MADE EASY

MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-5: Production Engineering and Material Science
Strength of Materials and Mechanics-1
Fluid Mechanics and Turbo Machinery-2

Name: Rakesh Singh Shekhawat

Roll No: M E 1 9 M T D L A 6 7 6

Test Centres

Delhi ☑ Bhopal ☐ Noida ☐ Jaipur ☐ Indore ☐
Lucknow ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Patna ☐
Hyderabad ☐

Student's Signature

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	40
Q.2	43
Q.3	—
Q.4	—
Section-B	
Q.5	28
Q.6	—
Q.7	39
Q.8	50
Total Marks Obtained	200

Signature of Evaluator Cross Checked by

Do not write in this margin

Section A : Production Engineering and Material Science

a) Iodine has an orthorhombic unit cell for which the a, b and c lattice parameters are 0.479 nm, 0.725 nm and 0.978 nm, respectively.

(i) If the atomic packing factor and atomic radius are 0.547 and 0.177 nm, respectively. Determine the number of atoms in each unit cell.

(ii) What will be the density of Iodine, if atomic weight of Iodine is 126.9 g/mol?

[12 marks]

→

$$\text{atomic packing factor} = \frac{n \times \text{vol. of atom}}{\text{volume of unit cell}}$$

$r = 0.177$ nm

$1\,nm = 10^{-9}\,m = 10^{-7}\,cm$

$$0.547 = \frac{n \times \frac{4}{3}\cdot\pi\cdot r^3}{abc}$$

$$0.547 = \frac{n \times \frac{4}{3}\cdot\pi \times 0.177^3\,nm^3}{0.479 \times 0.725 \times 0.978}$$

$n \simeq 7.998$ $n = 8$

(ii) $\boxed{\text{density} = \frac{\text{mass}}{\text{volume}}}$ $\rho = \frac{n \cdot m}{N_A \cdot \text{Volume of unit cell}}$ —(A)

$$\rho = \frac{8 \times 126.9}{6.023 \times 10^{23} \times (0.479 \times 0.725 \times 0.978) \times (10^{-7})^3}$$

$$\rho = \frac{1015.2}{204.56}$$

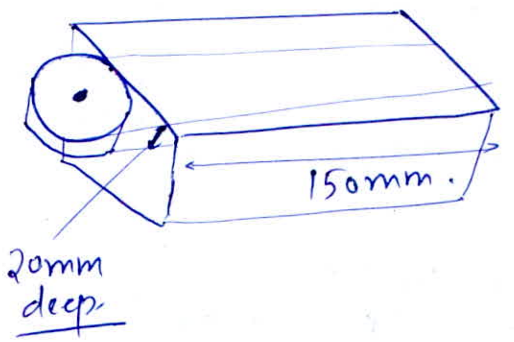
$$\boxed{\rho = 4.96\,g/cm^3}$$

in Eq. A
N_A = avagadro's number
m = atomic mass.

12

Q.1 (b) A 20 mm deep slot is to be cut through a workpiece of 150 mm length with the help of HSS side and face cutter whose diameter is 120 mm and has 10 teeth. The cutting speed is 40 m/min and feed is 0.20 mm per teeth. Calculate the time required to machine the slot.

[12 marks]



$V = \frac{\pi D N}{60}$

$40 = \frac{\pi \times 120 \times N}{1000}$

$N = 106.10$ rpm

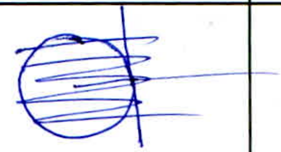
feed $= f_t \times Z$

$= 0.20 \times 10 = 2$ mm/rev

axial feed $f_a = f \times N = 2 \times 106.10 = 212.2$ mm/min

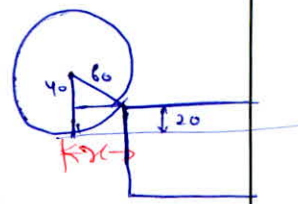
Total distance $= L + x_{overtravel}$

$x_{overtravel} = $ ~~...~~



$= 60 - \sqrt{60^2 - 40^2}$

$= 15.278$ mm.



