S4 Design and Applied Technology Practice Paper: Design and Innovation, Materials and Machining, Structures and Mechanics, Mechanisms and Transmission, Electronics and Control, Energy and Sustainable Design (100 marks)

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

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Part A: Design and Innovation (16 marks)

Four questions, 4 marks each. Show all working; answers alone score no marks.

1. A phone-stand prototype costs $240 in material and 3.5 hours of printing at $180 per machine hour. Find the total development cost, then the selling price at a 35% mark-up on cost. [4]

Answer: Material $240; machine time 3.5 x $180 = $630; total cost $870. Selling price = $870 x 1.35 = $1174.5.

2. Five users rate a prototype 8, 7, 9, 6 and 10 out of 10. Find the mean score, then the mean after removing the highest and lowest scores. [4]

Answer: Mean = (8+7+9+6+10)/5 = 8.0. Removing 10 and 6 gives (8+7+9)/3 = 8.0.

3. On a drawing, 45 mm represents an actual 180 mm. State the drawing scale, and the drawn length in mm of a part that is actually 2.4 m long. [4]

Answer: Scale = 45:180 = 1:4. Drawn length = 2400/4 = 600 mm.

4. A product costs $12000 to develop and $45 per unit to make. Find the total and average unit cost of the first batch of 800 units. [4]

Answer: Total = 12000 + 45 x 800 = $48000. Average = 48000/800 = $60 per unit.

Part B: Materials and Machining (16 marks)

Four questions, 4 marks each. State the formula used for density, cutting speed and nesting.

5. An acrylic sheet measures 600 x 400 x 5 mm and has a density of 1.19 g/cm3. Find its volume in cm3 and its mass in kg. [4]

Answer: Volume = 600 x 400 x 5 mm3 = 1200 cm3. Mass = 1200 x 1.19 = 1428 g = 1.428 kg.

6. A standard sheet is 2440 x 1220 mm and each part is 300 x 200 mm, nested parallel to the sheet edges. Find the maximum number of parts and the material utilisation in %. [4]

Answer: Columns 8, rows 6, giving 48 parts. Utilisation = 48 x 300 x 200 / (2440 x 1220) = 96.7%.

7. Drilling uses a cutting speed of 25 m/min with an 8 mm drill. Using n = 1000v/(pi d), find the spindle speed in rpm to the nearest whole number. [4]

Answer: n = 1000 x 25/(pi x 8) = 994.7, i.e. about 995 rpm.

8. A jig needs 4 welded joints at 12 s each, plus 90 s for loading and unloading. Find the total time per piece in seconds and in minutes. [4]

Answer: Welding = 4 x 12 = 48 s; total = 48 + 90 = 138 s = 2.3 min.

Part C: Structures and Mechanics (18 marks)

Questions 1 and 2 carry 5 marks each, questions 3 and 4 carry 4 marks each. Always state units.

9. A force of 150 N acts perpendicular at 0.4 m from a pivot. Find the moment, then the force needed at 0.6 m to produce the same moment. [5]

Answer: M = 150 x 0.4 = 60 N m. F = 60/0.6 = 100 N.

10. A simply supported beam 4 m long carries a central downward load of 800 N, beam weight neglected. Find both support reactions and justify the answer. [5]

Answer: Symmetry gives equal reactions: R = 800/2 = 400 N each, and 2 x 400 = 800 N balances the load.

11. A strut carries a compressive load of 2400 N over a cross-section of 120 mm2. Find the compressive stress in N/mm2 (MPa). [4]

Answer: Stress = F/A = 2400/120 = 20 N/mm2 = 20 MPa.

12. A material has an ultimate strength of 250 MPa and a design working stress of 50 MPa. Find the factor of safety and state whether it is safe. [4]

Answer: Factor of safety = 250/50 = 5. General machine design requires at least 2, so 5 is safe.

Part D: Mechanisms and Transmission (16 marks)

Four questions, 4 marks each. Treat gear ratio and efficiency separately.

13. A 12-tooth driving gear at 1500 rpm drives a 48-tooth gear. Find the reduction ratio and the output speed. [4]

Answer: Ratio = 48/12 = 4:1. Output speed = 1500 x 12/48 = 375 rpm.

14. With 2.4 N m input torque and 92%% gear train efficiency, find the output torque. [4]

Answer: Ideal output = 2.4 x 4 = 9.6 N m; actual = 9.6 x 0.92 = 8.832 N m, about 8.83 N m.

15. A pulley of 80 mm diameter runs at 900 rpm. Find the belt linear speed in m/s to two decimal places. [4]

Answer: v = pi x 0.08 x 900/60 = 3.77 m/s.

16. A lead screw has a 2 mm lead and turns 1.5 revolutions. Find the travel, and the number of revolutions needed for 45 mm of travel. [4]

Answer: Travel = 2 x 1.5 = 3 mm. Revolutions = 45/2 = 22.5.

Part E: Electronics and Control (16 marks)

Four questions, 4 marks each. Write the formula and the unit for every answer.

17. A 12 V supply is connected across a 220 ohm resistor. Find the current in mA to one decimal place. [4]

Answer: I = V/R = 12/220 = 0.0545 A = 54.5 mA.

18. A potential divider has R1 = 10 k ohm from the supply and R2 = 4.7 k ohm to ground, with 9 V input. Find the voltage across R2 to three decimal places. [4]

Answer: Vout = 9 x 4.7/(10 + 4.7) = 2.878 V.

19. An LED has a 2 V forward voltage at 20 mA and runs from a 5 V supply. Find the series resistor and its power dissipation in W. [4]

Answer: R = (5 - 2)/0.02 = 150 ohm. P = 0.02^2 x 150 = 0.06 W, so use a 0.25 W resistor.

20. An RC circuit has R = 1 k ohm and C = 470 uF. Find the time constant and the time to charge fully (about 5 time constants). [4]

Answer: tau = RC = 1000 x 470 x 10^-6 = 0.47 s; 5 tau = 2.35 s.

Part F: Energy and Sustainable Design (18 marks)

Questions 1 and 2 carry 5 marks each, questions 3 and 4 carry 4 marks each.

21. A 2.2 kW water heater runs 45 minutes a day. Find the daily energy use in kWh and the daily cost at $1.2 per kWh. [5]

Answer: Energy = 2.2 x 0.75 = 1.65 kWh. Cost = 1.65 x 1.2 = $1.98.

22. A school installs three 400 W panels with 4.5 effective sun hours a day and 80%% system efficiency. Find the daily generation in kWh. [5]

Answer: Generation = 3 x 400 x 4.5 x 0.8 = 4320 Wh = 4.32 kWh.

23. Using the previous answer, find the daily CO2 avoided in kg to three decimal places, given 0.55 kg CO2 per kWh. [4]

Answer: Avoided = 4.32 x 0.55 = 2.376 kg.

24. A product weighs 1.8 kg, of which 60% is metal recovered at a 90% rate. Find the mass of metal recovered. [4]

Answer: Metal = 1.8 x 0.6 = 1.08 kg; recovered = 1.08 x 0.9 = 0.972 kg.
