PHYSICS
Paper III

Time Allowed : 2½ Hours] **[Maximum Marks : 200**

Instructions :—This paper has four (**4**) sections. There are totally 19 questions to be answered. Log table is enclosed.

SECTION I

Instructions :—In this section you have to answer all questions (Q. No. **1** to Q. No. **2**). Each question carries **20** marks.

1. $f(x)$ vanishes as $x \to \pm \infty$.

Let $g(w)$ and $g_2(w)$ denote the Fourier transform of $f(x)$ and $f''(x)$. Show that $g_2(w) = (-iw)^2 g(w)$. Use this result to solve partial differential equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{w^2}\frac{\partial^2 y}{\partial t^2},$$

with initial condition $y(x, 0) = f(x)$.

Or

A particle of mass m is moving in a plane under an inverse square law attractive force. Set up the Lagrangian, hence obtain the equation describing its motion.

2. Magnetic field $\bar{B}(\bar{r})$ due to steady state currents localized in volume τ is given by Biot-Savart law as :

$$\bar{B}(\bar{r}) = \frac{\mu_0}{4\Pi}\iiint_{\tau} \frac{\bar{J}(\bar{r}') \times (\bar{r} - \bar{r}')}{|\bar{r} - \bar{r}'|^3} d\tau'$$

Show that :

$$\nabla . \bar{B}(\bar{r}) = 0$$

and

$$\nabla \times \bar{B}(\bar{r}) = \mu_0 \bar{J}(\bar{r}).$$

Or

Discuss the powder X-ray diffraction method for the determination of crystal structure of materials. Explain how will you determine a lattice constant for copper.

SECTION II

Instructions :—In this section you have to answer all questions (Q. No. **3** to Q. No. **5**). Each question carries **15** marks.

3. (*a*) Explain the mechanics by which junction voltage is developed across a *p-n* diode. Give values of this voltage for Silicon and Germanium diodes.

(*b*) Draw energy level diagrams for a *p-n* junction diode and discuss the shifting of bands under forward and reverse bias condition.

Or

Discuss Hund rules. Apply these rules to find the ground state (the basic level) of :

(*a*) Eu^{2+} (outer electronic configuration) : $4f^7 5s^2 5p^6$

(*b*) Yb^{3+} (outer electronic configuration) : $4f^{13} 5s^2 5p^6$

(*c*) Co^{2+} (outer electronic configuration) : $3d^7$.

Or

Describe He-Ne laser. Draw a schematic diagram of this laser. With the help of energy-level diagram, explain the pumping scheme of this laser.

Or

What do you understand by mirror nuclei ? Give some examples. Since $_{14}Si^{27}$ and $_{13}Al^{27}$ are "mirror nuclei, their ground states are identical except for charge. If their mass difference is 6 MeV, estimate their radius (neglecting the proton-neutron mass difference).

4. (*a*) Discuss the working principle of a depletion mode MOSFET with the formation of *n*-channel and show its transfer and output characteristic.

(*b*) Explain the working principle of JFET and discuss the pinchoff effect with the help of characteristics.

Or

Discuss the crystal structure of diamond and find out the angles between the tetrahedral bonds of this material.

Or

For the hydrogen atom in its ground state, the number density is $p(r) = (\Pi a_0^3)^{-1} \exp(-2r/a_o)$, where a_0 is the Bohr radius. Show that the form factor is :

$$f_G = 16/(4 + G^2 a_0^2)^2.$$

Or

(*a*) How does a charged particle interact with a gas medium ? In the same context explain the following in detail :

(*i*) Different modes of the gas detectors.

(*ii*) Production of space charge region in a G.M. tube and show its effect on dead time and paralysis time of a G.M. counter.

(*b*) The paralysis time of a G.M. tube is 400 μsec. Calculate the true count rate for measured count rate of 100 and 1000 counts per minute.

5. (*a*) Draw a logic circuit for full adder and summarize its action in a tabular form.

(*b*) Draw a diagram for transistorised R.S. flip-flop and explain its working principle with truth table.

Or

Obtain an expression for the frequency of the vibrational modes of a diatomic linear lattice.

Or

(*a*) Explain with the help of energy level diagram, the basic principle of nuclear magnetic resonance and derive the condition for magnetic resonance absorption.

(*b*) Draw a schematic arrangement for the study of nuclear magnetic resonance in laboratory. Label all the part of the arrangement.

Or

(*a*) With suitable example explain the meaning of the following terms used for the particles :

(*i*) Lepton

(*ii*) Muon number

(*iii*) Fermion

(*iv*) Boson

(*v*) Electromagnetic interaction.

(*b*) Based on the additive quantum numbers such as strangeness, baryon number and charge of the particles indicate with reasons whether the following nuclear reactions can be induced or not :

(*i*) $\Pi^- = p + \wedge^o + k^o$

(*ii*) $\Pi^- + n \rightarrow \Pi^- + p + k^o$

(*iii*) $\Sigma^+ + n \rightarrow \Sigma^\circ + p$

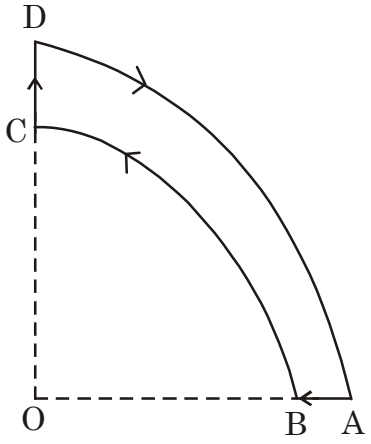
SECTION III

Instructions :—In this section you have to answer all questions (Q. No. **6** to Q. No. **14**). Each question carries **10** marks.