$x = \sqrt{60^2 - 40^2}$

$= \sqrt{100 \times 20}$

$= 44.72$ mm

$\text{time} = \frac{L_{Total}}{f_a}$

$= \frac{150 + 15.278}{212.2 \text{ mm/min}}$

$= 0.7788$ min

$= 46.73$ sec.

03

(c) Design general type GO and NO GO gauges for components having $25H_8f_9$ fit. The basic size falls in the diameter range of 18 – 30 mm. The fundamental deviation for '*f*' shaft = $(-5.5D^{0.41})$ microns. Take gauge tolerance as 10% of work tolerance. Sketch the gauges with important values. The multipliers for 8 and 9 grades are 25 and 40 respectively.

[12 marks]

$25 H_8 f_9$. H → means Hole will have zero fundamental deviation.

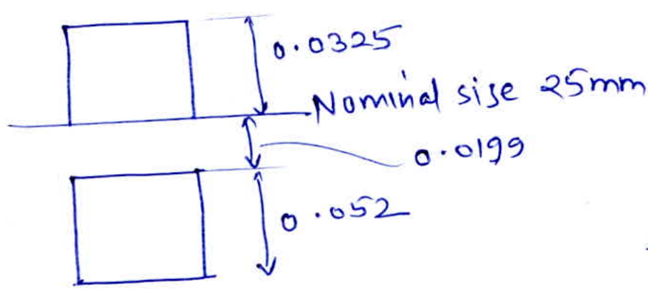
$D = \sqrt{18 \times 30} = 23.23$ mm.

$i = 0.45\sqrt[3]{D} + 0.001D = 1.307\ \mu m = 0.0013$ mm.

$25i$ = tolerance grade of Hole = 0.0325 mm.

$40i$ = tolerance grade of Shaft = 0.052 mm.

$fd = -5.5D^{0.41} = -5.5 \times 23.23^{0.41} = 0.0199$ mm.



gauge tolerance = 0.1×0.0325
= 0.00325 mm.

for Hole

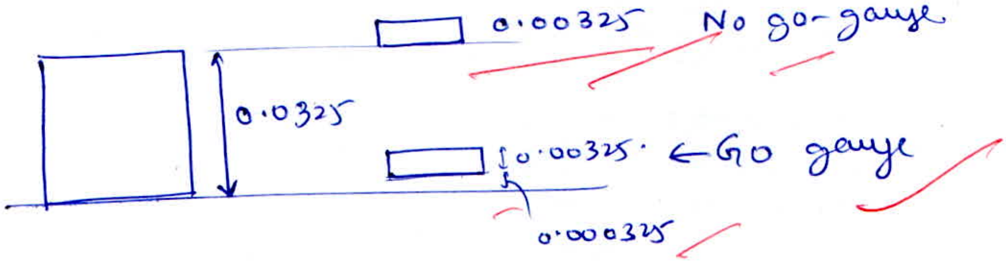
for shaft = 0.1×0.052
= 0.0052 mm.

~~Neglecting~~ Wear tolerance = $\frac{1}{10}$ of gauge T.

W.T of Hole = 0.000325 mm

WT of shaft = 0.00052 mm.

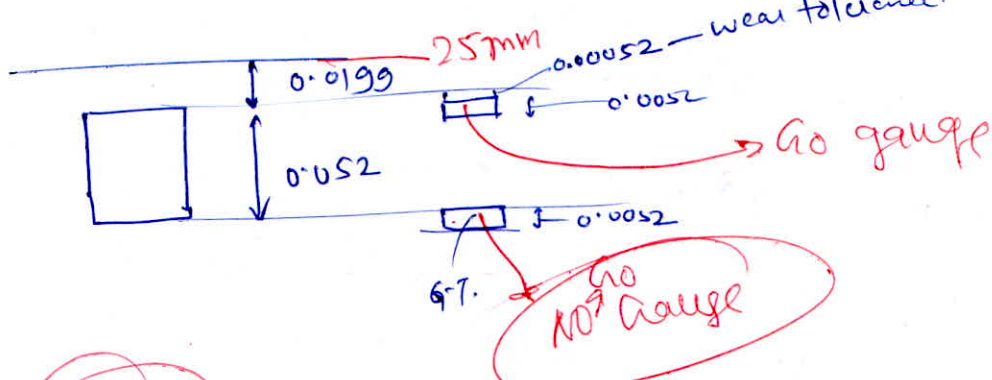
for No-Go and Go for Hole (in ISO tolerance type)



Dimension of Go = 25.00325 to 25.002575 mm

Dimension of No-Go gauge = 25.0325 to 25.03575 mm.

