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PHYSICS - Optional

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Solid State Physics, Devices & Electronics 2015 - 2019

UPSC – PHYSICS Optional – 2015 Questions

1. Show that any arbitrary rotation axis is not permitted in a crystal lattice. **[10M]**

2. Simplify the logical expression $[A\bar{B}(C + BD) + \bar{A}\bar{B}]C$. **[10M]**

3. Differentiate between n-p-n and p-n-p transistors. Give their device structure and biasing circuits when used as an amplifier. **[10M]**

4. Design a transistor based Colpitt oscillator which can oscillate at 9 MHz. Explain how the oscillations are created and sustained. **[15M]**

5. Describe an operational amplifier based integrator. Using operational amplifier integrators, design a circuit to solve the following differential equation:

$\frac{d^2v}{dt^2} + 2\frac{dv}{dt} + 3v = 0.$ **[20M]**

6. Draw the device structure of a p-n junction solar cell and explain how light energy is converted into electrical energy. Draw and explain its I-V characteristics. **[15M]**

7. Find an expression for lattice specific beat of a solid, and its low and high temperature limits. What is Debye temperature ? **[20M]**

8. Describe the motion of an electron in one dimensional periodic potential and show that it leads to formation of bands of allowed and forbidden states in the electron energy spectrum. How are the conductors, semiconductors and insulators discriminated on the basis of band structure ? **[20M]**

9. Distinguish between a superconductor and perfect conductor. Explain what is a Cooper pair. **[10M]**

UPSC – PHYSICS Optional – 2016 Questions

1. Why are NAND and NOR gates called universal gates ? Give the logic diagram, Boolean equation and the truth table of a NAND gate. **[10M]**

2. The primitive translation vectors of a two-dimensional lattice are

$$a = 2\hat{\imath} + \hat{\jmath},\ b = 2\hat{\jmath}$$

Determine the primitive translation vectors of its reciprocal lattice. **[10M]**

3. With the help of a schematic diagram, show how entropy and specific heat vary with temperature for a superconductor. **[10M]**

4. What is the difference between direct and indirect band gap semiconductors ? Which one is suitable for use in solar cells? **[20M]**

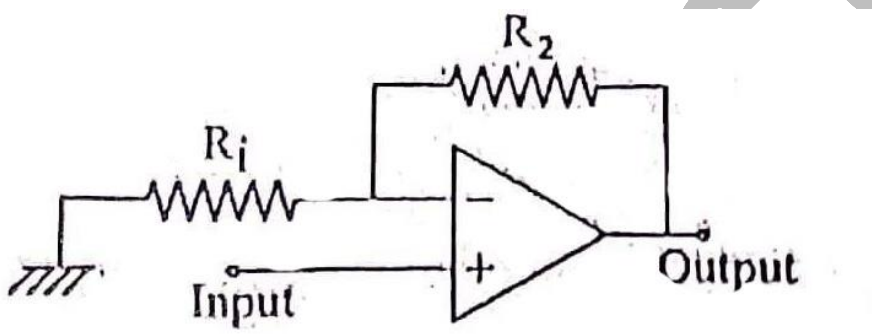
5. Obtain Laue's equations for X-ray diffraction by crystals. Show that these are consistent with the Bragg's law **[20M]**

6. Write down the salient features of the Einstein's theory of lattice heat capacity. Further write down the expression for specific heat in Einstein's theory and explain its high and low temperature limits. **[10M]**

UPSC – PHYSICS Optional – 2017 Questions

1. The energy (E) and wave vector (k) for a conduction band electron in a semiconductor are related as $E = \alpha \frac{h^2k^2}{m_0}$ where α is a constant and m_0 is the free electron mass. Calculate the effective mass of the electron. **[10M]**

2.



Consider the operational amplifier circuit given above :

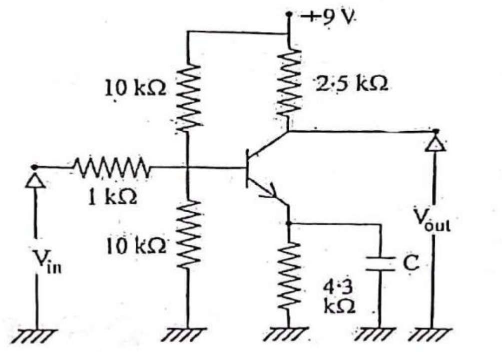
Given, $R_1 = 10\,\Omega$, $R_2 = 150\,k\Omega$ and the product of the open loop gain of the amplifier and its bandwidth = 10^6 Hz. Determine the closed loop bandwidth of the amplifier. **[10M]**

3. A system of paramagnetic atoms (N per unit volume) which can occupy only two energy levels in a uniform external magnetic field H is at a temperature T. If this system follows Boltzman's distribution, find the magnetization and susceptibility of the system. **[20M]**

4. Obtain the expression for penetration depth using London's equation of superconductivity and explain its significance. **[15M]**

5. In a semiconductor, the effective masses of an electron and a hole are 0.07 m_0 and 0.4 m_0, respectively, where m_0 is the free electron mass. Assuming that the average relaxation time for the hole is half of that for the electrons, calculate the mobility of the holes when the mobility of the electrons is 0.8 $m^2\ volt^{-1}s^{-1}$. **[15M]**

