Block 3 tutorials: Springs and Bolted Joints

Section A will be discussed in timetabled tutorial sessions. Section B contains a number of practice questions that resemble the format of class test and the final exam for you to complete in your own time. Model solutions will be made available after each block on LEARN.

Section A

Week 10

1. A helical compression spring is made of 1.18 mm wire having an ultimate tensile strength of 1350 MPa and modulus of rigidity of 96.8 GPa. It has an outside diameter of 12.7 mm and has 14 active coils.

   a) Find the maximum static load corresponding to the yield point of the material.
   b) What deflection would be caused by the load in a)?
   c) Calculate the spring rate.
   d) If the spring has one dead turn at each end, what is the solid length?
   e) What should be the free length of the spring so that when it is compressed solid the stress will not exceed the yield point?

2. A helical compression spring is required to exert a force of 3800 N when compressed to a length of 230 mm. At a length of 270 mm the force must be 2600 N. A nominal spring mean diameter of 65 mm and material chromium silicon steel wire have been proposed. The application involves slow cycling and a total life of 450 000 cycles is required. The maximum temperature of operation is 50°C.

   a) Find the spring rate.
   b) Estimate the wire diameter. Assume the Wahl factor as 1.2 and maximum allowable shear stress is 720 MPa.
   c) What is the spring index?
   d) What is the Wahl factor for the selected design?
   e) What is the maximum shear stress for the selected design?
   f) Calculate the number of active coils.
   g) Calculate the outer and inner diameters of the spring.

Week 11

3. Shown in Figure below is a 15 x 200 mm rectangular steel bar cantilevered to a 250 mm steel channel using four bolts. Based on the external load of 16 kN, find:
   a) The resultant load on each bolt.
   b) The maximum bolt shear stress.
   c) Select suitable grade for bolts based on this failure mode.

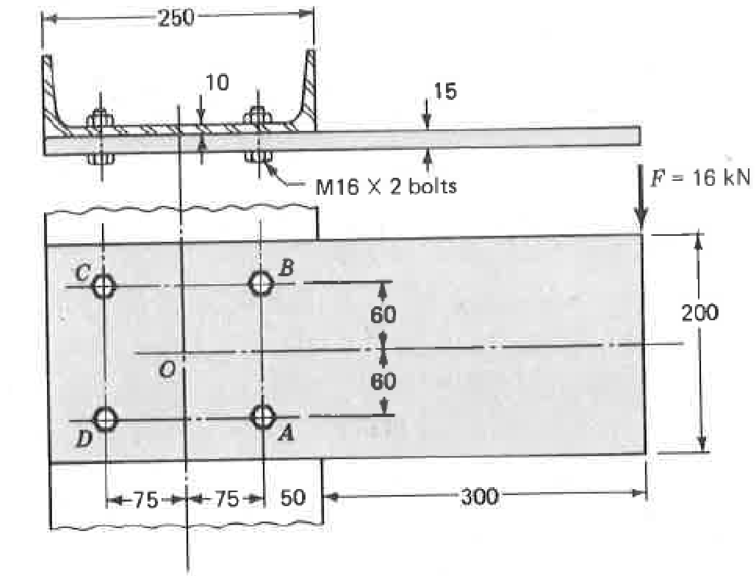
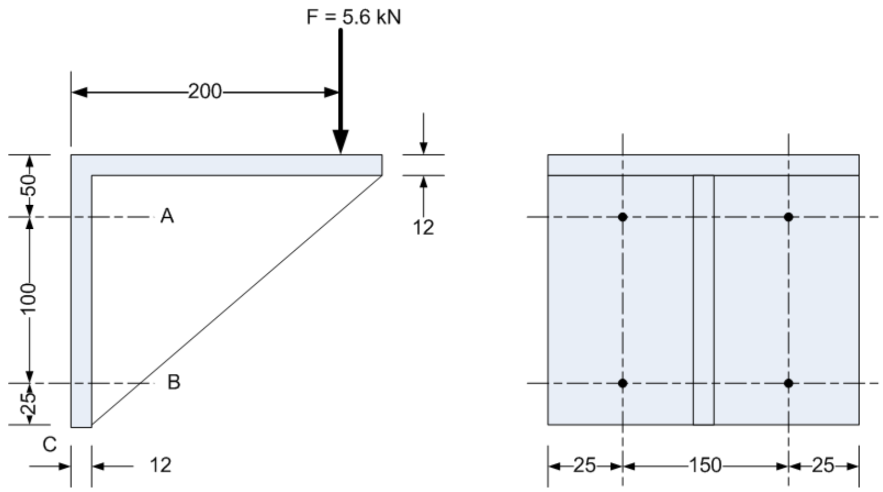