Similarly for Shaft



11

(d) What do you understand by fatigue? What are different stages of fatigue failure? What are factors which are necessary for fatigue failure?

[12 marks]

⇒ fatigue is condition of loading on an object of varying magnitude of stresses or varying direction of stresses. or both.

Fatigue can result in fatigue failure in which the material fails to perform its function even before the stresses in it reaches the yield or ultimate stresses.

add few more facts about crack initiation

factors

① The magnitude or direction of external load must change or both simultaneously.

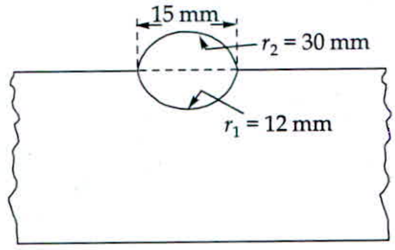
② Presence of stress concentration factor enhances the chances of fatigue failure.

03

Write down few more points

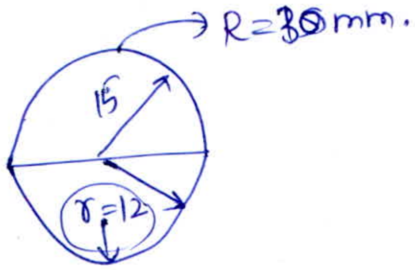
ME MADE EASY Question Cum Answer Booklet | Page 8 of 57
Do not write in this margin

Q.2 (a) The cross-section of weld bead is shown in figure. The profile of the bead and the fusion zone are taken circular for convenience. Bead width and radii of curvature of circular profiles are shown in figure. What is percentage dilution?

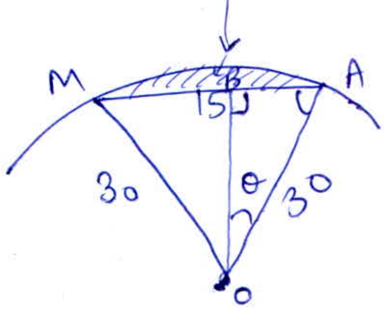


[20 marks]

→ percentage dilution = $\dfrac{\text{Area of Penetration}}{\text{Area of Penetration} + \text{Area of Reinforcement}}$



Area of Reinforcement



AB = 7.5mm.

AO = 30.

$30 \sin\theta = 7.5$ mm

$\theta = 14.47$.

$2\theta = 28.955$

Ar ΔAOM = $\frac{1}{2} \times (30 \cos 14.47) \times (15) = 217.86 \text{ mm}^2$

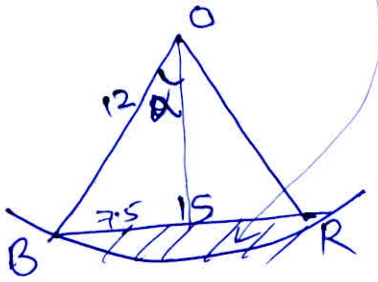
area of sector OAM $= \frac{28.955}{360} \cdot \pi \times 30^2$

$= 227.41 \text{ mm}^2$

Area of reinforcement $= 227.41 - 217.86$

$= 9.547 \text{ mm}^2$

Area of penetration:-



$12 \sin\alpha = 7.5$

$\alpha = 38.682$

$2\alpha = 77.364.$

Area of Δ OBR $= \frac{1}{2} \times 12(\cos 38.68) \times 15$

$= 70.256 \ mm^2$

Area of Sector OBR $= \frac{2\alpha}{360} \cdot \pi r^2$

$= 97.218 \ mm^2$

area of penetration:- $= 97.218 - 70.256$

$= 26.9624 \ mm^2$

Percentage dilution $= \frac{A_P}{A_P + A_R}$

$= \frac{26.9624}{26.9624 + 9.547}$

$= 0.7385$

73.85% dilution

Correct

19

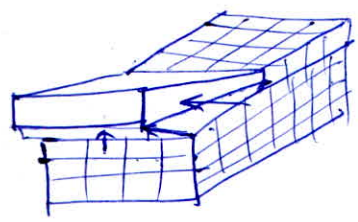
Movement of dislocation is specified by Burger vector. In case of edge dislocation

Do not write this m

Do not write this m

burger vector is perpendicular to slip plane.
Movement of planes when reaches at end results into fracture.

