D 51615 (Pages 3) Name..............................

Reg. No..............................

FIFTH SEMESTER B.TECH. (ENGINEERING) DEGREE EXAMINATION, DECEMBER 2008

EE 04 506—ELECTRICAL ENGINEERING MATERIAL SCIENCE

(2004 Admissions)

Time : Three Hours Maximum : 100 Marks

Constants :

$k = 1.38 \times 10^{-23}$ JK^{-1}

$h = 6.62 \times 10^{-34}$ JS

$e = 1.60 \times 10^{-19}$ C

$m = 9.11 \times 10^{-31}$ kg

$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}

I. (a) Write brief notes explaining the general electrical behaviour with temperature of (i) a classical resistor and (ii) a doped semiconductor.

(b) Give a brief description of the following magnetic materials and their appropriate applications in industry :

(i) Transition metals.

(ii) Ferrites and garnets.

(c) A P-type material has dimensions $10 \times 2 \times 2$ mm^3 and a carrier denisty of 10^2/m^3. A current of 10 mA flows along the long axis and a magnetic field of B = 0.5 wb/m^2 is applied to the crystal, normal to a 10×2 mm^2 face. Calculate the Hall voltage.

(d) A parallel plate condenser has an area of 10 cm^2 and a separation of 0.1 mm. The space between the plates is filled with polyethylene. An alternating voltage with an amplitude of 2 volts is applied at a frequency of 1 mega cycle. Given that at this frequency the real part of the relative dielectric constant is 2.25 and the loss tangent is 4×10^{-4}, find the elements of an equivalent parallel RC circuit. Also calculate the energy dissipation per second.

(e) List common insulator materials used in electrical apparatus.

(f) What is the difference between liquid insulators and Gasesous insulators.

(g) Explain Antireflection coatings.

(h) Explain about Nuclear magnetic resonance and ferromagnetic resonance.

($8 \times 5 = 40$ marks)

Turn over

II. (a) An intrinsic semiconductor has an energy gap of 1.1 eV with an effective mass ratio

$$\frac{m_p^*}{m_e^*} = 1.8 \text{ and } n_i = 10^{16}/m^3.$$

(i) Calculate the separation in eV between E_f and $\frac{E_c}{2}$ at 300 K.

(ii) If the material is now doped with $n = 10^{20}/M^3$ calculate the minority carrier density and the separation between E_f and E_i showing these levels on a band diagram.

Or

(b) Apply various biases to a pn diode and explain the currents that results. Derive the rectifier equation :

$$I = I_0 \left\{ e^{qv/kT} - 1 \right\}$$

Draw, explaining all of the important features, the curve of this expression.

III. (a) Derive the Dispersion Equation $k = \left\{ w^2 \mu' \varepsilon' - jw\mu' \sigma \right\}^{1/2}$. Discuss the significance of this equation in determining the velocity of electromagnetic wave, propagation in materials.

Or

(b) The attenuation coefficient (α) is obtained from the imaginary part of the dispersion equation.

Show that $\alpha = \frac{w\sqrt{\varepsilon_r}}{2C} \tan\delta$, where C is velocity of light. Calculate the attenuation loss in db/km for an optical fibre with the following data : $\varepsilon_r = 2.25$; $f = 3 \times 10^{14}$ Hz ; $\tan\delta = 10^{-11}$.

IV. (a) (i) Consider a parallel arrangement of a capacitance C and a resistance R. An external voltage $V(t) = V_0 \cos wt$ is applied to this arrangement. Show that the total current $i(t)$ is given by :

$$i(t) = \left(V_0/R \right) \cos wt - C_w V_0 \sin wt.$$

(ii) Consider a parallel plate condenser with a lossy dielectric between them. At an angular frequency w let the dielectric be characterized by a complex dielectric constant $\varepsilon_r^* = \varepsilon_r' - j\varepsilon_r''$. The area of the plates is 1 m^2, the distance between them 1 m. For an applied voltage $V(t) = V_0 \cos wt$. Show that the current through the lossy condenser is given by :

$$i(t) = (\varepsilon_0 \varepsilon_r'' w V_0) \cos wt - (\varepsilon_0 \varepsilon_r' V_0 w) \sin wt.$$

(ii) Are the elements of the equivalent circuit independent of the frequency ?

Or

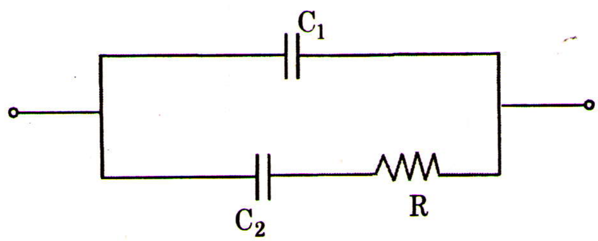
(b) (i) Suppose a dielectric has a complex dielectric constant given by $\varepsilon_r^* = \varepsilon_{ei} + \varepsilon_{ro}^*$ where ε_{ro}^* refers to the dipole orientations and ε_{ei} is a real quantity referring to the electronic and ionic polarizations. Assume that ε_{ro}^* is determined by a simple relaxation time τ. Consider the space between two parallel metal plates filled with this dielectric. If the distance between the plates is 1m. Show that the admittance of the condenser per m^2 plate area is equal to :

$$y^* = jw\,\varepsilon_0 \left\{ \varepsilon_{ei} + 1 + \frac{\varepsilon_{ro} - 1}{1 + jwr} \right\}.$$

(ii) Consider the circuit in the figure. Show that the admittance of this circuit is equal to :

$$y^* = jw \left\{ C_1 + \frac{C_2}{1 + jw\tau} \right\}.$$

where $\tau = RC_2$.



V. (a) If the battery and control unit are 80% efficient and the array consists of modules of 14% efficiency, what will be the unit electricity cost of the system if it is situated in a region with 5.5 k wh/m^2 day average daily irradiation ?

Or

(b) A village has a population of 350 people who require clean water and intend to install a pV pump. Assume a demand of 40 litres per person per day, and that the static water table is 15 m below the surface.

(i) What volume of water per day (in m^3) is required ?

(ii) For two days of storage, what volume (in m^3) of tank would be needed.

(iii) What is the total head over which water must be pumped ?Assume a draw down of 5 m once pumping begins and that the top of the tank will be 3 m above ground level.

(iv) What is the daily hydraulic energy required in kWh/day ?

(v) What is the size of pV array needed, in W_p ? Assume a daily solar irradiation of 5.0 kWh/m^2 day, an array mismatch of 0.8 and a daily subsystem efficiency of 0.3.

(4 × 15 = 60 marks))