S4 Design and Applied Technology Practice Paper (Set 2): Structures and Loads, Mechanical Drives, Stress and Strain, Electronic Circuits, Energy and Power, Product Specification and Production Cost

S4 | Design and Applied Technology | Time: 75 minutes | Total: 100 marks | 24 questions

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Part A - Structures and Loads (16 marks)

Show the formula or working and state the units.

1. A simply supported beam of span 4.0 m carries a uniformly distributed load of 12 kN/m and a point load of 24 kN at mid-span. Find the total load on the beam and the reaction at each support (the beam is symmetric). [4]

2. A cantilever 2.5 m long carries a downward point load of 6 kN at its free end (self-weight neglected). Find the bending moment at the fixed end and state which face is in tension. [4]

3. A bracket fails at a load of 90 kN and is designed to carry a working load of 36 kN. Find the factor of safety and explain why a value greater than 1 is required. [4]

4. A beam deflects 9 mm under an 18 kN load. Assuming linear elastic behaviour, find the deflection when the load rises to 27 kN, and state whether the proportion still holds beyond yield. [4]

Part B - Mechanical Drives (17 marks)

Use the speed-ratio relations for gears and belt drives, with units.

5. A driving gear with 60 teeth runs at 900 rev/min and drives a 20-tooth gear. Find the ratio and the output speed, and state whether the drive steps up or down. [5]

6. A 150 mm diameter pulley runs at 400 rev/min and drives a 300 mm pulley by belt. Find the driven speed. [4]

7. A lead screw has a pitch of 2.5 mm. Find the travel of the nut for 40 turns, and state what happens if the pitch becomes 5 mm with the same number of turns. [4]

8. A belt runs on a pulley of diameter 0.20 m turning at 600 rev/min. Find the belt speed (take pi = 3.14159, 2 decimal places). [4]

Part C - Stress and Strain (17 marks)

Give stress in N/mm2 (MPa) and state the formula used.

9. A member of cross-sectional area 250 mm2 carries a tensile load of 20 kN. Find the tensile stress. [4]

10. The same member is made of a material with Young modulus 200 000 N/mm2 and has a gauge length of 500 mm. Find the strain and the extension of the gauge length. [5]

11. An aluminium alloy part has a mass of 2.7 kg and a volume of 1.0 x 10^-3 m3. Find its density and explain why light materials are preferred for car parts. [4]

12. A steel sheet measures 1.2 m x 2.4 m x 3 mm and the density of steel is 7850 kg/m3. Find the volume and the mass (to 0.001 kg). [4]

Part D - Electronic Circuits (17 marks)

State the formula used; give current in A or mA and power in W.

13. Three resistors of 220 ohm, 330 ohm and 450 ohm are connected in series across a 12 V supply. Find the total resistance, the current and the voltage across the 330 ohm resistor. [5]

14. A 240 ohm resistor is connected across 12 V. Find the current through it and the power it dissipates, and explain why the power appears as heat. [4]

15. A potential divider has 8 kohm and 4 kohm in series across 12 V, with the output taken across the 4 kohm resistor. Find the output voltage. [4]

16. A 300 ohm resistor is connected in parallel with a 600 ohm resistor. Find the equivalent resistance and explain why it must be smaller than either resistor. [4]

Part E - Energy and Power (17 marks)

Give energy in kWh or kJ and show the working.

17. An extractor fan rated 1.5 kW runs 4 hours a day for 30 days. Find the monthly energy use in kWh and the electricity cost at 1.2 dollars per kWh. [5]

18. A motor takes 2.0 kW of input power and delivers 1.6 kW of mechanical output. Find the efficiency and state where the remaining energy goes. [4]

19. Water of mass 2 kg is heated through 40 K; the specific heat capacity of water is 4.2 kJ/(kg K). Find the energy needed, and the time in seconds for a 1.5 kW heater with no heat loss. [4]

20. Using the 180 kWh monthly consumption above, and 0.7 kg of carbon dioxide per kWh, find the indirect monthly emissions and suggest one measure that cuts both energy and emissions. [4]

Part F - Product Specification and Cost (16 marks)

Give costs in dollars and state where each figure comes from.

21. A part uses 18 dollars of material and 0.5 hour of labour at 120 dollars per hour; overhead is 20% of material plus labour. Find the unit cost and the cost of a batch of 500. [4]

22. A shaft has a nominal diameter of 25.0 mm with a tolerance of plus or minus 0.2 mm. Find the acceptable range, judge a part measured at 25.3 mm, and find the reject rate when 3 of 200 parts are out of tolerance. [4]

23. A product sells for 90 dollars, variable cost is 60 dollars per unit and fixed cost is 24 000 dollars per month. Find the contribution per unit and the monthly break-even quantity. [4]

24. A small assembly project has three operations taking 4, 3 and 2 days. Find the total lead time in sequence; find the lead time if 2 days of overlap are allowed; and state the quality-control risk of overlapping. [4]
