

COMBINED COMPETITIVE EXAMINATION (MAIN)

PHYSICS

Paper-I

Time : 3 Hours

Full Marks : 200

Note : (1) The figures in the right-hand margin indicate full marks for the questions.

(2) Attempt five questions in all.

(3) Question No. 1 is compulsory.

(4) The symbols used in the question paper have their usual meanings.

(5) Relevant constants and their approximate values for use in the calculation:

Velocity of light, $c = 3 \times 10^8$ m/sec; Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8} \text{Wm}^{-2}\text{K}^{-1}$

Room temperature, $T_0 = 300$ K; Radius of Earth, $R_0 = 6400$ km;

Acceleration due to gravity, $g = 10$ m/sec².

1. Answer any *ten* questions from the following : 4×10=40

- (a) Describe the conditions for the conservations of linear momentum and angular momentum of a moving body.
- (b) Calculate the Coriolis force experienced by a particle of unit mass moving with velocity vector $\vec{v} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ in the frame rotating with angular velocity $\vec{\omega} = 3\hat{k}$.
- (c) What are the distinctive features of the laboratory frame of reference and centre of mass frame of reference?
- (d) Can the second law of thermodynamics be related to the concept of entropy?
- (e) State the basic assumptions in the development of the kinetic theory of gases.
- (f) The phase velocity and the group velocity of waves can be different. How?
- (g) Define scattering cross-section. State its unit of measurement.
- (h) Is the interference phenomenon equivalent to the diffraction by double slits? Explain.
- (i) "The resolving power of an optical instrument is x mm." Explain the statement.

- (j) What is meant by solar constant? State if it varies during the course of the day.
- (k) Discuss the conditions for a streamline motion of fluids to become turbulent.
- (l) State the basic postulates of the special theory of relativity.

2. Answer any **eight** questions from the following : 5×8=40

- (a) Check if the force vector $\vec{F} = x^2\hat{i} + y^2\hat{j} + z^2\hat{k}$ represents a central force.
- (b) Give an interpretation of temperature in the kinetic theory of gases.
- (c) What is a gyroscopic motion?
- (d) A hollow iron pipe is more difficult to twist compared to a solid iron rod of the same mass and length. Why?
- (e) How much thermal energy will be radiated by a blackbody per unit surface area at a temperature of 350 K?
- (f) In the Rutherford experiment, most of the alpha particles could be detected behind the gold foil. Why?
- (g) What happens to the interference pattern, when a white light is used in the Newton ring experiment?
- (h) What is Debye temperature?
- (i) State the differences between resonance and beat formation.
- (j) Calculate the energy available on conversion of 1 gm of a given rest mass.

3. Answer any **five** questions from the following: 8×5=40

- (a) "The rocket motion is essentially different from the motion of a rigid body". Justify the statement.
- (b) Geostationary satellites move round the earth at an altitude of about 36000 kms. Why?
- (c) State and explain Joule-Kelvin effect.
- (d) Out of the isothermal and adiabatic processes, which process is related to the curve with greater slope in the PV diagram? Why?
- (e) Explain the different quantities involved in the propagation of a wave represented by the wave equation $\frac{d^2(100y)}{dx^2} - \frac{d^2y}{dt^2} = 0$
- (f) Describe the behaviour of a polarized light wave with suitable diagram.

4. Answer any *four* questions from the following: 10×4=40
- A body moving with speed 1 m/s, collides with another body of equal mass at rest. If the bodies stick together on collision, find the speed of the body after the collision.
 - Explain the role of equipartition theorem in finding the specific heat of solid bodies.
 - What is the colour of the central fringe in the Newton ring interference experiment?
 - Show that under low velocity assumption, the results of Lorentz Transformation reduce to Galilean Transformation laws.
 - Illustrate how adiabatic demagnetization can be used to achieve low temperature.
5. Answer any *two* questions from the following : 20×2=40
- Establish that the sum of the kinetic energy and the potential energy of a particle executing simple harmonic motion is always a constant.
 - A body moves with relativistic velocity such that the mass of the body is twice its rest mass. Calculate the velocity of the moving body.
 - The relation between the heat capacities for an ideal gas is given $C_p - C_v = R$.
If $\frac{C_p}{C_v} = \gamma$, show that under adiabatic conditions, the gas law is given by $PV^\gamma = \text{Constant}$.
6. Answer any *four* questions from the following : 10×4=40
- A constant torque of 10N-m is applied to a body for 5 seconds, raising its angular momentum to 80 kg m²/sec. Find the initial angular momentum of the body.
 - Illustrate the different stages of a Carnot cycle for adiabatic change.
 - Describe Planck's radiation formula and establish Wien's displacement law.
 - How can unpolarized beams of light be transformed to circularly polarized and elliptically polarized light?
 - Describe the principle of Holography. Draw a neat diagram of the holographic process.
7. Answer any *two* questions from the following: 20×2=40
- How are Kepler's laws of planetary motion deduced from Newton's laws? Comment, if the Kepler's laws of planetary motion can be applied universally.
 - Describe the light amplification and population inversion in lasers. Discuss Ruby laser as an optically pumped solid state laser.
 - Discuss the Fraunhofer class of diffraction of a monochromatic light by a single slit. What will happen when white light is used for such diffraction?

8. Answer the following questions : 40
- (a) An artificial satellite is placed at a height of 660 km above earth's surface. Calculate the orbital speed and the frequency of revolution of the satellite round the earth.
 - (b) For steady motion of fluids, obtain Bernoulli's equation. Explain the vertical lift of an aeroplane in terms of Bernoulli's equation.
9. Answer the following questions : 40
- (a) Which thermodynamical quantities are related by the Clausius-Clapeyron equation? Obtain Clausius-Clapeyron equation from the second law of thermodynamics.
 - (b) What are Maxwell's relations in thermodynamics? Deduce Maxwell's relations from the first and the second law of thermodynamics.
10. Answer the following questions : 40
- (a) Deduce the equation for a damped harmonic oscillator and find the condition for critically damped motion.
 - (b) What is a grating? Discuss the Rayleigh criterion for the resolving power of a grating.

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