1. Explain the importance of Free Body Diagrams (FBD) in Engineering Mechanics. Discuss common errors and their consequences. (5 Marks)

2. Explain the Principle of Virtual Work. Discuss its significance and applications in mechanics. (5 Marks)

3. Explain the structure of solids. Differentiate between crystalline and amorphous solids with engineering relevance. (5 Marks)

4. Explain defects in crystalline materials. Discuss their types and influence on material properties. (5 Marks)

5. Explain plastics, ceramics and composites. Compare their advantages and limitations. (5 Marks)

6. Explain Poisson's ratio. Discuss its physical meaning and limits. (5 Marks)

7. Explain Shear Force and Bending Moment diagrams. Why are they important? (5 Marks)

8. Explain deflection of beams. Why must it be controlled? (5 Marks)

9. Using the relative velocity method, obtain expressions for velocity and acceleration of the slider in a slider — crank mechanism. Briefly explain the effect of connecting rod obliquity on acceleration and inertia forces. (5 Marks)

10. State and explain the law of gearing. With reference to involute gears, explain interference and list two methods to avoid it. (5 Marks)

11. Derive the expression for magnification factor of a damped Single Degree of Freedom (SDOF) system under harmonic force. Explain the significance of damping near resonance. (5 Marks)

12. Define gyroscopic couple and derive its expression. Explain the effect of gyroscopic action on a ship during pitching. (5 Marks)

13. Explain the Soderberg and Goodman fatigue failure criteria. Comment on their relative conservatism. (5 Marks)

14. Explain the S–N curve and define endurance limit. List and briefly explain any three factors affecting endurance strength. (5 Marks)

15. Outline the design procedure of a transmission shaft subjected to combined bending and torsion using an appropriate failure theory. (5 Marks)

16. The compression and expansion process of a gas in a piston – cylinder device has been observed to satisfy the relationship $PV^n = C$, where n and C are constants. Calculate the work done when a gas expands from an initial pressure 100 kPa and initial volume 0.01 m^3 to a final volume of 0.1 m^3 for the case of n = 2. (5 Marks)

17. An engine operating on a thermodynamic cycle receives heat from a source at 1200 K and rejects heat to a sink at 300 K. The engine needs to develop a power output of 12.5 kW. The heat input is 10 kJ per cycle. Determine the minimum number of cycles per minute required for delivering the power output. (5 Marks)

18. How does an increase in compression ratio affect the performance of a cold air standard Otto cycle? (5 Marks)

19. What are the advantages of regeneration using open feed water in a steam power plant? (5 Marks)

20. The single-stage compression process of an ideal Brayton cycle without regeneration is replaced by a multi-stage compression process with intercooling between the same pressure limits. List any two effects of this modification on the performance of the cycle. (5 Marks)

21. Consider a 5-kg copper cube and a 4-kg copper ball submerged in a liquid. Will the buoyant forces acting on these two bodies be the same or different? Explain. (5 Marks)

22. The drag force **F**, on a smooth sphere depends on the relative speed **V**, the sphere diameter **D**, the fluid density ρ and the fluid dynamic viscosity, μ. Obtain a set of dimensionless groups that can be used to correlate experimental data. (5 Marks)

23. A gas initially at a supersonic velocity enters an adiabatic converging duct. Discuss how this affects

    (a) the velocity,

    (b) the temperature,

    (c) the pressure and

    (d) the density of the fluid. (5 Marks)

24. Some engineers are evaluating potential sites for a small hydroelectric dam. At one such site, the gross head is **500 m** and they estimate that the volume flow rate of water through each turbine would be **2.0 m^3/s**. Estimate the ideal power production per turbine in MW (mega Watt). Acceleration due to gravity, **g = 10.0 m/s^2.** Also give one example for Impulse and Reaction turbines. (5 Marks)

25. Derive an expression for temperature distribution and heat transfer through a rectangular fin with length **"L"**, Width **"W"** and thickness **"t"** with following boundary condition. **T** is the temperature. Consider steady one-dimensional approach.
    At $x = 0$, $T = T_b$ (Temperature at one end, base temperature)

    At $x = L$, *tip of the fin is insulated*, $\frac{dT}{dx} = 0$. (5 Marks)

26. Consider heat transfer between two identical hot solid bodies (same material and dimensions) and their environments. The first solid is dropped in a large container filled with water, while the second one is allowed to cool naturally in the air. For which solid is the lumped system analysis more likely to be applicable? Why? (5 Marks)

27. Under what conditions is the effectiveness – NTU method preferred over the LMTD method in heat exchanger analysis? Is a heat exchanger with a very large NTU (say, 10) necessarily a good one to buy? Justify. (5 Marks)

