S5 Design and Applied Technology Practice Paper: Mechanical Advantage and Efficiency, Gear and Belt Drives, Stress and Strain, Beam Moments, Fluid Pressure and Circuits (100 marks)

Level: S5 | Subject: Design and Applied Technology | 75 minutes | 100 marks | 24 questions | answer key

Section A: Mechanical Advantage and Efficiency (17 marks)

Each question is worth 4-5 marks; state the formula and units.

#	Question	Answer	Marks
1	A simple hoist lifts a load of 1200 N with an effort of 250 N. The load rises 0.80 m while the effort moves 4.80 m. (a) Find the mechanical advantage (MA). (b) Find the velocity ratio (VR). (c) Find the efficiency.	(a) MA = load / effort = 1200 / 250 = 4.8. (b) VR = effort distance / load distance = 4.80 / 0.80 = 6.0. (c) Efficiency = MA / VR x 100% = 4.8 / 6.0 x 100% = 80%.	4
2	A ramp is 3.00 m long and 0.90 m high. A load of 600 N is pulled up the ramp with an effort of 220 N. Find the velocity ratio, mechanical advantage and efficiency.	VR = ramp length / height = 3.00 / 0.90 = 3.33. MA = 600 / 220 = 2.73. Efficiency = 2.73 / 3.33 x 100% = 81.8%.	4
3	A screw jack has a handle 0.30 m long and a pitch of 4.0 mm. An effort of 90 N raises a load of 15000 N. Find the velocity ratio, mechanical advantage and efficiency.	VR = 2 pi r / pitch = 2 x 3.1416 x 0.30 / 0.004 = 471.2. MA = 15000 / 90 = 166.7. Efficiency = 166.7 / 471.2 x 100% = 35.4%.	4
4	A pulley system has 4 supporting rope sections. An effort of 300 N lifts a load of 1020 N, and the effort moves 2.00 m while the load rises 0.50 m. (a) Find MA and VR. (b) Find the efficiency. (c) Find the work input and the useful work output.	(a) MA = 1020 / 300 = 3.4; VR = 2.00 / 0.50 = 4.0. (b) Efficiency = 3.4 / 4.0 x 100% = 85%. (c) Work input = 300 x 2.00 = 600 J; useful work = 1020 x 0.50 = 510 J.	5

Section B: Gear and Belt Drives (17 marks)

Each question is worth 4-5 marks; give speed in rpm.

#	Question	Answer	Marks
5	A motor runs at 1440 rpm and its 20-tooth gear drives a 60-tooth gear. Find the output speed and the torque multiplication.	Speed = 1440 x 20 / 60 = 480 rpm. Torque multiplication = 60 / 20 = 3 times.	4
6	Pulley A is 80 mm in diameter and runs at 900 rpm; it drives pulley B of 240 mm diameter by belt with no slip. (a) Find the speed of B. (b) Find the belt linear speed.	(a) Speed = 900 x 80 / 240 = 300 rpm. (b) Belt speed = pi x diameter x rpm / 60 = 3.1416 x 0.080 x 900 / 60 = 3.77 m/s.	4
7	A gear train has a 24-tooth input gear driving a 48-tooth intermediate gear, which is on the same shaft as an 18-tooth output gear. Input speed is 600 rpm. (a) Find the output speed. (b) Find the overall ratio (output / input).	(a) Stage 1: 600 x 24 / 48 = 300 rpm; stage 2: 300 x 48 / 18 = 800 rpm. (b) Overall ratio = 800 / 600 = 1.333 (a speed increase of 1.33 times).	4
8	A gearbox takes 1500 W input and delivers 1320 W output. (a) Find the efficiency. (b) Find the power loss. (c) If all the loss becomes heat, find the heat generated in 5 minutes in kJ.	(a) Efficiency = 1320 / 1500 x 100% = 88%. (b) Loss = 1500 - 1320 = 180 W. (c) Heat = 180 x 300 s = 54000 J = 54 kJ.	5

Section C: Stress, Strain and Young Modulus (17 marks)

Each question is worth 4-5 marks; give stress in MPa and show the area calculation.

#	Question	Answer	Marks
9	A steel rod of 10 mm diameter carries a tensile force of 15 kN. Find the tensile stress in MPa (3 significant figures).	Area A = pi d^2 / 4 = 3.1416 x 0.010^2 / 4 = 7.854e-05 m2. Stress = F / A = 15000 / 7.854e-05 = 191.0 MPa.	4
10	The same steel rod is 2.00 m long and stretches 1.2 mm under the load. Find the strain and the Young modulus of the steel in GPa.	Strain = extension / original length = 0.0012 / 2.00 = 6.0e-04. Young modulus = stress / strain = 191.0 MPa / 6.0e-04 = 318.3 GPa.	4
11	An aluminium wire of 2.0 mm diameter and 1.50 m length has a Young modulus of 70 GPa and carries 500 N. Find the stress, the strain and the extension in mm.	A = 3.142e-06 m2; stress = 500 / 3.142e-06 = 159.2 MPa. Strain = stress / E = 159.2 x 10^6 / 70 x 10^9 = 2.27e-03. Extension = strain x length = 2.27e-03 x 1.50 m = 3.41 mm.	4
12	A steel cable of 8.0 mm diameter has a permissible stress of 250 MPa and a safety factor of 2.0. (a) Find the breaking load. (b) Find the maximum safe working load. Why is a safety factor used?	A = 5.027e-05 m2. (a) Breaking load = 250 x 10^6 x 5.027e-05 = 12.57 kN. (b) Safe load = 12.57 / 2.0 = 6.28 kN. The safety factor covers material defects, calculation errors, impact loads and fatigue so the structure does not fail in extreme conditions.	5

Section D: Moments, Beams and Centre of Gravity (17 marks)

Each question is worth 4-5 marks; give moments in N m.

