KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechanical Engineering

B. Sc. Engineering 2nd Year 2nd Term Examination, 2021

ME 2213

(Fluid Mechanics II)

Time: 3 Hours Full Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.
iii) Assume reasonable data if any missing.

SECTION-A

1(a) What are meant by Reynolds number and hydraulic diameter? Discuss their significance in fluid flow problems. 08

1(b) Derive an expression for the head loss in a pipe diameter D and length L in terms of Reynolds number and velocity head. 12

1(c) For the distribution main of Khulna WASA water supply, a main of diameter D is required. However, the authority decided to lay 'n' number of parallel mains of smaller diameter d, since the diameter D is not available in the market. Obtain a relationship between D and d. 15

2(a) Show that for a steady, incompressible laminar flow through circular pipes, the velocity distribution is – 18

$$\frac{V}{V_{\max}} = 1 - \left(\frac{r}{R}\right)^2$$, where symbols have their usual meanings.

2(b) Glycerin at 40°C ($\rho = 1252$ kg/m^3 and $\mu = 0.3073$ kg/m.s) is flowing steadily through a 4 mm diameter 1.2 m long horizontal pipe at an average velocity of 0.8 m/s. Determine: (i) the head loss, (ii) the pressure drop, and (iii) the pumping power requirement to overcome this pressure drop. 17

3(a) Explain boundary layer phenomena for a fluid flow over a flat plate. 10

3(b) Derive the expression for boundary layer thickness for laminar flow with zero pressure gradient over a flat plate using the momentum integral equation. 13

3(c) Water flows at 1 m/s past a flat plate of 1 m length in flow direction. The boundary layer is tripped so it becomes turbulent at the leading edge. Evaluate the disturbance thickness, δ, displacement thickness, δ^* and wall shear stress, τ_w at $x = 1$ m. Assume a 1/7 power turbulent velocity profile. 12

4(a) What are favorable and adverse pressure gradients? Discuss the flow separation phenomena in a diverging flow over a surface. Illustrate the effect of pressure gradient on boundary layer velocity profile. 15

4(b) A hydrofoil 0.35 m long and 1.8 m wide is placed in a sea-water flow of 12 m/s, with $\rho = 1025$ kg/m^3 and $\nu = 1.044\times10^{-6}$ m^2/s. 20

(i) Estimate the boundary layer thickness at the end of the plate.

(ii) Calculate the friction drag for (a) turbulent smooth-wall flow from the leading edge, (b) laminar turbulent flow with $Re_{trans} = 5\times10^5$, (c) turbulent rough-wall flow with $\epsilon = 0.12$ mm.

SECTION-B

5(a) What is impulse-momentum principle? Express the principle in mathematical forms applicable to (i) discrete body, and (ii) continuous, steady flow of fluid. 10

5(b) Apply the linear momentum equation to determine the exerted force of free jet of water on series of symmetric curved vanes attached on large wheel. Show that the maximum efficiency reduces to $\frac{1}{2}(1+\cos\theta)$, where θ is the angle of tangent line of tips with the horizontal. State the assumptions you made. 15

5(c) A 6 cm diameter 20°C water jet strikes a plate containing a hole of 4 cm diameter. Part of the jet passes through the hole, and part is deflected. Determine the horizontal force required to hold the plate in place. 10

6(a) Explain the characteristics of wave propagation with neat sketches for stationary source and moving source travelling at less, equal and greater speed than the speed of sound. 10

6(b) Explain how the shock waves and expansion waves are created? How the normal shock wave relations can be used for oblique shock wave analysis? 10

6(c) Air flows through a pipe of diameter 10 cm made of drawn tubing. At a particular location, its static temperature is 50°C. How much longer should the pipe be so that at the exit (static pressure and temperature are 1 atm and 20°C, respectively), the flow is at Mach 0.9? Assume friction factor $f = 0.02$. Take T^* as constant and use the relation below: 15

$$\frac{T}{T^*} = \frac{k+1}{2+(k-1)M^2}$$

7(a) Deduce an expression of the maximum mass flow rate for a compressible fluid flowing through a converging-diverging duct. 20

7(b) For a variable flow cross-sectional area, show that 15

$$\frac{dA}{dV} = \frac{A}{V}(M^2-1),$$ where symbols have their usual meanings.

Also, explain the variation of velocity with change in area for the subsonic and supersonic velocities.

