(Time: 3 hours) **(Total Marks: 100)**

N.B : (1) All questions are compulsory.
(2) Figures to the right indicate maximum marks.
(3) Use of non-programmable calculators is permitted.
(4) Symbols used have their usual meaning

Q1. A) Select correct answer **(12)**

1 A body is moving in a circular orbit. Its angular momentum at a point is
a) radial b) tangential c) perpendicular to the plane of orbit
d) in the plane of orbit

2 The time in which the amplitude of a damped harmonic oscillator decays to 1/e of its original value is called
a) time period b) damping time c) relaxation time d) none of the above

3 A heat engine absorbs heat at 1000 K and rejects heat at 600 K. If the engine operates at maximum possible efficiency the work done by the engine at 2000 J input is
a) 1600 J b) 1200 J c) 800 J d) 400 J

4 The thermal efficiency of all reversible engines working between the same two temperature limits are
a) the same b) different c) zero d) 100%

5 A diesel engine has compression ratio from
a) 6 to 10 b) 10 to 15 c) 15 to 20 d) 25 to 40

6 In Joule-Thomson effect, if $\frac{2a}{RT} - b$ is positive then after expansion, the temperature
a) decreases b) stay constant c) increases d) becomes zero

B) Answer in one sentence **(03)**

1 State the expression for displacement of damped harmonic oscillator.
2 Give the property used to define the Kelvin's absolute scale of temperature.
3 What is the entropy of an ideal crystal at absolute zero temperature?

C) Fill in the Blanks **(5)**

1 An oscillator returns to its equilibrium state in the shortest time when it is _____
2 Time period of a compound pendulum about centre of suspension and centre of oscillation is _____

3 The _____ is a system operating in a cyclic process that converts heat into work

4 If two or more engines operate between the same source but different sinks the one operating with the highest temperature difference will have the _____ efficiency.

5 In Otto engine _____ is used as a working substance.

Q2. A) Attempt any one **(8)**

1 Show that energy of a damped harmonic oscillator decreases exponentially with time as $E(t) = E(0)e^{-2rt}$.

2 State the expression of amplitude and phase angle in steady state term of forced damped harmonic oscillator. Discuss amplitude and phase at various driving frequencies.

B) Attempt any one **(8)**

1 What is meant by internal and external forces? Derive law of conservation of linear momentum for a system of particles clearly mentioning the assumptions made.

2 Obtain the expression of time period for compound pendulum. Hence obtain the minimum and maximum time period for it.

C) Attempt any one **(4)**

1 Three particles in a system have position vectors in metres specified by $\overrightarrow{r_1} = 3t\hat{\imath} + 4\hat{\jmath} + 2\hat{k}, \overrightarrow{r_2} = 3\hat{\imath} + 6t\hat{\jmath} + 6\hat{k}$ *and* $\overrightarrow{r_3} = \hat{\imath} + \hat{\jmath} + \hat{k}$. If the masses of the particles are 2 kg each, find the centre of mass of the system.

2 Write a short note on Quality Factor of damped harmonic oscillator.

Q3. A) Attempt any one **(8)**

1 State the Clausius theorem and prove it.

2 Draw the p – V diagram of a Carnot cycle and explain each of the four stages

B) Attempt any one **(8)**

1 Obtain expressions for entropy change in an ideal gas in different processes.

2 Show that the Kelvin – Planck and Clausius statements of second law of thermodynamics are logically equivalent.

C) Attempt any one **(4)**

1 Explain why it is not possible to have negative temperatures on the thermodynamic scale of temperature.

2 Calculate the change in entropy if 10 g of water is heated from 313 K to 353 K. Given:- specific heat of water = 1 cal/g - K

Q4. A) Attempt any one **(8)**

1 What is Joule-Thomson effect? Explain the theory behind the porous plug experiment and show that it is an isenthalpic process.

2 State third law of thermodynamics. Explain any two consequences of it.

B) Attempt any one **(8)**

1 Using Maxwell's equations derive the Clausius-Clapeyron's equation and discuss the effect of pressure on the boiling point and melting point of a substance.

2 With the help of PV diagram explain the step by step working of a diesel engine.

C) Attempt any one **(4)**

1 Using Maxwell's thermodynamic relation, show that for a perfect gas $\left(\frac{\partial U}{\partial V}\right) = 0$

2 Calculate the inversion temperature of hydrogen and helium if the critical temperature of hydrogen and helium are 29 K and 5.2 K respectively.

Q5. Attempt any Four **(20)**

1 What is centre of oscillation and centre of suspension for compound pendulum? Show that time period about them are equal.

2 Show that resonance in a forced damped harmonic oscillator occurs at a frequency slightly less than natural frequency.

3 From the expression for efficiency of a Carnot engine show that lowering the temperature of the sink is more effective in increasing its efficiency.

4 Write a short note on reversible processes.

5 Distinguish between Otto engine and Diesel engine.

6 Calculate under what pressure water will boil at 110°C, if the change in specific volume when 1 gram of water is converted to steam is 1676 cm^3. (Given:- Latent heat of steam = 540 cal/g, J = 4.2 x 10^7 ergs/cal and 1 atm pressure =10^6 dyne/cm^2)

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