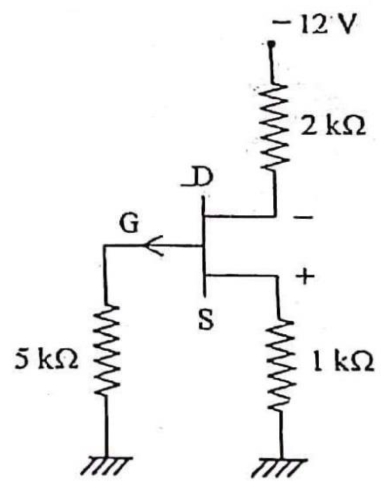
6.



An amplifier in common-emitter configuration is shown in the above figure.

If the current gain $\beta = 100$ and the a.c emitter resistance = 25.0 Ω, determine the input impedance and the voltage gain of the amplifier. **[15M]**

7.



Given above is a circuit of self biased $p -$ channel JFET.

If the pinch off voltage is 5.0 V and $V_{DS} = 6.0$ V, calculate the saturation current I_{DSS}.

[15M]

8. Draw a schematic diagram of the single particle energy levels in a shell model including the effect of spin-orbit coupling. Show how it explains magic numbers in nuclei. Give two examples to show how this scheme predicts the spins and particles of odd A nuclei. **[20M]**

UPSC – PHYSICS Optional – 2018 Questions

1. Calculate Atomic Packing Fraction (APF) for FCC and HCP structures, and show that these are the most closely packed structures. **[10M]**

2. Derive Bragg diffraction law for X-ray diffraction. Compare Laue and Debye-Scherrer methods for crystal structure determination. **[10M]**

3. Derive an expression for lattice specific heat in Debye model. Find its how temperature limit (Debye T^3 law). **[15M]**

4. What are intrinsic and extrinsic semiconductors? Show that in the intrinsic semiconductors, Fermi level lies exactly in the middle of bottom of conduction band and top of valence band.

[15M]

5. What are type I and type II superconductors? Give examples. Discuss and compare Meissner effect and perfect diamagnetic behaviour for type I and type II superconductors.

[20M]

6. What are operational amplifiers? How can it be used as an inductor? Prove it mathematically. **[15M]**

7. Describe the working of a microprocessor system in block diagram. How is its performance affected in a pipelined processor? **[15M]**

UPSC – PHYSICS Optional – 2019 Questions

1. Deduce the Miller indices of the close-packed planes of atoms in the f.c.c. lattice. [**10M]**

2. The angles between the tetrahedral bonds of diamond are the same as the angles between the body diagonals of a stack of neighbouring cubes having common edges and not faces. Use vector analysis to find the value of the angle. [**10M]**

3. A silicon semiconductor sample at $T = 300K$ having cross-sectional area of $0.5\mu m^2$ has a pentavalent donor doping profile given by $C(x) = 5 \times 10^{16} e^{(-x/l_n)} cm^{-3}$. Given, the mobility of the electrons in the sample is 1250 $cm^2 V^{-1} s^{-1}$ and the diffusion length of the electrons, L_n, is $4\mu m$. Calculate the diffusion current in the sample at distance $x = 2\mu m$.

[**10M]**

4. Consider a face-centred cubic lattice of side a. Deduce

(i) the primitive translation vectors'

(ii) the volume of the primitive cell;

(iii) the reciprocal primitive translation vector;

(iv) the volume of the reciprocal lattice. **[20M]**

5. Derive the expression for the average energy of a quantum oscillation of frequency v. Assume Fermi-Dirac distribution and $E - E_F > 2$, where E_F is the Fermi level. **[15M]**

6. Sketch the cross-sectional structure of an enhancement mode MOSFET and explain its principles of operation with the help of its output characteristics. **[15M]**

7. A silicon semiconductor sample is doped with $6 \times 10^{16} cm^{-3}$ of aluminum and $7 \times 10^{15} cm^{-3}$ of phosphorus atoms. Given at $T = 300K$, the intrinsic carrier concentration, $n_i = 1.5 \times 10^{10} cm^{-3}$; the band gap, $E_g = 1.1eV$; the electron mobility, $\mu_n = 1250 cm^2 V^{-1} s^{-1}$ and the hole mobility, $\mu_p = 480 cm^2 V^{-1} s^{-1}$.

Determine in the sample of the following:

(i) The type of the semiconductor, $n\ or\ p$

(ii) The hole carrier concentration

(iii) The electron carrier concentration

(iv) The position of the Fermi level in the sample with respect to the bottom of the conduction band

(v) The conductivity of the sample. **[20M]**

8. A 5 cm^2 Ge solar cell with a dark reverse saturation current of 2 nA has solar radiation incident upon it, producing 4×10^{17} electron-hole pairs per second. The electron and hole diffusion lengths are given to be $5\mu m$ and $2\mu m$, respectively. Calculate for the cell of the following:

(i) The short-circuit current

(ii) The open-circuit voltage **[10M]**