8(a) Show that a normal shock wave decelerates a flow discontinuously from supersonic to subsonic conditions. 12

8(b) "Heating the fluid in a frictionless, constant area duct always drives to sonic condition" – Explain the statement in the light of Rayleigh curve. 08

8(c) Air at 1 MPa and 610°C enters a converging nozzle, with a velocity of 150 m/s. Determine the mass flow rate through the nozzle for a throat area of 60 cm^2 when the back pressure is 0.4 MPa. [Take $c_p = 1.005$ kJ/kg.K, $k = 1.4$ and $p^*/p_0 = 0.5283$] 15

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechanical Engineering

B. Sc. Engineering 2nd Year 2nd Term Examination, 2021

Math 2205

(Mathematics IV)

Time: 3 Hours | Full Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
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iii) Assume reasonable data if any is missing.

SECTION-A

1(a) Write down the Dirichlet conditions for Fourier series expansion. Obtain the Fourier series for the expansion of $f(x) = x\sin x$ in the interval $-\pi < x < \pi$, hence deduce that, 22

$$\frac{\pi}{4} = \frac{1}{2} + \frac{1}{1.3} - \frac{1}{3.5} + \frac{1}{5.7} - \cdots\cdots$$

1(b) Define odd and even function. if $f(t) = t^2, 0 \le t \le 1$ find half range Fourier sine series. 13

2(a) Write down the complex form of Fourier series. Find a series of sine and cosine multiple of x which represent $x + x^2$ in the interval $-\pi < x < \pi$ and hence deduce that, 20

$$\frac{\pi^2}{6} = \sum_{n=1}^{\infty} \frac{1}{n^2}$$

2(b) Use parseval's identity to the function $f(x) = \sin x$, $0 < x < \pi$ and show that, 15

$$\frac{1}{1^2.3^2} + \frac{1}{3^2.5^2} + \frac{1}{5^2.7^2} + \cdots\cdots = \frac{\pi^2 - 8}{16}$$

3(a) Define integral transform, find the kernel of the transform. Also find the kernel of Fourier sine transform. 09

3(b) Find the Fourier integral of the function 10

$$f(x) = \begin{cases} 1 & \text{for } \ 0 < x < k \\ 0 & \text{for } \ x > k \\ \pi/2 & \text{for } \ x = k \end{cases}$$

3(c) Solve the partial differential equation $\frac{\partial U}{\partial t} = 2\frac{\partial^2 U}{\partial x^2}$, $U(0,t) = 0$, $U(5,t) = 0$, $U(x,0) = 10\sin 4\pi x$ using Laplace transform. 16

4(a) Write down the existence conditions of a function to possess Laplace transform. 10

4(b) Find the inverse Laplace transform of the functions 10

$$F(s) = \frac{1}{s^2 + 6s + 13} \quad \text{and} \quad F(s) = \frac{1}{s(s^2 + 1)}$$

4(c) Solve the initial value problem 15

$$\frac{d^2y}{dt^2} + y = e^{-2t}\sin t\,,\ y(0) = y'(0) = 0$$

by the help of Laplace transform.

SECTION-B

5(a) Write down the Legendre differential equation. From the Rodrigue's formula 15

$$P_n(x) = \frac{1}{2^n\, n!}\frac{d^n}{dx^n}(x^2-1)^n$$

find the values of $P_0(x)$, $P_1(x)$, $P_2(x)$, $P_3(x)$ and roughly sketch their graphs.

5(b) Let $P_n(x)$ and $P_m(x)$ are two solutions of Legendre equation. Check whether they are orthogonal or not? 10

5(c) Express $4x^3 - 2x^2 - 3x + 8$ in terms of Legendre polynomials. 10

6(a) Write down the Bessel's differential equation. Also, write down the 1st kind and 2nd kind of Bessel's function. 08

6(b) Prove that, 12

(i) $J_{-1/2}(x) = \sqrt{\frac{2}{\pi x}}\cos x$ (ii) $\frac{d}{dx}\{x^n J_n(x)\} = x^2 J_{n-1}(x)$

6(c) Prove that, 15

$$\exp\left\{\frac{1}{2}x\left(z-\frac{1}{z}\right)\right\} = \sum_{n=-\infty}^{\infty} z^n J_n(x)$$

7(a) Form a partial differential equation by eliminating arbitrary constant a, b, c from 07

