Civil Services (Main) Examination, 2003

PHYSICS

(Paper I)

Time Allowed : Three Hours **Maximum Marks : 300**

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.
Candidate has to attempt FIVE questions in all.
Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Attempt any three of the following: **20×3=60**

(a) A block of mass m, attached to an ideal massless spring of force constant k, is at rest on a smooth horizontal floor. A second block of mass 2 m, moving with an initial velocity strikes the free end of the spring. The collision is one dimensional and elastic. (i) Calculate the maximum compression of the spring. (ii) What are the velocities of the block long time after the collision?

(b) An observer S_1 sees two bodies A and B having equal rest mass approach each other with equal but opposite velocities 4c/5. To a second observer S_2, the body A is at rest. What is the velocity of the body B as seen by observer S_2? What are the kinetic energies of the body B in the frames of S_1 and S_2?

(c) Two transverse harmonic waves, each of amplitude 5mm, wavelength 1m and speed 3 m/s are travelling in opposite directions along a stretched string fixed at both ends. Obtain an expression for the standing wave Produced. Locate the position at the nodes and antinodes.

(d) Two thin convex lenses of focal length 0.2 m and 0.1 m are located 0.1m apart on the axis of symmetry. An object of height 0.1m is placed at a distance of 0.2 m from the first lens. Find by the matrix method, the position and the height of the image.

2. (a) Write the Euler's equations for the rotational motion of a rigid body with one point fixed, under the action of torque N. Apply these equations to discuss the rotational motion of a symmetrical top in the absence of any force other than the reaction at the fixed point. **30**

(b) An ideal massless spring of force constant k has a mass m attached to one of its ends, the other and being fixed to a rigid support. The spring is horizontal floor, A resistive force $-bv$, proportional to the velocity v acts on the mass. Assuming the damping to be light, obtain the frequency of oscillation. When m=0.1 kg and k=10 N/m, it is found that the frequency of oscillation is $\sqrt{(1/2)}$ times the frequency in the absence of damping. Calculate the value of the constant b. **30**

3. (a) Write the Lagrange's equation for a system of particles which is acted upon by Conservative forces. What is a cyclic coordinate? Show that the generalized momentum conjugate to a cyclic coordinate is conserved. **20**

(b) How does Doppler effect of light of relativistic physics qualitatively differ from its non-relativistic analogue? Calculate the Doppler shift in the frequency of a photon travelling along the y-axis. with respect to an observer moving along the x-axis with a constant speed **20**

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v.

(c) Explain the phenomenon of pulse dispersion in a step index optical fibre. **20**

4. (a) What is holography? Describe the experimental set up for Gabor's on-line holographic recording. What are the limitations of Gabors experiments? How these were over come by Leith and Upatneiks? **20**

(b) Obtain an expression for the intensity of light in the Fraunhofer diffraction pattern due to a circular aperture. What is Airy pattern? Explain with a neat diagram. **20**

(c) Explain the phenomenon of self focusing of laser beams. **20**

SECTION 'B'

5. Answer any three of the following

20×3=60

(a) A cylinder of length L and radius b has its axis coincident with z-axis. The electric field in the region is $E=100k$. Find the electric flux through (i) the top circular end (ii) the bottom circular end (iii) the curved wall of the cylinder (iv) the closed surface of the cylinder

(b) A bridge network with resistance, capacitance and inductance is given in the above figure. Show that the conditions for balancing the bridge are independent of the frequency of applied voltage.

[Figure: Printed before the text: a four-arm bridge drawn as a diamond. Upper-left arm: an inductor labelled L_x in series with a resistor R_1, from the left node to the top node; upper-right arm: resistor R_2, from the top node to the right node; lower-left arm: capacitor C_3, from the left node to the bottom node; lower-right arm: capacitor C_4, from the bottom node to the right node. A detector (labelled "Detector") is connected between the top and bottom nodes. An a.c. source (circle with ~) is connected through the outer rectangular loop between the left and right nodes. No component values are given.]

(c) Earth receives 1.3 KW/m^2 of radiant energy from the Sun. Assuming Sun to be a spherical black body of radius 7×10^8m and Earth-sun distance to be 1.5×10^{11}m, Calculate the surface temperature of Sun. (Stefan-Boltzmann constant $\sigma=5.67\times10^{-8}$ Wm^{-2}K^{-4}).

(d) 100 particles at a temperature T and distributed among three energy levels $E_0=0$, $E_1=kT$ and $E_2=2kT$. What is the total energy of the system?

6. (a) Consider an infinite grounded conducting plane. If a point charge is held at a distance d from the plane, compute by method of images, the electric potential above the plane and the induced charges on the conductor. **20**

(b) Define Poynting vector and explain its significance. The electric field vector for an electromagnetic field travelling in vacuum is given by

$$\mathbf{E}=E_0\cos(kz-\omega t)\,\hat{\imath}$$

Calculate the Poynting vector for the wave and show that its magnitude is equal to the energy density of the wave time the velocity of light. **20**

(c) A parallel LC circuit is operated at a frequency ω, which is less than the resonant frequency ω_0 of the LC circuit. Explain whether the reactance is inductive or capacitative.

[Figure: Printed before the text: an inductor L (top branch) and a capacitor C (middle branch) connected in parallel between two vertical side wires, fed by an a.c. source (circle with ~) in the bottom branch.] **20**

7. (a) What is Laplace equation? Determine the average electric potential over a spherical surface, due to a point charge q placed at a distance r from the centre of the sphere. Assume r to be greater than the radius of the sphere. **30**

(b) A plane wave of frequency ω, which into two linear dielectric media. It has a normal incidence at the interface of the media. Giving appropriate for the intensities of reflected and transmitted rays. **30**

8. (a) Two bodies A and B have the same mass m each and are made of the same material with specific heat C per unit mass. A is at a temperature T and B is at a temperature 4T. What **20**

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will be the entropy change of the universe when the bodies are brought into diathermic contact with each other?

(b) Describe the Otto cycle and obtain an expression for the efficiency of the cycle, Show that the efficiency is lower than that of a Carnot cycle operating between the highest and the lowest temperature of Otto cycle. **20**

(c) Define Fermi energy. For an ideal Fermi gas of N particles at absolute zero temperature, show that the total energy of is 3/5 NE_F, where E_F is the Fermi energy. **20**

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