S4 Design and Applied Technology Practice Paper: beam reactions and moments, bending moment and section modulus, inclined planes and efficiency, gears and pulleys, lead screw, stress and strain, Young modulus and thermal expansion, Ohm law and power, series and parallel resistors and battery capacity, solar energy and emission savings, tolerances, production cost and drawing scales (100 marks)

Level: S4 | Subject: Design and Applied Technology | 75 minutes | 100 marks | 24 questions | answer key

Section A — Structures and Forces

Answer all questions. Show your working and state the units.

#	Question	Answer	Marks
1	A simply supported beam 4 m long rests on supports at both ends. A load of 600 N is placed 1 m from the left end. (a) Find the reaction at the right support. (b) Find the reaction at the left support and check that the sum equals the load.	(a) Moments about the left support: R_right x 4 = 600 x 1, so R_right = 150 N. (b) R_left = 600 - 150 = 450 N; sum = 600 N, equal to the load.	4
2	A technician uses a 0.25 m spanner and applies 80 N perpendicular at its end to tighten a bolt. (a) Find the moment on the bolt. (b) If the arm is lengthened to 0.5 m with the same force, what is the new moment?	(a) Moment = 80 x 0.25 = 20 N m. (b) Moment = 80 x 0.5 = 40 N m, doubled.	4
3	A simply supported beam spans 2 m and carries a central point load of 1,200 N. (a) Find the maximum bending moment using PL / 4. (b) If the section changes from 50 mm x 100 mm to 50 mm x 200 mm, how does the bending capacity change?	(a) M = 1,200 x 2 / 4 = 600 N m. (b) Doubling the depth roughly quadruples the section modulus, so the bending capacity rises to about 4 times.	4
4	A 400 N load is pushed up a 5 m ramp rising 1 m onto a truck with an actual effort of 100 N. (a) Find the ideal (frictionless) effort. (b) Find the efficiency of the ramp.	(a) Ideal effort = 400 x 1 / 5 = 80 N. (b) Efficiency = 80 / 100 x 100% = 80%.	4

Section B — Mechanisms and Transmission

Answer all questions. Show your working and state the units.

#	Question	Answer	Marks
5	Gear A with 20 teeth drives gear B with 60 teeth. Gear A turns at 300 rpm. (a) Find the speed of gear B. (b) Find the reduction ratio.	(a) n_B = 300 x 20 / 60 = 100 rpm. (b) Reduction ratio = 60 / 20 = 3:1.	4
6	A movable pulley with two rope segments lifts a 500 N load, ignoring friction and the pulley weight. (a) Find the effort needed. (b) How much rope must be pulled to raise the load by 1.5 m?	(a) Effort = 500 / 2 = 250 N. (b) Rope pulled = 1.5 x 2 = 3.0 m.	4

7	A lead screw advances 2 mm per turn. (a) How far does the nut move if the handle is turned 50 times? (b) How many turns are needed to move 300 mm?	(a) Travel = 2 x 50 = 100 mm. (b) Turns = 300 / 2 = 150 turns.	4
8	A hoist is supplied with 500 J of energy and does 350 J of useful work lifting a load. (a) Find the efficiency. (b) Where does the remaining energy go?	(a) Efficiency = 350 / 500 x 100% = 70%. (b) The other 150 J is lost as heat and sound through friction.	4

Section C — Materials and Mechanical Properties

Answer all questions. Show your working and state the units.

#	Question	Answer	Marks
9	A steel rod of cross-sectional area 200 mm² carries a tensile force of 10,000 N. (a) Find the tensile stress in N/mm². (b) Is it safe if the ultimate stress is 250 N/mm²?	(a) Stress = 10,000 / 200 = 50 N/mm². (b) 50 is below 250, so it is safe.	4
10	A 200 mm specimen stretches 0.6 mm under tension. (a) Find the strain as a decimal. (b) If the strain doubles while still in the elastic range, what is the extension?	(a) Strain = 0.6 / 200 = 0.003. (b) Extension = 0.6 x 2 = 1.2 mm.	4
11	Steel has a Young modulus of 200,000 N/mm² and a component shows a strain of 0.0015 in the elastic range. (a) Find the stress. (b) If an aluminium alloy with a modulus of 70,000 N/mm² shows the same strain, what is its stress?	(a) Stress = 200,000 x 0.0015 = 300 N/mm². (b) Stress = 70,000 x 0.0015 = 105 N/mm².	4
12	An aluminium rail 2,000 mm long has a coefficient of linear expansion of 12 x 10^{-6} /°C and its temperature rises by 40 °C. (a) Find the expansion. (b) What problem arises if both ends are fixed with no gap?	(a) ΔL = 12 x 10^{-6} x 2,000 x 40 = 0.96 mm. (b) Restrained expansion creates compressive stress and can buckle the rail or damage the joints.	4

Section D — Electrical and Electronic Principles

Answer all questions. Show your working and state the units.

