UNIVERSITY OF NORTH BENGAL

B.Sc. Honours Part-III Examination, 2022

PHYSICS

PAPER-VII

Time Allotted: 4 Hours   Full Marks: 90

The figures in the margin indicate full marks.
All symbols are of usual significance.

Answer question No. 1 and *five* from the rest,
taking at least *one* each from Group-A and Group-B and at least *two* from Group-C

1. (a) A particle of mass m is acted on by a force $F = -\lambda x^2$. Show that the quantity $U = \frac{1}{2}mv^2 + \frac{1}{3}\lambda x^3$ is a constant of motion. — 3

   (b) The atomic weight of lithium is 6.94 a.m.u. and its density is 0.53 gm/cm^3. Calculate the Fermi energy and Fermi temperature of the electron. — 3

   (c) How many flip-flops are required to build a counter that counts from 0 to 1023? — 3

   (d) Sketch the Fermi-Dirac distribution function at $T = 0\,\text{K}$ and at two other finite temperatures T_1 and T_2, where $T_2 > T_1$. — 2

   (e) Find the output voltage of the circuit given below: — 4
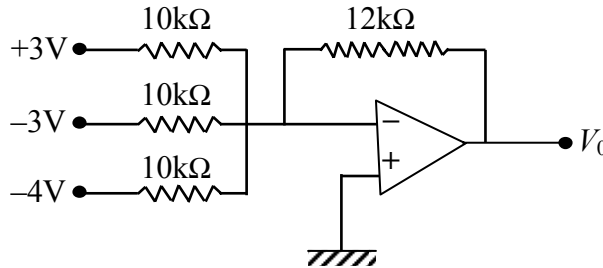
GROUP-A

(CLASSICAL MECHANICS-II AND FLUID MECHANICS)

2. (a) Deduce Euler's equation of motion for a non-viscous fluid and hence prove Bernoulli's theorem for an incompressible and irrotational fluid. — 8

   (b) Prove the following Poisson bracket relations: — 2+2
   (i) $[q_i, q_k] = [p_i, p_k] = 0$
   (ii) $[L_x, L_y] = L_z$
   where the notations have their usual meaning.

(c) Show that a small displacement of a body from its stable equilibrium position results in a simple harmonic motion. 3

3. (a) Define the Hamiltonian of a system when is it equal to the total energy of the system. When is it conserved? 6

(b) Set up the Hamiltonian and the equations of motion for a system with the Lagrangian $L = \frac{1}{2}\alpha \dot{q}^2 - \frac{1}{2}\beta q^2$ where α, β are constants. 4

(c) A tube has diameters of 2 cm at one place and of 1 cm at a level 40 cm below the first. The rate of flow of water through the tube per second is 30 c-c . What is the pressure difference between the two levels in cm of water? [Assume a streamline flow of water.] 3

(d) Write down the Navier-Stokes equation and explain the terms involved in it. 2

4. (a) Deduce the eigenvalue equation for a small oscillation. 4

(b) Show that if the Hamiltonian and a quantity G are constants of motion, then $\frac{\partial G}{\partial t}$ must also be constant. 4

(c) State Hamilton's variational principle. Deduce Lagrange's equation of motion from the variational principle. 2+5

GROUP-B
(STATISTICAL MECHANICS)

5. (a) Explain the terms 'phase-space' and 'ensemble'. Distinguish between different types of ensembles. 2+4

(b) What are the physical arguments that lead to three different statistical distribution functions (MB, FD and BE)? Write down the three distribution formulae and explain all the terms present. Plot the above distribution functions against single particle energy at a given temperature. 3+3+3

6. (a) Deduce Einstein's formula for the specific heat of solids. Discuss how far it agrees with the experimental results at low temperatures. Show that the formula yields the Dulong and Petit's law at high temperature. 5+2+2

(b) Show that the average energy of an electron in a metal at $T = 0$ K is $\frac{3}{5}E_f$, where E_f is the Fermii energy at $T = 0$ K . What is the physical significance of Fermi energy of a semiconductor? Explain your answer. 4+2

GROUP-C
(ELECTRONICS-II)

7. (a) What are the advantages of a FET over a BJT? Draw the circuit diagram of a common source amplifier circuit and derive an expression for the voltage gain. 2+4

(b) Explain the meaning of class-A, class-B, class-C as applied for the power amplifiers. 3

(c) Show that in an R–C coupled amplifier the bandwidth increases with negative feedback but the gain bandwidth product remains unchanged. 4

(d) Define the terms 'bandwidth' and 'Q-factor' of a single tuned amplifier. 1+1

8. (a) What is Barkhausen criterion? Obtain the conditions for sustained oscillations, and the frequency of oscillation in a Hartley oscillator. 1+7

(b) Define modulation. Name the different types of modulation. What is modulation index? 1+1+1

(c) Draw the circuit diagram of a series voltage regulator using two transistors and a Zener diode, and explain its operation. 1+3

9. (a) What is a half-adder? Construct a half-adder using only NAND gates. Show that a full-adder can be constructed by using two half-adders and one OR gate. 1+2+3

(b) What is flip-flop? Explain the importance of flip-flops in digital systems. Draw the logic circuit of an R–S flip-flop using NAND gates and write down its truth table. 1+1+2+2

(c) Consider two 1-bit numbers A and B. What are the logic gates required to test for— 1+1+1

      (i) $A = B$;

      (ii) $A > B$;

      (iii) $A < B$?

10.(a) What is a D/A converter? Explain the principle of operation of a ladder converter. 1+6

(b) Derive the expression for the voltage gain of an inverting amplifier using an OPAMP. 3

(c) What is meant by a shift register? Explain the operation of a 4-bit shift-register. 1+4

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