# S5 Design and Applied Technology Practice Paper (Set 1): Structures, Materials, Drives, Electronics and Design Practice

S5 Design and Applied Technology | Time: 75 minutes | Total: 100 marks | 24 questions

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## Section A: Structures and Moments (17 marks)

**Answer all parts. Show your working and state the units.**

**1. (a) A 4.0 m horizontal beam is hinged at its left end. A 600 N load hangs 2.5 m from the left end, and the right end rests on a roller. Find the right support force and the left reaction. (4 marks)**

(a) Take moments about the left end: F_R x 4.0 = 600 x 2.5, so F_R = 375 N. Vertical equilibrium gives F_L = 600 - 375 = 225 N.

**2. (b) A steel rod of 12 mm diameter carries a tensile load of 15 kN. Calculate the tensile stress in MPa. (4 marks)**

(b) Cross-sectional area A = pi x (0.006)^2 = 1.131 x 10^-4 m^2; stress = 15000 / 1.131 x 10^-4 = 132.6 MPa.

**3. (c) The Young modulus of the steel is 200 GPa. Find the strain and the extension of a 2.0 m length of the rod in mm. (5 marks)**

(c) Strain = 132.6 / 200000 = 6.63 x 10^-4; extension = 6.63 x 10^-4 x 2000 mm = 1.33 mm.

**4. (d) State three ways to increase the bending strength of a beam and explain each in one sentence. (4 marks)**

(d) 1. Increase the depth of the section: the second moment of area rises with the cube of depth. 2. Use an I or box section: material is placed away from the neutral axis, giving a larger second moment for the same mass. 3. Add supports or shorten the span: maximum bending moment is proportional to span, so a shorter span lowers it directly.

## Section B: Materials and Manufacture (17 marks)

**Show formulae and units in your calculations.**

**5. (a) An aluminium plate measures 1.2 m x 0.8 m x 3 mm. The density of aluminium is 2700 kg/m^3. Find the volume in m^3 and the mass in kg. (5 marks)**

(a) Thickness 3 mm = 0.003 m; volume = 1.2 x 0.8 x 0.003 = 0.00288 m^3; mass = 2700 x 0.00288 = 7.78 kg.

**6. (b) The aluminium costs $38 per kg and 20% is allowed for waste. Find the material cost of the plate. (4 marks)**

(b) Material required = 7.776 x 1.2 = 9.33 kg; cost = 9.33 x 38 = $354.6, about $355.

**7. (c) Explain the purpose of annealing, quenching and tempering of steel, and why tempering usually follows quenching. (4 marks)**

(c) Annealing heats and cools slowly to relieve internal stress, soften the metal and improve machinability. Quenching cools rapidly to give high hardness and strength. Tempering reheats to a lower temperature after quenching to reduce brittleness and quenching stresses while keeping useful toughness, so quenched parts are rarely used without it.

**8. (d) Compare welding with mechanical fastening such as screws or rivets: give one advantage and one limitation of each. (4 marks)**

(d) Welding gives a continuous, stiff joint with a flush appearance, but heat alters the material locally, causes distortion and cannot easily be undone. Mechanical fastening is reversible, simple to assemble and leaves the material structure unchanged, but holes reduce the section and fasteners can loosen under vibration without locking features.

## Section C: Gear and Belt Drives (17 marks)

**Assume 100% efficiency unless stated otherwise.**

**9. (a) In a gear pair the driver has 24 teeth and the driven gear 72 teeth. Input speed is 300 rpm at 8 N m. Find the output speed and torque. (5 marks)**

(a) Gear ratio = 72/24 = 3; output speed = 300 / 3 = 100 rpm; torque rises inversely = 8 x 3 = 24 N m. Power is unchanged, P = torque x angular velocity, so one third the speed means three times the torque.

**10. (b) A belt drive has a 80 mm driver and a 240 mm driven pulley at 900 rpm input. Find the output speed ignoring slip, then the actual speed with 5% slip. (5 marks)**

(b) Speed ratio = 240/80 = 3; ideal output = 900 / 3 = 300 rpm; with 5% slip the actual output is 300 x 0.95 = 285 rpm. Slip lowers the driven speed and dissipates part of the power as friction heat.

**11. (c) A lead screw has a lead of 4 mm. How many turns are needed to move the table 60 mm? (3 marks)**

(c) Turns = 60 / 4 = 15 turns.

**12. (d) Describe one use of a cam mechanism in an automated machine and explain how rotary motion becomes reciprocating motion. (4 marks)**

(d) Example: the pusher of a packaging machine is driven by a cam and pushes each product out on a fixed beat. The cam profile radius varies with angle, so a roller or flat follower held against the profile rises as the radius grows and returns under spring or gravity as it falls, turning continuous rotation into regular reciprocating motion.