#	Question	Answer	Marks
13	A 6 ohm resistor is connected across a 12 V supply. (a) Find the current. (b) Find the power dissipated in the resistor.	(a) I = 12 / 6 = 2 A. (b) P = 2^2 x 6 = 24 W.	4
14	The 24 W resistor runs continuously for 30 minutes. (a) Find the energy used in joules. (b) Convert it to kilowatt-hours.	(a) E = 24 x 1,800 = 43,200 J. (b) 43,200 / 3,600,000 = 0.012 kWh.	4
15	Two resistors of 6 ohm and 3 ohm are available. (a) Find their equivalent resistance in parallel. (b) Find their equivalent resistance in series.	(a) R = (6 x 3) / (6 + 3) = 2 ohm. (b) R = 6 + 3 = 9 ohm.	4
16	A 5 V, 2,000 mAh battery powers a 2 W device. (a) Find the stored energy in Wh. (b) How many hours can it run in theory?	(a) Energy = 2.0 Ah x 5 V = 10 Wh. (b) Time = 10 / 2 = 5 hours.	4

Section E — Energy and Sustainable Design

Answer all questions. Show your working and state the units.

#	Question	Answer	Marks

17	A 2 m² solar panel with 18% efficiency works under solar irradiance of 1,000 W/m². (a) Find its output power. (b) If the effective sunshine is 5 hours a day, find the daily energy output in kWh.	(a) P = 2 x 1,000 x 0.18 = 360 W. (b) E = 360 x 5 / 1,000 = 1.8 kWh.	5
18	A 10 W LED lamp replaces a 60 W filament lamp, used 4 hours a day for 365 days. (a) Find the annual energy saving in kWh. (b) If each kWh emits 0.7 kg of carbon dioxide, find the annual reduction in emissions.	(a) Saving = (60 - 10) x 4 x 365 / 1,000 = 73 kWh. (b) Reduction = 73 x 0.7 = 51.1 kg.	5
19	A split air conditioner has a coefficient of performance (COP) of 3.0. (a) How much heat can it remove with 1.2 kWh of electricity? (b) If the COP drops to 2.0, how much heat can the same electricity remove?	(a) Heat removed = 1.2 x 3.0 = 3.6 kWh. (b) Heat removed = 1.2 x 2.0 = 2.4 kWh, i.e. 1.2 kWh less.	4
20	A workshop runs five 2 kW machines from 8 hours to 6 hours a day for 250 days a year. (a) Find the annual energy saving in kWh. (b) If electricity costs $1.2 per kWh, find the annual saving in dollars.	(a) Saving = 5 x 2 x 2 x 250 = 5,000 kWh. (b) Money saved = 5,000 x 1.2 = $6,000.	4

Section F — Manufacturing and Quality Control

Answer all questions. Show your working and state the units.

#	Question	Answer	Marks
21	A drawing specifies a part as 40.00 mm ±0.05 mm. (a) State the upper and lower limits. (b) Find the tolerance range.	(a) Upper limit 40.05 mm, lower limit 39.95 mm. (b) Tolerance range = 40.05 - 39.95 = 0.10 mm.	5
22	A production line needs 4.5 minutes per unit over an 8-hour shift with an overall equipment efficiency of 90%. (a) Find the output per shift. (b) Find the output if the efficiency rises to 95%.	(a) Output = 480 x 0.9 / 4.5 = 96 units. (b) Output = 480 x 0.95 / 4.5, about 101 units.	5
23	A part costs $12 in material and needs 4.5 minutes of machining at $0.8 per minute. (a) Find the unit cost. (b) Find the selling price with a 20% mark-up.	(a) Cost = 12 + 4.5 x 0.8 = $15.6. (b) Price = 15.6 x 1.2 = $18.72.	4
24	A drawing is made to a scale of 1:5. (a) A line measures 36 mm on the drawing; what is the real length? (b) If the real length is 250 mm, how long should the line be on the drawing?	(a) Real length = 36 x 5 = 180 mm. (b) Drawing length = 250 / 5 = 50 mm.	4