Name : ....Asma Vinod....................................  Reg. No. :........B130530EC...........................

# National Institute of Technology Calicut

## End Semester Examination, April 2014

## PHYSICS (PH1001)

**Duration: 3 hour** **Answer all the questions** **Max. Marks: 50**

---

*Useful data:* $h = 6.626 \times 10^{-34}$ Js , $e = 1.6 \times 10^{-19}$ C, *mass of an electron or a positron* = $9.1 \times 10^{-31}$ kg, *Boltzmann constant* $k = 1.381 \times 10^{-23} JK^{-1}$, *Avogadro's number* $N_A = 6.022 \times 10^{-23}$, *speed of light in vacuum* = $3 \times 10^{8} ms^{-1}$, $\int_0^\infty \sqrt{x}\, e^{-x} dx = \frac{\sqrt{\pi}}{2}$

---

1. A particle of mass $m_o = 1.7 \times 10^{-28} kg$ and carrying the same charge as the electron has a mean life time $\tau = 10^{-6}\ s$ when it is at rest. The particle is accelerated instantaneously through a potential gap $\Delta V = 10^{8} V$. What is the expected life time of the particle, in the laboratory, after the acceleration? **(3 Marks)**

2. A particle moves in the *yz-plane* with a speed of magnitude $v$, in a direction making an angle 45° with the y axis. What is the magnitude of the velocity of the particle to an observer moving with a speed $w$ along the positive direction of *x-axis*? What is the direction of motion of the particle as felt by the observer? **(3 Marks)**

3. A spaceship of length $150\ m$ moves with respect to a space station with a speed of $2 \times 10^{8}\ ms^{-1}$. What is the length of the spaceship as measured by an observer on the space station? **(3 Marks)**

4. Write down four different examples where relativistic effects can be observed in real life. Name the relativistic effect observed in each case. **(2 Marks)**

5. The velocity of a positron is measured to be $v_x = (4.00 \pm 0.18) \times 10^{5}\ ms^{-1}$, $v_y = (0.34 \pm 0.12) \times 10^{5}\ ms^{-1}$, $v_z = (1.41 \pm 0.08) \times 10^{5}\ ms^{-1}$. Within what minimum volume was the positron located at the moment the measurement was carried out? **(3 Marks)**

6. An electron is described by the wavefunction

$$\psi(x) = \begin{cases} 0 & for\ x < 0 \\ Ce^{-x}(1 - e^{-x}) & for\ x \geq 0 \end{cases}$$

Where $x$ is in nanometers and $C$ is a constant. (a) Find the value of $C$ that normalizes $\psi$. (b) Calculate the expectation value of position, $\langle x \rangle$ for the electron.

**(2+2 = 4 Marks)**

7. A quantum particle of mass $m$ is trapped in a one dimensional box of size $L$. Derive equations for its energy eigen values, **normalised** eigen functions, and the momentum eigen functions. **(1.5+1.5+1 = 4 Marks)**

8. Silver ($Ag$) has a Fermi energy of $\varepsilon_F = 5.5\ eV$. Find the temperature at which there is a $10\%$ probability that the free electrons in Silver have an energy $1\%$ above the Fermi level. **(3 Marks)**

9. (a) Write down (**do not derive**) Maxwell's speed distribution law. Draw the $n(v)dv$ **vs.** $v$ graph clearly labelling the positions of $v_{rms}$ , $v_{avg}$ , and the most probable speed $v_p$. **(1.5 Marks)**

(b) Starting from Maxwell's energy distribution law find the expression for the most probable energy of a gas molecule at a temperature $T$. **(1.5 Marks)**

10. Consider an ideal gas with five (identical) atoms in a container. If the atoms move with speeds of *640, 552, 695, 533* and 697 $ms^{-1}$, respectively, determine the temperature of the system. The mass of the atoms is $12\ g\text{-}mol^{-1}$. **(3 Marks)**

11. A blackbody has its cavity of cubical shape. Determine the number of modes of vibration per unit volume in the wavelength region *4990* to 5010 $\AA$ within the cavity. **(3 Marks)**

12. (a) Derive an expression for the concentration of **holes** in the valence band of an *intrinsic* semiconductor. **(4 Marks)**

(b) Write down (**do not derive**) the expression for the concentration of free electrons in the conduction band of an intrinsic semiconductor and show that the Fermi level lies at the centre of the energy gap in *intrinsic* semiconductors. **(3 Marks)**

13. In a semiconductor the effective mass of electrons is $0.07m_o$ and that of holes is $0.4m_o$, where $m_o$ is the free electron mass. Assuming that the average relaxation time $\tau$ for the holes is half that for the electrons, calculate the mobility of holes when the electron mobility is $\mu_e = 0.8\ m^2V^{-1}s^{-1}$. **(3 Marks)**

14. (a) Draw graphs representing the variation of magnetic susceptibility ($\chi$) with temperature in diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic and ferrimagnetic materials with equations wherever relevant? Give one example for each type of material. **(0.5+1+1+1+0.5 = 4 Marks)**

(b) A magnetic material has a magnetization of 3300 $Am^{-1}$ and a flux density of $0.0044\ Wb\text{-}m^{-2}$. Calculate the magnetising field $H$ and the relative permeability of the material. ($\mu_0 = 4\pi\times10^{-7}Hm^{-1}$). **(2 Marks)**

~ o ~