S4 Design and Applied Technology Practice Paper: Design Process and Human-centred Design, Structures and Moments, Mechanisms and Transmission, Electronics and Control, Materials and Manufacturing, Systems and Sustainable Development

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

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Part A: Design Process and Human-centred Design (16 marks)

Show the formula and steps for calculations; answer explanation questions in numbered points.

1. A design project has 40 working days in total, of which 25 percent is for research and 30 percent for sketching. Find the total number of working days used for research and sketching, and the number of days remaining. [4]

Answer: Answer: research 10 days and sketching 12 days, 22 days in total; 18 days remain (40 x 25% = 10, 40 x 30% = 12).

2. An ergonomics guideline recommends a desk height of 720 mm with a tolerance of plus or minus 25 mm. Find the upper and lower limits of the acceptable height and the width of the acceptable range. [4]

Answer: Answer: upper limit 745 mm, lower limit 695 mm; range width 50 mm.

3. A company registers 8 designs. Each registration costs 1,200 dollars and a handling fee of 3,500 dollars is charged once. Find the total cost and state one benefit of registering a design for a designer. [4]

Answer: Answer: 13,100 dollars (1,200 x 8 + 3,500); benefit such as legal protection against unauthorised copying of the appearance.

4. List four main stages of the modern design process and give one example of how user needs can be collected. [4]

Answer: Answer: four stages such as identifying the problem and needs, research and information gathering, idea generation and sketching, prototyping and testing, evaluation and improvement; user needs may be collected by questionnaire, interview, observation or focus group.

Part B: Structures and Moments (16 marks)

Show the formula, substitute the values and state the unit.

5. A force of 60 N acts perpendicularly at 0.35 m from a pivot. Find the moment of the force about the pivot. [4]

Answer: Answer: moment = force x distance = 60 x 0.35 = 21 N m.

6. A timber strut has a cross-section of 12 mm by 20 mm and carries an axial tensile force of 4,800 N. Find the cross-sectional area and the tensile stress in N/mm2. [4]

Answer: Answer: area = 12 x 20 = 240 mm2; stress = 4,800 / 240 = 20 N/mm2.

7. The ultimate strength of a steel is 320 MPa and the design working stress is 80 MPa. Find the factor of safety and explain why it must be greater than 1. [4]

Answer: Answer: factor of safety = 320 / 80 = 4.0; because of material defects, overload, simplified assumptions and fatigue, the working stress must be well below the ultimate strength to keep a margin.

8. State three ways of increasing the bending resistance of a beam and briefly explain each. [4]

Answer: Answer: increase the depth of the section (second moment of area rises with the cube of depth), place material away from the neutral axis such as in an I-beam, shorten the span or add supports, and use a stronger material.

Part C: Mechanisms and Transmission (17 marks)

Give ratios in simplest form and state speeds in rpm.

9. A pair of meshing gears has a driver of 18 teeth and a driven gear of 54 teeth. The driver turns at 900 rpm. Find the speed ratio and the speed of the driven gear. [4]

Answer: Answer: speed ratio = 54 / 18 = 3; driven speed = 900 / 3 = 300 rpm (speed reduction).

10. In a belt drive the driving pulley has a diameter of 80 mm and the driven pulley 200 mm. The driving pulley turns at 1000 rpm. Find the velocity ratio and the driven speed. [4]

Answer: Answer: velocity ratio = 200 / 80 = 2.5; driven speed = 1000 / 2.5 = 400 rpm.

11. A gearbox receives 500 W and delivers 425 W. Find the transmission efficiency and the power lost. [4]

Answer: Answer: efficiency = 425 / 500 x 100 percent = 85 percent; loss = 75 W, mainly friction and noise.

12. A single-start worm drives a worm wheel with 40 teeth. The worm turns 20 revolutions. Find the number of revolutions of the wheel and state two advantages of this drive in high reduction applications. [5]

Answer: Answer: 0.5 revolution (20 / 40); advantages such as a very high reduction in one stage, compact construction, self-locking against reverse driving, and smooth quiet running.

Part D: Electronics and Control (17 marks)

Current may be given in A or mA; give voltages to two decimal places.

13. A 240 ohm resistor is connected across a 12 V supply. Find the current in mA. [4]

Answer: Answer: I = V / R = 12 / 240 = 0.05 A = 50 mA.

