confined to a box of size 1 nm.

11. To ionize hydrogen atom, 13.6 eV energy must be supplied to it. Find the orbital radius and velocity of the electron in a hydrogen atom. What does this say about relativistic effects in $n = 1$ state of hydrogen atom ?

12. Using the results in problem (11), calculate the wavelength of the electron and compare it with the circumference of ground state in hydrogen atom.

13. Consider a one dimensional box of width $L$. Explicitly determine the conditions for standing waves in the box. (*Hint : Start from a wave of form* $y = Ae^{i(\omega t - kx)}$ *and another one of same amplitude travelling in the opposite direction.*)

14. Given two travelling waves with amplitudes $A$ and frequencies $\omega$, $\omega - \Delta\omega$, find the amplitude of the resultant waves. From this, deduce the group velocity.

15. A charged particle of mass $m$ is accelerated by the application of a potential difference $V$. Derive a non-relativistic relation for the de Broglie wavelength of the particle.

16. Derive a relation connecting the energy $E$ and radius $r$ for an electron in hydrogen atom.

Show that if two energies $E_1$ and $E_2$ correspond to two radii $r_1$ and $r_2$ respectively, then $E_1/E_2 = r_2/r_1$.

17. According to Planck's hypothesis, energy exchange takes place in quanta, i.e, $E = nh\nu$, $(n = 0, 1, 2...)$. Assuming Boltzmann distribution for energies, i.e, $f(E) = e^{-E/kT}$, show that the average energy of oscillator is $\langle E \rangle = h\nu/e^{hv/kT} - 1$.

18. Given that the temperature of the sun is $T_s$, obtain an expression for the temperature $T_p$ of planet located at a distance $d$ from the sun. The radius of sun and planet are $r_s$ and $r_p$. Use the standard data to estimate the temperature of the earth.

19. The brightest part of the spectrum of star Sirius is located at a wavelength of about 290 nm. What is the surface temperature of Sirius.

20. An electron at rest is released far away from a proton, toward which it moves. Show that the de Broglie wavelength of the electron is proportional to $\sqrt{r}$ where $r$ is the distance of the electron from the proton.

21. Hydrogen atom emits a radiation of wavelength 102.55 nm while returning to ground state. Find the quantum number of the orbit from which electron returned to the ground state.

Some useful constants :

$c = 2.997 \times 10^8$ m/s (speed of light)
$\hbar = 1.054 \times 10^{-34}$ J.s (Planck's constant/$2\pi$)
$m = 9.109 \times 10^{-31}$ kg (Electron mass)
$k = 1.380 \times 10^{-23}$ J/K (Boltzmann constant)
$a_0 = 0.529 \times 10^{-10}$ m (Bohr radius)
$r_s = 7 \times 10^8$ m (Solar radius)
$R_o = 1.5 \times 10^{11}$ m (Radius of earth's orbit)