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$$

7(b) Form a partial differential equation by eliminating arbitrary function φ from $\varphi(x^2+y^2+z^2,\ z^2-xy)=0$. What is the order of the partial differential equation? 10

7(c) The diameter of a semicircular plate of radius 'a' is kept at 0°C and the temperature at the semicircular boundary is T°C. Show that the steady state temperature in the plate is given by 18

$$u(r,\theta) = \frac{4T}{\pi}\sum_{n=1}^{\infty}\frac{1}{2n-1}\left(\frac{x}{a}\right)^{2n-1}\sin(2n-1)\theta$$

8(a) Find the temperature of a thin metal bar of length L at different points from the heat transfer equation $\frac{\partial u}{\partial t} = c^2\frac{\partial^2 u}{\partial x^2}$ with the conditions $u(0,t)=u(L,t)=0$ and $u(x,0)=f(x)$. 25

8(b) Find the temperature $u(x,t)$ in a laterally insulated copper bar 80 cm long if the initial temperature is $100\sin\left(\frac{\pi x}{80}\right)$ °C and the ends are kept at 0°C. How long will it take for the maximum temperature in the bar to drop 50°C? (Given that $c^2 = 1.158\ \text{cm}^2/\text{sec}$) 10

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B. Sc. Engineering 2nd Year 2nd Term Examination, 2021

ME 2211

(Mechanics of Solid)

Time: 3 Hours Full Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
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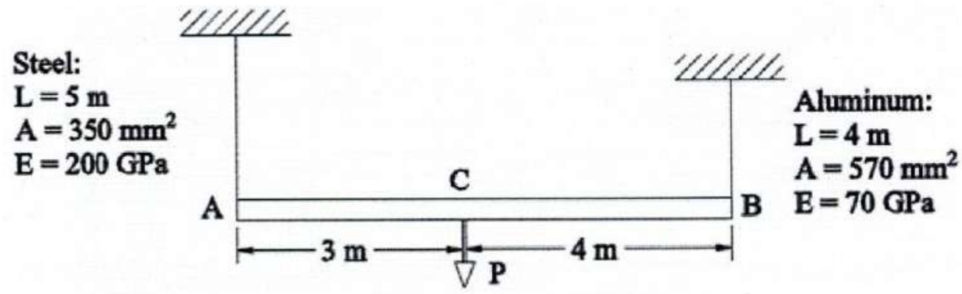
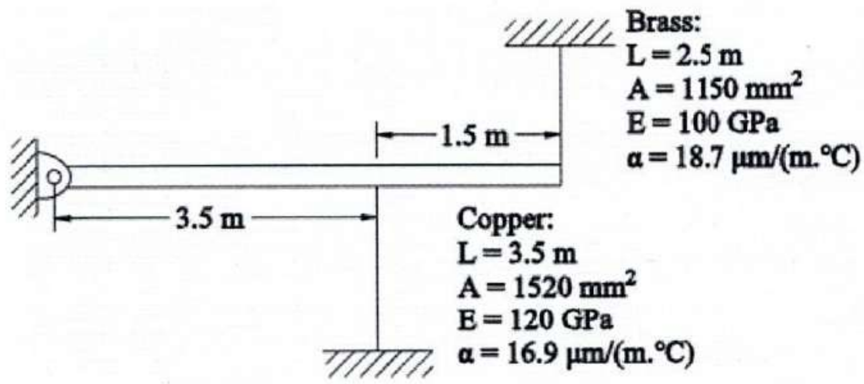
SECTION-A

1(a) What are the relations between hoop stress and longitudinal stress for thin-walled cylindrical shell? If it is subjected to internal pressure p having diameter D and wall thickness t; show that the longitudinal stress (σ_l) is $pD/4t$. 11

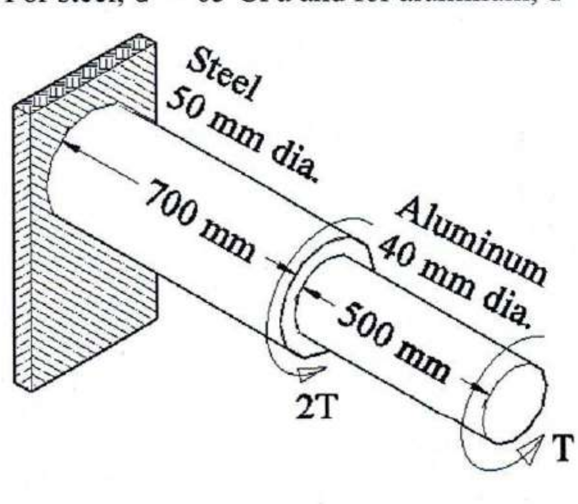
1(b) The rigid bar AB, attached to two vertical rods as shown in figure, is horizontal before the load P is applied. Determine the vertical movement of P if its magnitude is 65 kN. 13