28. Atmospheric air at a flow rate of 3 kg/s (on dry basis) enters a cooling and dehumidifying coil with an enthalpy of 85 kJ / kg of dry air and a humidity ratio of 20 grams/kg of dry air. The air leaves the coil with an enthalpy of 45 kJ / kg of dry air and a humidity ratio of 10 grams/kg of dry air. If the condensate water leaves the coil with an enthalpy of 70 kJ / kg. Determine the required cooling capacity of the coil in kW. (5 Marks)

29. Two aluminium castings of equal volume are produced in the same mould material. One casting is cylindrical and the other is cubical in shape. Using Chvorinov's rule, predict which casting will solidify faster.
Metal Casting Principles T.V. Ramana Rao, New Age International Publishers. (5 Marks)

30. A ductile material is subjected to the following plane stress state :

$$[\sigma_{ij}] = \begin{bmatrix} 40 & 30 & 0 \\ 30 & 40 & 0 \\ 0 & 0 & 0 \end{bmatrix} \text{ MPa}$$

(a) Determine the principal stresses.

(b) Find the minimum uniaxial yield stress required to prevent yielding according to Tresca yield criterion.

Mechanical Metallurgy, George E Dieter, Mc Graw - Hill series in Material Science and Engineering. (5 Marks)

31. For a machining operation, the tool life is governed by Taylor's tool life equation: $VT^n = C$
It is observed that when the cutting speed is reduced to half, the tool life increases by 300%.

If the tool life at a cutting speed of 20 m/min is 256 minutes, determine the values of the tool life exponent n and the constant C.

Serope Kalpakjian & Steven Schmid, Manufacturing Engineering and Technology, Pearson. (5 Marks)

32. A cutting tool material for continuous turning of a hardened alloy steel component at high production rates has to be selected. The operation involves high cutting speeds, elevated interface temperatures, and intermittent vibration due to machine tool limitations.
Compare High Speed Steels (HSS), Cemented Carbides, and Ceramic tools with respect to :

(a) Operating temperature

(b) Cutting speed suitability

(c) Brittleness and toughness

Based on the comparison, select a suitable tool material and justify your answer

Serope Kalpakjian & Steven Schmid Manufacturing Engineering and Technology, *Pearson.* (5 Marks)

33. Compare NC and CNC machines with respect to

(a) Program storage and editing

(b) Feedback and control system

(c) Flexibility in batch production

M.P. Groover, *Fundamentals of Modern Manufacturing*, *Pearson.* (5 Marks)

34. The main scale of a vernier caliper is graduated in millimetres, with the smallest division being 0.5 mm. Twenty divisions on the vernier scale correspond to 19 divisions on the main scale.
Answer the following :

(a) Is the vernier scale a forward vernier or a backward vernier?

(b) What is the least count of the instrument?

(c) If the main scale reads 25 mm and the 12^{th} division on the vernier scale coincides with a division on the main scale, what is the value of the dimension being measured?

N.V. Raghavendra & L. Krishnamurthy, Engineering Metrology and Measurements, Oxford University Press. (5 Marks)

35. Explain the fundamental difference in the measurement principles between a mechanical comparator and an electronic comparator. Discuss how the difference affects :

(a) Sensitivity and resolution

(b) Response to high-frequency vibration in production conditions

(c) Integration with automated inspection systems

N. V Raghavendra & L. Krishnamurthy, Engineering Metrology and Measurements, Oxford University Press. (5 Marks)

36. **Production Planning and Control**

The demand values of an item for the past six periods are as follows. Prepare four period simple moving average forecast for the inventory system for the periods 5 through 7. Compare these forecast values with the actual demand for the periods 5 and 6 as

(a) Deviation and

(b) Absolute deviation and find their mean values.

If the forecasts are made as weighted moving average by taking weights 0.4, 0.3, 0.2 and 0.1 with more weight to the recent demand value, what are the forecast values for the above periods? What are the error values found out above?

Demand values are: 110, 120, 110, 120, 110 and 120 respectively.

(5 Marks)

37. **Operations Scheduling**

In a project network of activities, the critical duration is observed as 136 days. The critical path duration has been determined on the assumption that the durations are deterministic. However, it has been observed that there is a likely deviation from this duration with a variance of 16 days.

A quote for the project was submitted by a firm for 140 days. With what expected probability the project can be completed within this quoted duration?

If a probability of 0.10 for the delay in the project duration can lead to an excess cost of 1% of the quoted amount, what will be the expected income form the project as the percentage of the quoted amount? Use normal approximation for the project duration. Also, approximate the area under the normal curve within ±1 standard deviation as 68%, ±2 standard deviation as 95% and ±3 standard deviation as 99.7%. (5 Marks)