14. Three resistors of 120 ohm, 180 ohm and 200 ohm are connected in series across 10 V. Find the total resistance and the current. [4]

Answer: Answer: total resistance = 500 ohm; current = 10 / 500 = 0.02 A = 20 mA.

15. An LED operates at 3.3 V and 20 mA. Find the power of one LED and the total power of 5 such LEDs in mW. [4]

Answer: Answer: one LED P = 3.3 x 0.020 = 0.066 W = 66 mW; 5 LEDs give 330 mW.

16. In a potential divider R1 = 4.7 k ohm is between the supply and the output and R2 = 10 k ohm between the output and earth, with a 5 V supply. Find the output voltage to two decimal places and state how the output changes if R2 is replaced by a light-dependent resistor as light increases. [5]

Answer: Answer: Vout = 5 x 10 / (4.7 + 10) = 3.40 V; the resistance of an LDR falls as light increases, so less voltage appears across R2 and the output falls with brighter light, which can be used for automatic switching or light sensing.

Part E: Materials and Manufacturing (17 marks)

Give density in g/cm3 and state the unit of every cost.

17. An aluminium plate measures 200 mm by 300 mm by 2 mm. The density of aluminium is 2.7 g/cm3. Find the volume in cm3 and the mass in grams. [4]

Answer: Answer: volume = 200 x 300 x 2 = 120,000 mm3 = 120 cm3; mass = 120 x 2.7 = 324 g.

18. A part costs 45 dollars in material and 18 dollars in labour, and tooling is apportioned at 7 dollars per unit. If the selling price is 98 dollars, find the unit cost, the unit profit and the profit margin as a percentage of the selling price to one decimal place. [4]

Answer: Answer: cost = 45 + 18 + 7 = 70 dollars; profit = 98 - 70 = 28 dollars; margin = 28 / 98 x 100 percent = 28.6 percent.

19. A shaft has a nominal diameter of 25.00 mm with a tolerance of plus or minus 0.05 mm. Find the upper and lower limits and the tolerance range, and decide whether a measured diameter of 24.94 mm is acceptable, giving a reason. [4]

Answer: Answer: upper limit 25.05 mm, lower limit 24.95 mm, tolerance range 0.10 mm; 24.94 mm is below the lower limit 24.95 mm, so it is undersize and rejected because the fit would be affected.

20. Explain how jigs and fixtures, standardisation of parts and quality control each reduce the unit cost of batch production, one point each. [5]

Answer: Answer: jigs and fixtures locate and hold the work, cutting marking and machining time and giving consistent accuracy; standardised parts share tooling and processes, reduce stock variety and lower tooling and purchasing cost; quality control detects defects early, reducing scrap, rework and returns.

Part F: Systems and Sustainable Development (17 marks)

Give efficiency as a percentage and state the unit of every amount of energy and cost.

21. A machine takes 2.4 kW and delivers 1.8 kW. Find its efficiency and the power lost in watts. [4]

Answer: Answer: efficiency = 1.8 / 2.4 x 100 percent = 75 percent; loss = 600 W.

22. An appliance uses 180 kWh a year, has a service life of 8 years and electricity costs 1.2 dollars per kWh. Find the total energy used and the total electricity cost. [4]

Answer: Answer: total energy = 180 x 8 = 1440 kWh; total cost = 1440 x 1.2 = 1,728 dollars.

23. An off-grid system needs 1.2 kWh a day. The panels have an area of 2 m2 and an efficiency of 20 percent, and receive 1,000 W/m2 for 4 effective hours a day. Find the daily generation and decide whether it meets the demand. [4]

Answer: Answer: power = 2 x 1,000 x 0.20 = 400 W; daily generation = 400 / 1,000 x 4 = 1.6 kWh, which exceeds 1.2 kWh and meets the demand.

24. For one domestic appliance, state two benefits of automatic control and two benefits of sustainable design. [5]

Answer: Answer: automatic control gives saved labour and time, consistent accuracy, and sensing-based adjustment that saves energy; sustainable design uses recyclable or low-energy materials, extends life and ease of repair, cuts packaging and waste, and lowers energy use and carbon emissions in the use phase.