FIGURE 8-22 Dimensions in millimeters.

4. The figure shows a welded steel bracket which is to support a force F as shown below. The bracket is to be bolted to a smooth vertical face by means of four grade 5.8 M10 x 1.5 bolts, two on centreline A and the other two on centreline B. **Hint**: One way of analysing such a connection would be to assume that the bolts on centreline A carry the entire moment load and those on B carry the entire shear load.



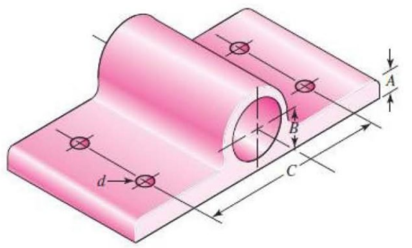
a) Find the external tensile load carried by the bolts at A.
b) What is the factor of safety of the connection based on the A bolts? Assume $k_m = 3k_b$.
c) Find the external shear load carried by the bolts at B.
d) What is the factor of safety of the connection based on the B bolts?

Section B

1. The outer of two concentric helical compression springs has a rate of 4 N/mm; the inner one has a rate of 3 N/mm. The outer spring is 10 mm longer than the inner one. If the total force on the two springs is 270 N, what force does each spring carry?

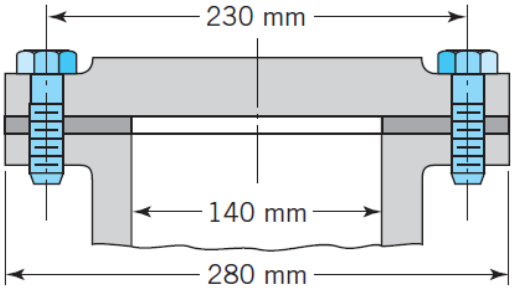
2. A helical compression spring is made of 4 mm wire having allowable yield shear strength of 740 MPa and a shear modulus of 80 GPa. It has an outside diameter of 20 mm and has 8 active coils. Assume a shear modulus of 80 GPa.
   a) Find the inner and mean diameter of the spring.
   b) What is the spring index? What are the likely consequences of having a very large spring index on a helical compression spring?
   c) Find the maximum static load, Fmax corresponding to the yield point of the material.
   d) Calculate the deflection at this particular load.
   e) Find the spring rate.
   f) If the spring has one dead turn at each end, calculate the maximum permissible free length of the spring – why should you not wind this spring to have a longer free length?
   g) If a spring with a larger outside diameter but otherwise similar were substituted, to operate at the same deflection as above, would the operating forces be increased, decreased or remain unchanged - explain?

3. The figure below shows a cast-iron bearing block that is to be bolted to a steel ceiling joist and is to support a gravity load. Bolts used are M20 ISO 8.8 with coarse threads. The joist flange are 20 mm in thickness, and the dimension A, shown in the figure, is 20 mm.



   The modulus of elasticity of the bearing block is 135 GPa.
   a) Find the wrench torque required if the fasteners are lubricated during assembly and the joint is to be permanent.
   b) Determine the safety factor against joint separation for the design if the gravity load is 15 kN. Take cast-iron block stiffness k_{block} = 3 x 108 N/m and steel ceiling joist stiffness k_{joist} = 1.5 x 108 N/m.