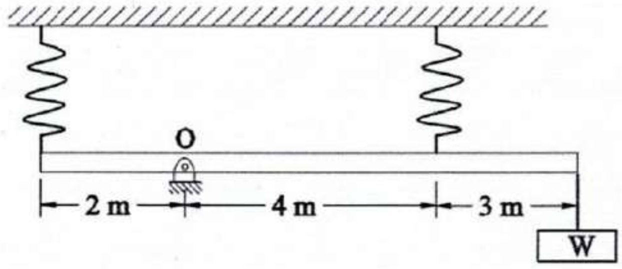
1(c) A rigid horizontal bar of negligible mass is connected to two rods as shown in figure. If the system is initially stress-free. Calculate the temperature change that will cause a tensile stress of 95 MPa in the brass rod. Assume that both rods are subjected to the change in temperature. 11



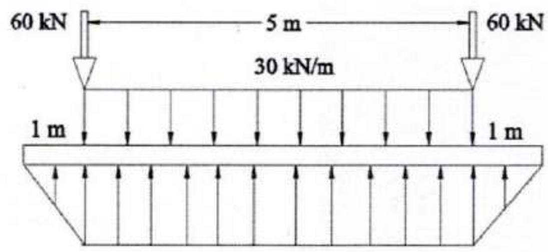
2(a) A compound shaft consisting of a steel segment and an aluminum segment is acted upon by two torques as shown in figure. Determine the maximum permissible value of T subjected to the following conditions: $\tau_{st} \leq 88$ MPa, $\tau_{al} \leq 60$ MPa, and the angle of rotation of the free end is limited to 7°. For steel, $G = 83$ GPa and for aluminum, $G = 28$ MPa. 18



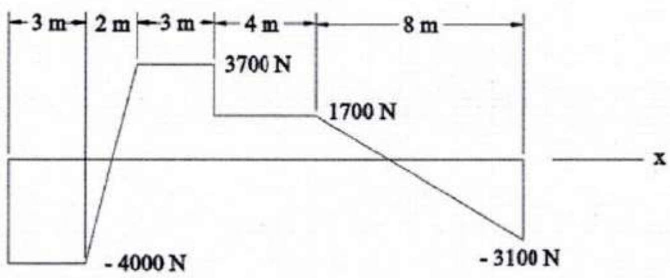
2(b) A rigid bar, pinned at O, is supported by two identical springs as shown in figure. Each spring consists of 20 turns of 18 mm wire having a mean diameter of 175 mm. determine the maximum load W that may be supported if the shearing stress in the springs is limited to 140 MPa. 17



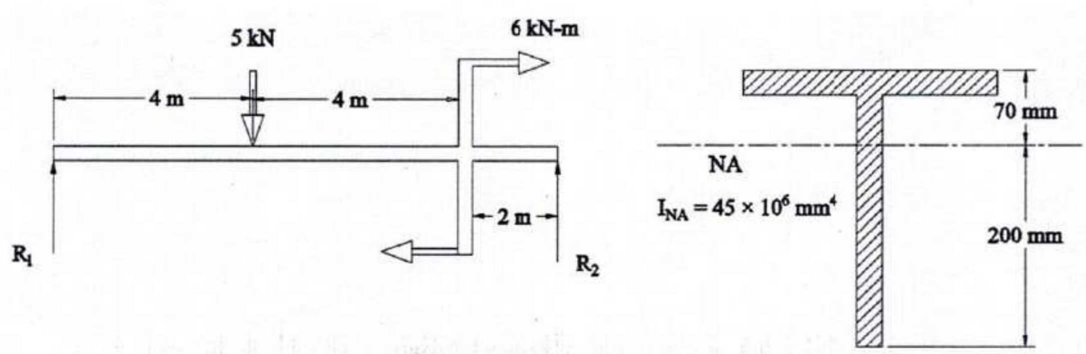
3(a) Without writing shear and moment equations, draw shear and moment diagrams for the beam loaded as shown in figure. Give numerical values at all change of loading positions and at all points of zero shear. 18



