S6 Design and Applied Technology Practice Paper | beam reactions, Euler buckling, water pressure, pump power, transformer loss and solar payback

Senior Secondary Design and Applied Technology

S6 Design and Applied Technology practice paper with answers: beam reactions, bending stress, buckling load, pump power, transformer loss and solar payback. Free PDF.

Question 1 Reactions and bending stress of a beam

A simply supported beam spans 8.0 m and carries a point load of 12 kN at 3.0 m from the left support. Its rectangular section is 150 mm wide and 300 mm deep, and the allowable bending stress is 12.0 MPa.

#	Question	Answer and marking notes
1	(a) Taking moments about the supports, calculate the reaction at each end.	Answer: right reaction = 4.5 kN and left reaction = 7.5 kN.
2	(b) Find the maximum bending moment and state where it occurs.	Answer: M = 22.5 kN m, directly under the point load.
3	(c) Calculate the section modulus and the maximum bending stress.	Answer: Z = 2,250,000 mm cubed and the stress is 10.0 MPa.
4	(d) Find the stress utilisation and judge whether the beam is safe under the allowable stress.	Answer: utilisation 83.3 per cent, so the beam is safe but with little reserve.

Question 2 Euler buckling load of a steel column

A steel column is pinned at both ends, 3.0 m long, with E = 200 GPa, second moment of area 8.0 x 10^-7 m^4 and effective length factor 1.0. The applied load is 60 kN.

#	Question	Answer and marking notes
5	(a) Use Euler formula to calculate the critical buckling load in newtons to three significant figures.	Answer: the critical load is about 175 kN.
6	(b) Find the ratio of the critical load to the applied load and comment on its adequacy.	Answer: the ratio is 2.92, well above the usual requirement of 2.0.
7	(c) If the column length is doubled to 6.0 m, find the new critical load and explain the change.	Answer: 44 kN, one quarter of the original, because the critical load varies with the inverse square of length.
8	(d) Suggest two practical ways to raise the critical load of the column and explain why they work.	Answer: fix the ends to shorten the effective length, and brace the weak axis or use a section with a larger second moment of area.

Question 3 Hydrostatic pressure and stored water weight

In a housing estate the water surface in the tank is 25.0 m above the lowest tap. The tank is a cylinder 4.0 m in diameter with 6.0 m of water. Take water density as 1,000 kg per cubic metre and g as 9.8 m per second squared.

#	Question	Answer and marking notes
9	(a) Find the hydrostatic pressure at the lowest tap in kilopascals.	Answer: 245.2 kPa.
10	(b) Calculate the stored volume and the weight of the water in kilonewtons.	Answer: volume 75.4 cubic metres and weight 740 kN.
11	(c) Find the pressure at 12.0 m below the water surface.	Answer: 117.7 kPa, which depends only on depth.
12	(d) If the tap needs at least 150 kPa to supply water, find the minimum height of the water surface.	Answer: at least 15.29 m above the tap.

Question 4 Pump power and electricity cost

A pumping station lifts water through 18.0 m at a flow of 0.02 cubic metres per second. The pump efficiency is 0.70, electricity costs 1.20 dollars per kWh and the pump runs 6.0 hours a day.

#	Question	Answer and marking notes
13	(a) Calculate the hydraulic power of the pump in kilowatts.	Answer: 3.53 kW.
14	(b) Find the electrical input power required.	Answer: 5.05 kW.
15	(c) Find the daily energy use and the daily electricity cost.	Answer: 30.27 kWh a day costing 36.33 dollars.
16	(d) If a new impeller raises efficiency to 0.80, find the new input power and the percentage saved.	Answer: 4.41 kW, a saving of 12.5 per cent.

Question 5 Step up transformer and line loss

A step up transformer raises the voltage from 11 kV to 132 kV with a primary current of 400 amperes. The total resistance of the transmission line is 6.0 ohms and the transformer is ideal.

#	Question	Answer and marking notes
17	(a) Find the transmitted power and the secondary current.	Answer: 4.40 MW and 33.3 amperes.
18	(b) Find the turns ratio of the transformer.	Answer: a step up ratio of 1 to 12.
19	(c) At 132 kV, find the line power loss and its percentage of the transmitted power.	Answer: about 6.67 kW, or 0.15 per cent.
20	(d) If the same power were sent at 11 kV, find the loss, its percentage and the ratio between the two cases.	Answer: 960 kW or 21.8 per cent, 144 times the loss at high voltage.

Question 6 Payback period of a rooftop solar system

A school roof carries 30 solar panels of 400 W peak each. The site has 4.0 peak sun hours a day with a performance ratio of 0.80. The system costs 180,000 dollars, electricity is 1.20 dollars per kWh and each kWh avoids 0.70 kg of carbon dioxide.

#	Question	Answer and marking notes
21	(a) Calculate the daily energy yield in kilowatt hours.	Answer: 38.4 kWh a day.
22	(b) Find the annual energy yield and the annual saving.	Answer: 14,016 kWh a year, saving 16,819 dollars.
23	(c) Find the simple payback period in years to two decimal places.	Answer: 10.70 years.
24	(d) Find the annual carbon dioxide avoided in tonnes and comment on whether the payback makes the investment worthwhile.	Answer: 9.8 tonnes a year; with a module life of 20 to 25 years a 11 year payback leaves over a decade of net saving.