4. Figure shows a pressure vessel with a gasketed end plate. The internal pressure is sufficiently uniform that the bolt loading can be considered static. The gasket supplier advises a gasket clamping pressure of at least 13 MPa (this includes an appropriate safety factor) to ensure a leak-proof joint. To simplify the problem, you may neglect the bolt holes when calculating gasket area.



   a) If 12-, 16-, and 20- mm bolts that have coarse threads and are made of SAE class 8.8 or 9.8 steel (whichever is appropriate) are to be used, determine the number of bolts needed.
   b) If the ratio of bolt spacing to bolt diameter should not exceed 10 in order to maintain adequate flange pressure between bolts, and if this ratio should not be less than 5 in order to provide convenient clearance for standard wrenches, which of the bolt sizes considered gives a satisfactory bolt spacing?

Tables and Charts

Table: Material for springs

MATERIAL	YOUNG'S MODULUS (GPa)	MODULUS OF RIGIDITY (GPa)	DENSITY (kg/m^3)	MAXIMUM SERVICE TEMPERATURE (^oC)
Music wire	207	79.3	7860	120
Hard drawn wire	207	79.3	7860	150
Oil tempered	207	79.3	7860	150
Valve spring	207	79.3	7860	150
Chrome vanadium alloy steel wire	207	79.3	7860	220
Chrome silicon alloy steel wire	207	79.3	7860	245
302 stainless steel	193	69	7920	260
17-7 PH stainless steel	203	75.8	7810	315

Table: Constant K for determining tightening torque

CONDITIONS	K
¼ in. to 1 in. mild steel bolts	0.2
Non-plated black finish steel bolts	0.3
Zinc plated steel bolts	0.2
Lubricated steel bolts	0.18
Cadmium plated steel bolts	0.16

Table 15-2 Principal Dimensions of ISO Metric Standard Screw Threads
Data Calculated from Equations 15.1—See Reference 4 for More Information

	Coarse Threads			Fine Threads		
Major Diameter d (mm)	Pitch p mm	Minor Diameter d_r (mm)	Tensile Stress Area A_t (mm^2)	Pitch p mm	Minor Diameter d_r (mm)	Tensile Stress Area A_t (mm^2)
3.0	0.50	2.39	5.03			
3.5	0.60	2.76	6.78			
4.0	0.70	3.14	8.78			
5.0	0.80	4.02	14.18			
6.0	1.00	4.77	20.12			
7.0	1.00	5.77	28.86			
8.0	1.25	6.47	36.61	1.00	6.77	39.17
10.0	1.50	8.16	57.99	1.25	8.47	61.20
12.0	1.75	9.85	84.27	1.25	10.47	92.07
14.0	2.00	11.55	115.44	1.50	12.16	124.55
16.0	2.00	13.55	156.67	1.50	14.16	167.25
18.0	2.50	14.93	192.47	1.50	16.16	216.23
20.0	2.50	16.93	244.79	1.50	18.16	271.50
22.0	2.50	18.93	303.40	1.50	20.16	333.06
24.0	3.00	20.32	352.50	2.00	21.55	384.42
27.0	3.00	23.32	459.41	2.00	24.55	495.74
30.0	3.50	25.71	560.59	2.00	27.55	621.20
33.0	3.50	28.71	693.55	2.00	30.55	760.80
36.0	4.00	31.09	816.72	3.00	32.32	864.94
39.0	4.00	34.09	975.75	3.00	35.32	1028.39

Table 15-7 Metric Specifications and Strengths for Steel Bolts

Class Number	Size Range Outside Diameter (mm)	Minimum Proof Strength (MPa)	Minimum Yield Strength (MPa)	Minimum Tensile Strength (MPa)	Material
4.6	M5–M36	225	240	400	low or medium carbon
4.8	M1.6–M16	310	340	420	low or medium carbon
5.8	M5–M24	380	420	520	low or medium carbon
8.8	M3–M36	600	660	830	medium carbon, Q&T
9.8	M1.6–M16	650	720	900	medium carbon, Q&T
10.9	M5–M36	830	940	1 040	low-carbon martensite, Q&T
12.9	M1.6–M36	970	1 100	1 220	alloy, quenched & tempered