## Section D: Electronics and Control (17 marks)

**Show formulae and units in your calculations.**

**13. (a) In a voltage divider R1 = 4.7 k ohm and R2 = 10 k ohm across 12 V, the output is taken across R2. Find the output voltage. (4 marks)**

(a) V_out = 12 x 10 / (4.7 + 10) = 12 x 10 / 14.7 = 8.16 V.

**14. (b) An LED with a 2.0 V forward drop runs at 20 mA from a 5 V supply. Find the series resistor and state the power rating to choose. (5 marks)**

(b) R = (5 - 2.0) / 0.020 = 150 ohm; resistor power = 0.020^2 x 150 = 0.06 W, so a 0.25 W part is chosen to leave thermal margin.

**15. (c) An RC circuit has R = 10 k ohm and C = 470 microfarad. Find the time constant and the time to charge to about 95%. (4 marks)**

(c) Time constant = 10000 x 470 x 10^-6 = 4.7 s; about 3 time constants, 14.1 s, are needed to reach 95%.

**16. (d) Using a temperature sensor, a comparator and a relay, describe the sequence from rising temperature to the cooling fan starting. (4 marks)**

(d) The sensor converts temperature to a voltage which the comparator compares with a reference. When the temperature voltage exceeds the set point the comparator output goes high, drives a transistor, energises the relay coil so its normally open contact closes and the fan motor starts. When the temperature falls below the set point the output reverses, the relay releases and the fan stops. A small hysteresis band prevents rapid switching.

## Section E: Drawings, Scale and Tolerance (16 marks)

**Answer all parts.**

**17. (a) On a drawing at 1:50 a wall measures 84 mm. Find its actual length in metres. (4 marks)**

(a) Actual length = 84 x 50 = 4200 mm = 4.2 m.

**18. (b) In third angle projection, which views are normally used and how are they arranged on the sheet? (4 marks)**

(b) Front, top and side views are normally used. In third angle projection the top view is placed above the front view and the right side view to its right, that is, the view lies between the observer and the object, the opposite of first angle projection.

**19. (c) A shaft is dimensioned 30 plus or minus 0.2 mm. Find the maximum and minimum limits, and the worst-case clearance or interference with a hole of 30 plus or minus 0.1 mm. (4 marks)**

(c) Shaft limits are 30.2 mm and 29.8 mm; hole limits are 30.1 mm and 29.9 mm. Maximum clearance = 30.1 - 29.8 = 0.3 mm and maximum interference = 30.2 - 29.9 = 0.3 mm, so the fit can become an interference fit and a proper fit system such as H7/g6 should be specified.

**20. (d) Compare isometric and oblique projection for showing a solid, giving one suitable use for each. (4 marks)**

(d) An isometric drawing has three axes at 120 degrees with equal foreshortening, giving balanced depth, and suits exploded views and assembly instructions. An oblique drawing keeps the front face true in shape and size, which makes circles and detail easy to draw, with the depth axis receding at an angle, and suits part sketches where the front detail must be measured directly.

## Section F: Design, Sustainability and Intellectual Property (16 marks)

**Answer in full sentences.**

**21. (a) State three principles of sustainable design and give a product example for each. (4 marks)**

(a) 1. Reduce material: use the least material that meets the function, for example a thin sheet metal case instead of a solid block. 2. Design for disassembly and recycling: snap fits instead of adhesive, as in a torch with a replaceable battery. 3. Extend life and ease repair: modular parts replaced individually, as in a water filter with replaceable cartridges.

**22. (b) What is a product life cycle assessment and which stages does it usually cover? (4 marks)**

(b) Life cycle assessment quantifies the environmental impact of a product from cradle to grave. It usually covers raw material extraction, manufacture, distribution, use and end of life, converting energy use, carbon emissions, water and pollutants at each stage into comparable indicators so that the dominant stage can be identified.

**23. (c) How do a registered design and a standard patent differ in what they protect? Give one example for each. (4 marks)**

(c) A registered design protects the appearance, shape, pattern or ornament of a product, not its function, for example the distinctive outline of a chair. A standard patent protects the technical concept, construction or method, and requires novelty, inventiveness and industrial application, for example the locking mechanism of a folding chair.

**24. (d) Using ergonomic principles, state two factors to consider when designing a hand tool handle and the consequence of ignoring them. (4 marks)**

(d) 1. Grip diameter and shape: about 30 to 40 mm, slightly oval and shaped to the palm, spreads grip force and reduces local pressure; ignoring it causes blisters, higher grip effort and long-term tendon strain. 2. Keep the wrist near neutral: align the handle with the working axis to avoid flexion and ulnar deviation; ignoring it raises carpal tunnel pressure and leads to wrist pain and cumulative trauma.

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