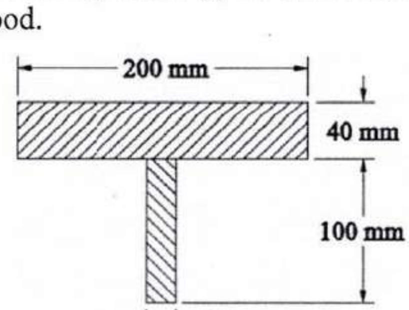
3(b) Draw moment and load diagrams corresponding to the given shear diagram as shown in figure. Specify values at all change of load positions and at all points of zero shears. 17



4(a) Determine the maximum tensile and compressive bending stress developed in the beam shown in the figure. 17

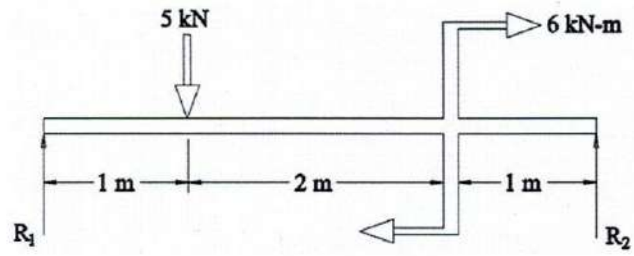


4(b) The T section shown in figure is the cross-section of a beam formed by joining two rectangular pieces of wood together. The beam is subjected to a maximum shearing force of 60 kN. Show that the NA is 34 mm from the top and the $I_{NA} = 10.57 \times 10^6$ mm^4. Using these values, determine the shearing stress (i) at the neutral axis and (ii) at the junction between the two pieces of wood. 18

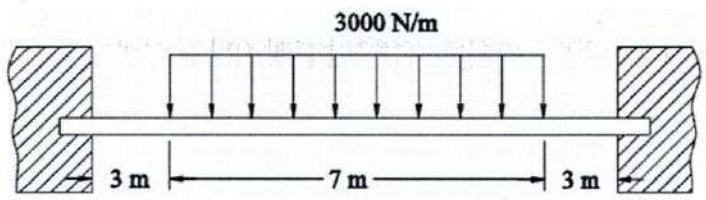


SECTION-B

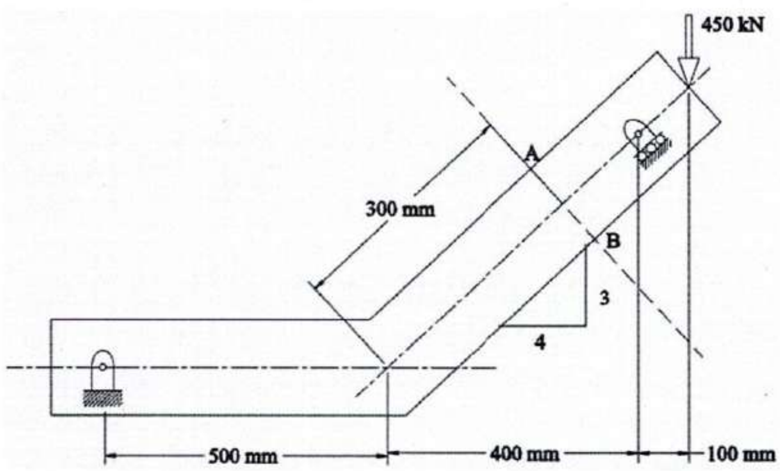
5(a) Determine the midspan value of $EI\delta$ for the beam loaded as shown in figure. 18



5(b) For the restrained beam shown in figure, compute end moments and maximum $EI\delta$. 17



6(a) The bent steel bar shown is 200 mm square. Determine the normal stresses at A and B. 16



6(b) The state of stress at a point is the result of two separate actions: one produces the pure shear of 30 MPa shown in Fig. (i) and other produces the pure shear of 40 MPa shown in Fig. (ii). Find the resultant stress by rotating the state of stress in Fig. (ii) to coincide with that in Fig. (i) so that the stresses can be superimposed and added directly. After that determine the principal stresses and principal planes for the combined state of stress. Show all results on complete sketches of differential elements. 19

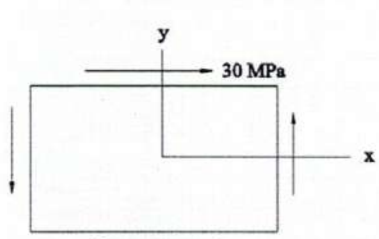


Fig. (i)

