S6 Design and Applied Technology Practice Paper: Structures and Mechanics, Gears and Power Transmission, Electronics and Control, Materials and Manufacturing, Energy Systems, Design Analysis and Ergonomics (100 marks)

Level: S6 | Subject: Design and Applied Technology | 75 minutes | 100 marks | 24 questions | answer key

Part 1 Structures and Mechanics (16 marks)

Show all formulae, substitutions and calculation steps.

#	Question	Answer	Marks
1	A steel rod 2.0 m long has a cross-sectional area of 250 mm2 and carries a 50 kN tensile load. Find the tensile stress in MPa.	Stress = force / area = 50000 / 250 = 200 MPa.	4
2	The same rod extends by 1.2 mm. Find the strain (decimal) and the Young modulus in GPa to 1 decimal place.	Strain = 1.2 / 2000 = 6.0e-04; Young modulus = stress / strain = 200 / 6.0e-04 = 333333 MPa = 333.3 GPa.	4
3	A rectangular beam is 50 mm wide and 100 mm deep. Find its second moment of area in mm4 to 3 significant figures, then the bending stress in MPa at 50 mm from the neutral axis when the maximum bending moment is 2.5 kNm.	Second moment = 50 x 100^3 / 12 = 4.167e+06 mm4; bending stress = 2.5e6 x 50 / 4.167e+06 = 30 MPa.	4
4	The steel has an ultimate strength of 480 MPa and a working stress of 160 MPa. Find the factor of safety; if the working load is doubled, find the new factor and say whether it meets the usual requirement of at least 2.	Factor of safety = 480 / 160 = 3.0; after doubling the load = 480 / 320 = 1.5, below 2, so the design fails and a larger section or stronger material is needed.	4

Part 2 Gears and Power Transmission (16 marks)

Give units for every power and efficiency answer and state significant figures.

#	Question	Answer	Marks
5	Gear A has 20 teeth and runs at 900 rpm, driving gear B with 60 teeth. Find the gear ratio and the speed of gear B in rpm.	Gear ratio = 60 / 20 = 3.0; speed of B = 900 / 3.0 = 300 rpm, a speed reduction with torque increase.	4
6	A motor delivers 12 Nm at 1450 rpm. Find its output power in watts (whole number) and in kW to 3 decimal places.	Power = 2 pi N T / 60 = 2 pi x 1450 x 12 / 60 = 1822 W = 1.822 kW.	4
7	The motor drives a load through a gearbox of 85% efficiency. Find the gearbox output power in watts and the power lost in watts.	Output = 1822 x 0.85 = 1549 W; loss = 1822 - 1549 = 273 W, mainly tooth friction and oil churning.	4
8	A screw jack has a 5 mm lead, an input torque of 8 Nm and 40% efficiency. Find the axial load it can raise in newtons (whole number) and in kN to 2 decimal places.	Axial load = 2 pi T eta / lead = 2 pi x 8 x 0.40 / 0.005 = 4021 N = 4.02 kN.	4

Part 3 Electronics and Control Circuits (17 marks)

For electronics questions, describe the circuit and state the formulae used.

#	Question	Answer	Marks
9	A 12 V supply is connected to 4 kohm and 8 kohm resistors in series. Find the current in mA and the voltage across the 8 kohm resistor in V.	Total resistance = 12 kohm; current = 12 / 12000 = 1.0 mA; voltage across 8 kohm = 0.0010 x 8000 = 8 V.	4
10	A potential divider uses 10 kohm and 22 kohm resistors across a 12 V supply with no load. Find the output voltage across the 22 kohm resistor to 2 decimal places.	Output = 12 x 22 / (10 + 22) = 12 x 22 / 32 = 8.25 V; the output falls once a load is connected.	4
11	A 47 kohm resistor and a 100 microfarad capacitor are in series across 12 V. Find the time constant in seconds (1 decimal place), the time to reach 63.2% of full charge, and the 5 time-constant time treated as fully charged.	Time constant = 47000 x 100e-6 = 4.7 s; 63.2% is reached in one time constant = 4.7 s; five time constants = 23.5 s.	4
12	An inverting op-amp has a 100 kohm feedback resistor, a 10 kohm input resistor and ±12 V rails. Find the voltage gain, the output for a 0.25 V input, and say whether the output saturates.	Gain = -Rf / Rin = -100 / 10 = -10; output = -10 x 0.25 = -2.5 V, which is 9.5 V inside the -12 V rail, so it is not saturated.	5

Part 4 Materials and Manufacturing (17 marks)

Use the units given in each material and machining question.