#	Question	Answer	Marks
13	A spanner is 0.25 m long and a force of 120 N is applied at its end. Find the moment when the force is perpendicular to the handle, and when it acts at 60 degrees to the handle.	Perpendicular: M = F x d = 120 x 0.25 = 30.0 N m. At 60 degrees: M = 120 x 0.25 x sin 60 = 26.0 N m.	4
14	A student of 40 kg sits 1.20 m to the left of a seesaw pivot. What mass must sit 0.80 m to the right to balance it? (Ignore the plank weight.)	Moments balance: 40 x 1.20 = m x 0.80, so m = 48 / 0.80 = 60 kg.	4
15	A simply supported beam is 6.0 m long with a 900 N point load 2.0 m from the left end. Find the two support reactions and show that their sum equals the load.	Moments about the right end: R_left x 6.0 = 900 x (6.0 - 2.0), so R_left = 3600 / 6.0 = 600 N. R_right = 900 - 600 = 300 N. Sum = 600 + 300 = 900 N, equal to the load.	5
16	A uniform rod is 2.00 m long and weighs 200 N; a 300 N weight hangs from one end. Find the distance of the combined centre of gravity from that end.	Take the weighted end as origin: x = (200 x 1.00 + 300 x 0) / (200 + 300) = 200 / 500 = 0.40 m.	4

Section E: Fluid Pressure and Hydraulics (16 marks)

Each question is worth 4 marks; take g = 9.81 m/s2 and give pressure in kPa.

#	Question	Answer	Marks
17	What is the pressure at 12 m depth in a water tank (density 1000 kg/m3, g = 9.81	P = rho g h = 1000 x 9.81 x 12 = 117720 Pa, about 117.7 kPa. Pressure depends only on	4

	m/s2)? Why does the pressure not depend on the shape of the tank?	depth, density and g because the weight of the liquid column divided by area cancels the shape (P = rho g h).	
18	A pump delivers 0.80 m3/min of water through a 15 m lift. Find its useful output power in kW (density 1000 kg/m3).	Flow = 0.80 / 60 = 0.0133 m3/s. Power = rho g Q h = 1000 x 9.81 x 0.0133 x 15 = 1962 W, about 1.96 kW.	4
19	In a hydraulic jack the small piston is 20 mm in diameter with an applied force of 150 N; the large piston is 100 mm in diameter. Find the force it can raise and state the principle used.	Area ratio = (100 / 20)^2 = 25. Force = 150 x 25 = 3750 N. This follows Pascal principle: pressure is transmitted equally in a confined liquid, so P = F / A is the same on both pistons.	4
20	A cylinder has a gauge pressure of 600 kPa and a piston of 50 mm diameter. Find the piston force, and the work done per 120 mm stroke.	A = pi x 0.050^2 / 4 = 1.963e-03 m2. F = P x A = 600000 x 1.963e-03 = 1178 N (about 1.18 kN). Work = F x s = 1178 x 0.120 = 141 J.	4

Section F: Circuits and Power (16 marks)

Each question is worth 4 marks; state the Ohm law and power equations used.

#	Question	Answer	Marks
21	A 12 V supply is connected to a 220 ohm and a 330 ohm resistor in series. (a) Find the current in mA. (b) Find the voltage across each resistor.	Total resistance = 220 + 330 = 550 ohm. (a) I = 12 / 550 = 0.022 A = 21.8 mA. (b) V220 = 0.0 x 220 = 4.8 V; V330 = 12 - 4.8 = 7.2 V (ratio 220:330 = 2:3).	4
22	A 24 V supply is connected across 120 ohm and 180 ohm in parallel. Find the equivalent resistance, the total current and each branch current.	Equivalent resistance = (120 x 180) / (120 + 180) = 72 ohm. Total current = 24 / 72 = 0.333 A = 333 mA. Branch currents: 24 / 120 = 200 mA and 24 / 180 = 133 mA, which add up to 333 mA.	4
23	An electric kettle is rated 2000 W at 220 V and is used for 15 minutes. (a) Find the current and the element resistance. (b) Find the energy used in kWh. (c) Find the cost at 1.20 dollars per kWh.	(a) I = 2000 / 220 = 9.09 A; R = 220^2 / 2000 = 24.2 ohm. (b) Energy = 2.0 kW x 15/60 h = 0.5 kWh. (c) Cost = 0.5 x 1.20 = 0.60 dollars.	4
24	A potential divider has a 4.7 kohm and a 2.2 kohm resistor in series across 12 V, with the output taken across the 2.2 kohm resistor. Find the output voltage and suggest how to obtain about 5 V.	Vout = 12 x 2.2 / (4.7 + 2.2) = 3.83 V. To obtain about 5 V use a potentiometer, or choose resistors with an upper to lower ratio of about 1.4:1 (for example 4.7 kohm and 3.3 kohm gives 4.95 V).	4