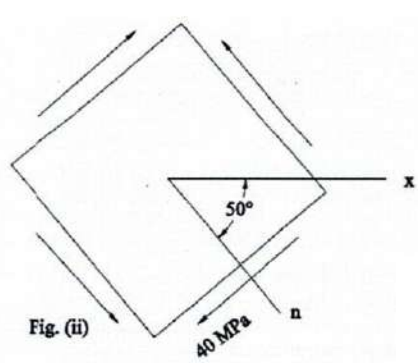
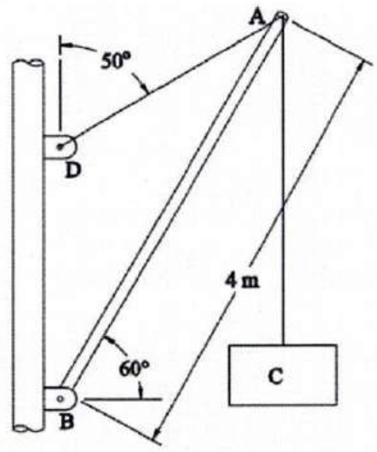
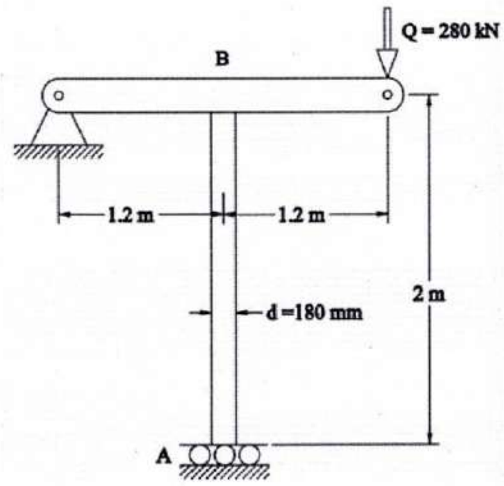


Fig. (ii)

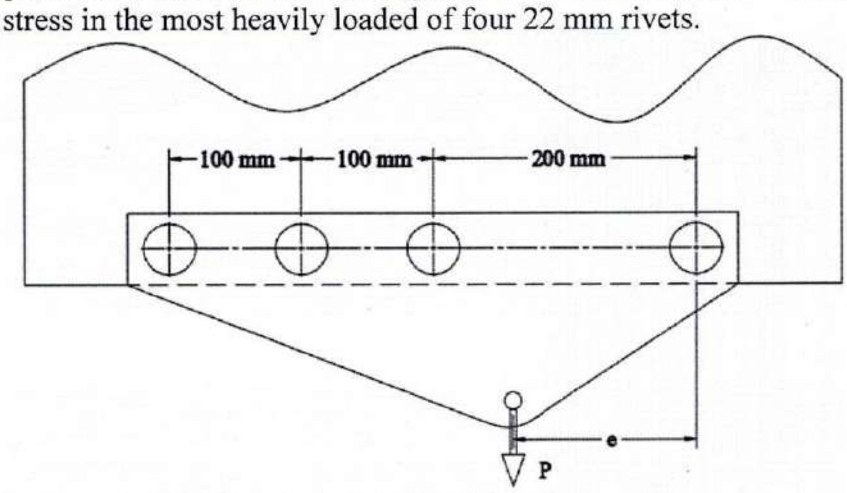
7(a) If the diameter of the solid steel rod AB is 60 mm, determine the maximum mass C that the rod can support without buckling. Use F.S. = 2.5 against buckling. Also, check the validity of the Euler's formula. 18



7(b) An aluminum tube of AB of circular cross-section has a guided support at the base and is pinned at the top to a horizontal beam supporting a load Q = 280 kN. Determine the required thickness t of the tube if its outside diameter d is 180 mm and F.S. = 2.5. Use, E = 75 GPa. 17



8(a) In the gusset plate connection shown in the figure, if $e = 150$ mm and $P = 30$ kN, determine the shearing stress in the most heavily loaded of four 22 mm rivets. 16



8(b) A plate is lapped over and welded to a gusset plate as shown in figure below. Determine the size of fillet welds to be specified using $\tau = 140$ MPa through the throats of welds. What maximum value P can be applied vertically if 7 mm welds are used? 19