#	Question	Answer	Marks
13	An aluminium plate measures 200 x 100 x 20 mm and aluminium has a density of 2700 kg/m3. Find the volume in m3 and the mass in kg to 2 decimal places.	Volume = 0.2 x 0.1 x 0.02 = 4e-04 m3; mass = 4e-04 x 2700 = 1.08 kg.	4
14	A 25 m steel rail has a coefficient of linear expansion of 12e-6 per degree and sees a 40 degree temperature change. Find the change in length in mm (whole number) and explain why expansion gaps are needed.	Expansion = 25 x 12e-6 x 40 = 12 mm; without a gap the rail would be in compression and could buckle, so expansion gaps or stressed continuously welded rail are used.	4
15	A milling cutter is 50 mm in diameter and runs at 1200 rpm. Find the cutting speed in m/min to 1 decimal place.	Cutting speed = pi D N / 1000 = pi x 50 x 1200 / 1000 = 188.5 m/min.	4
16	The same cut uses 0.05 mm per tooth with 4 teeth. Find the feed rate in mm/min and the time to mill a 480 mm long workpiece in minutes to 1 decimal place.	Feed rate = 0.05 x 4 x 1200 = 240 mm/min; time = 480 / 240 = 2.0 min.	5

Part 5 Energy System Efficiency (17 marks)

Separate input, output and losses in every energy answer.

#	Question	Answer	Marks
17	A 1.6 m2 PV panel has 20% efficiency under 800 W/m2 irradiance. Find its instantaneous output in W.	Output = 1.6 x 800 x 0.20 = 256 W.	4
18	The panel gets 5 effective sun hours a day and the home uses 3.2 kWh a day. Find the daily generation in kWh and the percentage of demand covered (whole number).	Daily generation = 256 x 5 / 1000 = 1.28 kWh; coverage = 1.28 / 3.2 x 100 = 40%.	4

19	A 12 V 100 Ah battery is limited to 80% depth of discharge. Find the usable energy in kWh (2 decimal places) and how long it runs a 200 W load in hours (1 decimal place).	Usable energy = 12 x 100 x 0.80 = 960 Wh = 0.96 kWh; run time = 960 / 200 = 4.8 h.	4
20	The PV system has 90% charging efficiency and a 92% efficient inverter. Find the overall system efficiency as a percentage (2 decimal places) and the AC output in W (whole number).	Overall efficiency = 20% x 0.90 x 0.92 = 16.56%; AC output = 256 x 0.90 x 0.92 = 212 W, losing 44 W in total.	5

Part 6 Design Analysis and Ergonomics (17 marks)

State your assumptions and rounding for costing and ergonomics answers.

#	Question	Answer	Marks
21	A part has a net mass of 0.35 kg, a scrap rate of 15% and material costing $48 per kg. Find the material consumed per part in kg (4 decimal places) and the material cost per part to 2 decimal places.	Material used = 0.35 x 1.15 = 0.4025 kg; cost = 0.4025 x 48 = $19.32.	4
22	Tooling costs $120,000 for a batch of 5000 parts. Find the tooling cost per part and the total cost per part to 2 decimal places.	Tooling per part = 120000 / 5000 = $24.00; total cost = 19.32 + 24.00 = $43.32.	4
23	The selling price is $65 per part. Find the profit per part, total profit and contribution margin as a percentage to 1 decimal place.	Profit per part = 65 - 43.32 = $21.68; total = 21.68 x 5000 = $108,400; contribution margin = (65 - 19.32) / 65 = 70.3%.	4
24	User height for a product is normal with a mean of 170 cm and standard deviation of 6 cm. Find the 5th and 95th percentile heights in cm (1 decimal place, using z = ±1.645) and explain why the adjustable range is set this way.	5th percentile = 170 - 1.645 x 6 = 160.1 cm; 95th = 170 + 1.645 x 6 = 179.9 cm, covering about 90% of users; the remaining 5% tails are handled by adjustability or accessories instead of over-sizing every unit.	5