S5 DAT Practice Paper 1 | Gear ratio, efficiency, moments, stress and circuits

Senior Secondary Design and Applied Technology

S5 DAT practice paper with worked answers: gear ratio and output speed, worm reduction, lever moments, material stress and safety factor, resistor networks and energy cost.

1. Gear ratio and output speed (16 marks)

Give speeds in rpm and velocity in m/s to 2 decimal places.

#	Question	Answer and marking notes
1	(a) A 60-tooth driver gear at 900 rpm drives a 40-tooth driven gear. Find the gear ratio and the driven speed.	Gear ratio = 60 / 40 = 1.5; driven speed = 900 / 1.5 = 600.0 rpm, torque is 1.5 times larger.
2	(b) A three-gear train has a 48-tooth driver, a 16-tooth idler and a 24-tooth driven gear at 900 rpm input. Find the output speed and state the function of the idler.	Ratio = 48 / 24 = 2.0 (the idler does not change the ratio); output = 900 x 2.0 = 1800.0 rpm; the idler only reverses the direction.
3	(c) A single-start worm drives a 40-tooth worm wheel from a 1440 rpm motor. Find the reduction ratio and the output speed.	Reduction ratio = 40 / 1 = 40; output speed = 1440 / 40 = 36.0 rpm.
4	(d) The 40-tooth driven gear has a module of 2 mm. Find its pitch circle diameter and, using the 600 rpm in (a), the pitch line velocity in m/s.	Pitch diameter = 2 x 40 = 80 mm; velocity = pi x 0.08 x (600 / 60) = 2.51 m/s.

2. Mechanical advantage and efficiency (18 marks)

Show working; give efficiency to 1 decimal place.

#	Question	Answer and marking notes
5	(a) A pulley system lifts a 1500 N load with an effort of 375 N. Find the mechanical advantage.	MA = load / effort = 1500 / 375 = 4.0.
6	(b) While the effort moves 2.0 m the load rises only 0.4 m. Find the velocity ratio.	VR = effort distance / load distance = 2.0 / 0.4 = 5.0.
7	(c) Calculate the efficiency of the system and state where the remaining energy goes.	Efficiency = MA / VR x 100% = 4.0 / 5.0 x 100% = 80.0%; the remaining 20.0% is lost to friction, rope bending and deformation.
8	(d) The lift takes 5 s. Find the input work, output work, energy lost, and the input and output power.	Input work = 375 x 2.0 = 750.0 J; output work = 1500 x 0.4 = 600.0 J; loss = 150.0 J; input power = 750.0 / 5 = 150.0 W; output power = 120.0 W.

3. Levers and moment balance (16 marks)

Give moments in N m and write the balance equation.

#	Question	Answer and marking notes
9	(a) A 250 N downward force acts 0.8 m to the left of a fulcrum. What force is needed at 0.5 m to the right to balance it?	250 x 0.8 = F x 0.5, so F = 200 / 0.5 = 400.0 N.
10	(b) A 120 N weight hangs 0.45 m to the left of the fulcrum. What weight is needed at 0.36 m to the right?	Moment = 120 x 0.45 = 54.0 N m; required weight = 54.0 / 0.36 = 150.0 N.
11	(c) A handle is 0.25 m long and an effort of 160 N is applied at right angles. Find the moment and explain why an inclined effort gives a smaller effective moment.	Moment = 160 x 0.25 = 40.0 N m; an inclined effort contributes only its perpendicular component (F sin theta), so the effective moment is F x d x sin theta.
12	(d) A crowbar has a load arm of 0.25 m and an effort arm of 1.5 m for a 900 N load. Find the effort needed and the velocity ratio.	Effort = 900 x 0.25 / 1.5 = 150.0 N; VR = 1.5 / 0.25 = 6.0.

4. Material stress and safety factor (18 marks)

Give stress in MPa and use suitable units for strain and modulus.

#	Question	Answer and marking notes
13	(a) A tie bar of cross-section 150 mm^2 carries a tensile force of 4500 N. Find the tensile stress.	Stress = force / area = 4500 / 150 = 30.0 MPa.
14	(b) The 2.0 m gauge length extends by 1.2 mm under load. Find the strain and the Young modulus in GPa.	Strain = 1.2 / 2000 = 0.0006; Young modulus = 30.0 MPa / 0.0006 = 50 GPa.
15	(c) The yield strength is 240 MPa. Find the safety factor at the working stress of 30.0 MPa and judge whether it meets the usual design requirement (at least 3).	Safety factor = 240 / 30.0 = 8.0; since 8.0 is at least 3, the design is acceptable.
16	(d) If the design code requires a safety factor of at least 3, find the allowable stress and the maximum permissible load on this bar.	Allowable stress = 240 / 3 = 80.0 MPa; maximum load = 80.0 x 150 = 12,000 N.

5. Resistor networks and power (16 marks)

Current may be given in mA; give power to 3 decimal places.

#	Question	Answer and marking notes
17	(a) A 180 ohm and a 270 ohm resistor are connected in series. Find the total resistance.	Series total = 180 + 270 = 450 ohm.
18	(b) The same pair is reconnected in parallel. Find the equivalent resistance.	Parallel: 1/R = 1/180 + 1/270, R = (180 x 270) / 450 = 108.0 ohm.

#	Question	Answer and marking notes
19	(c) The series combination is connected to 12 V. Find the current in mA and the voltage drop across the 180 ohm resistor.	Current = 12 / 450 = 26.7 mA; voltage across 180 ohm = 26.7 mA x 0.18 kohm = 4.800000000000001 V.
20	(d) Find the power dissipated in the 270 ohm resistor in W.	P = I^2 R = (0.0267)^2 x 270 = 0.192 W.

6. Energy, power and electricity cost (16 marks)

Take g = 9.81 m/s^2 and give energy to 2 decimal places.

#	Question	Answer and marking notes
21	(a) A hoist raises a 25 kg load through 1.8 m in 4 s. Find the work done and the average power.	W = mgh = 25 x 9.81 x 1.8 = 441.45 J; P = 441.45 / 4 = 110.4 W.
22	(b) If the motor input power is 160 W, find the system efficiency.	Efficiency = 110.4 / 160 x 100% = 69.0%.
23	(c) Find the energy lost as heat and sound during these 4 s.	Lost power = 160 - 110.4 = 49.6 W; lost energy = 49.6 x 4 = 198.6 J.
24	(d) If the system runs continuously for 2.5 hours at 160 W input, find the energy used in kWh and the cost at $1.20 per kWh.	Energy = 0.160 x 2.5 = 0.4 kWh; cost = 0.4 x 1.20 = $0.48.