6. Write the Laurent series expansion of $\frac{e^z}{(z-1)^2}$ about $z = 1$. Also state the pole and its order of this function. What is the residue at the pole ?

7. Two identical simple pendulums, each of length 0.5 m, are connected by a light spring. The force constant of the spring is 2 N/m and the mass of each bob is 0.1 kg. If one pendulum is clamped, calculate the period of other pendulum. When the clamp is removed, determine the periods of two normal modes of the system (g = 9.8 m/sec^2).

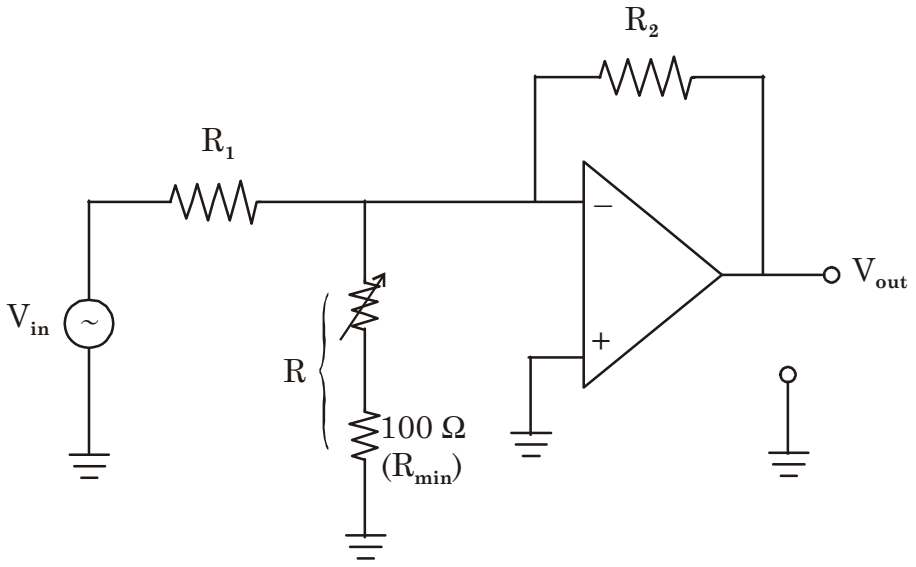
8. Steady state current I flows through a loop ABCDA. BC and DA are circular arcs of radii a and b respectively and have center at O. AB and CD are segments of lines intersecting in O. Find magnetic field produced at the point O.



9. For the angular momentum operator $\vec{L}$, show that $\vec{L} \times \vec{L} = i\hbar \vec{L}$.

10. The atomic weight of sodium is 23 and the density of the metal is 0.95 gm/cc. There is one conduction electron per atom. Obtain the Fermi energy in eV.

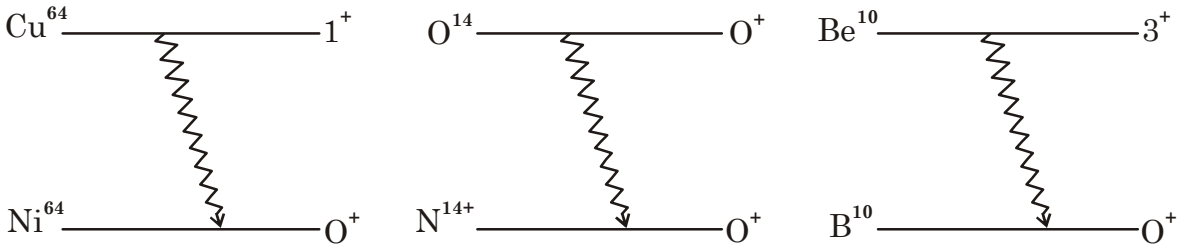
11. In the adjustable-bandwidth circuit of the following figure, R_1 = 10 kΩ and R_2 = 180 kΩ. If the 100 Ω resistor is changed to 130 Ω and the variable resistor to 25 kΩ, what is the voltage gain ? What are the minimum and maximum bandwidth if f_{unity} = 1 MHz ?



12. The ground state of chlorine is $^2P_{3/2}$. Obtain the magnetic moment. Calculate the number of substates into which the ground state will split in a weak magnetic field.

13. Discuss flux quantization in a superconducting ring, and show that the total magnetic flux that passes through this ring is quantized in integral multiples of $2\pi\hbar c/q$.

14. Clarify the following decay mode in the category of type of decay, allowed, forbidden, fermi or Gamow-Teller transition.



(*a*) (*b*) (*c*)

SECTION IV

Instructions :—In this section you have to answer all questions (Q. No. **15** to Q. No. **19**). Each question carries **5** marks.

15. Draw the logic circuit for the Boolean equation $Y = \bar{A}B + A\bar{B}$. Write the truth table for the same.

16. Given the equivalent force constant C of a vibrating HCl molecule is 470 nt/m, estimate the energy difference between the lowest and the first vibrational states of HCl.

17. Estimate the weight of Cs-137 radioisotope in gm, if the total number of gamma rays emitted over 4Π geometry is 1000 per second. The half life of Cs-137 is 30 years.

18. For what value of relative refractive index of medium 2 to medium 1, one will have the coefficient of reflection (R) equal to the coefficient of transmission (T) for normal incidence at the interface between medium 1 and medium 2 ?

19. A free particle is in a state (unnormalized)

$$\phi(x) = e^{ikx} + e^{-2ikx} + e^{3ikx}$$

Calculate the energy of the particle in units of $\hbar^2k^2/2m$.

ROUGH WORK

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