(ii) Screw Dislocation :-



The screw dislocation has the ~~gliding~~ climbing motion on the application of stresses. The Burger vector is parallel to dislocation line. and the motion is similar to the screwing motion of a screw when one rotation is provided as the screw moves in direction ⊥ to rotation. This is why these are named screw dislocation.

13

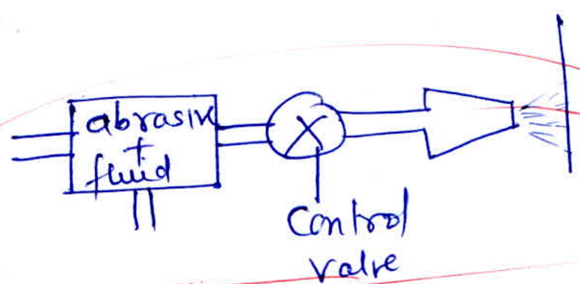
add mixed dislocation.

Please go through soln for more better points

(c) Explain the principle of abrasive water-jet machining using suitable schematic diagram. Write the advantages and applications of AWJM.

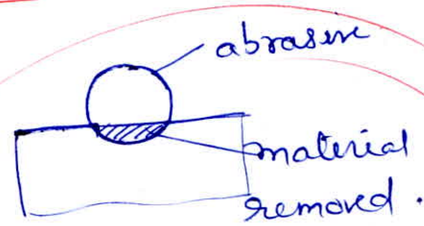
[20 marks]

→ Abrasive Water Jet maching is a non conventional machinig process which uses a fluid to carry high velocity abrasive particles which create the impact on the surface of workpiece. The impact creates stresses higher than the failure stresses and hence cause small pit fracture on surface. The machined surface containg the fractured material is carried away by the fluid particles.



Advantages:-

① Power consumption is lower as compared to other nonconventional processes.

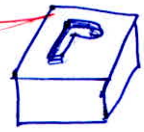


② Depending upon the type of abrasives used we can utilize the same system for maching alternate workpieces.

③ Automation of this AWJM is possible.

Applications:-

(1) Creating the symbols or designs on a workpiece using automation system.



(2) Various types of workpiece can be cutt easily by the AWJM process.

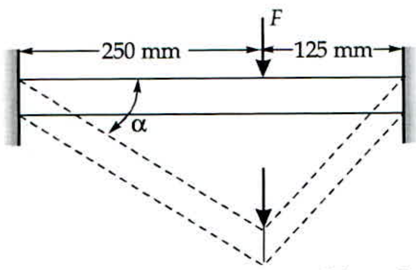
11

~~write~~

Please go through made easy soln

Do not write in this margin

(a) A 375 mm long sheet with a cross-sectional area of 5×10^{-4} m^2 is stretched with a force, F, until $\alpha = 20°$. The material has a true stress-true strain relationship as, $\sigma = (700 \text{ MPa})\epsilon^{0.3}$. Calculate:



(i) The total workdone, ignoring end effects and bending.

(ii) What is α_{max} before necking begins?

[20 marks]

Q.3 (b) Sketch the setup for spot welding and also explain about spot welding in detail. Show the pressure v/s time graph for different phases. Explain how melting efficiency is calculated? Write down major drawbacks of spot welding process and also write down process parameters for spot welding.

[20 marks]

Q.3 (c) For the lead-tin alloy 40 wt% Sn and 60 wt% Pb at 150°C. Assume that 10 wt% Sn is fully soluble in Pb at 150°C and 2 wt% Pb is fully soluble in Sn at 150°C. At 150°C densities of Pb and Sn are 11.23 g/cm^3 and 7.24 g/cm^3 respectively. Calculate the relative amount of α and β phase present in terms of (i) mass fraction and (ii) volume fraction. Also draw Pb-Sn phase diagram.

[20 marks]

Do not write in this margin

Q.4 (a) For a continuous and oriented fiber reinforced composite, the moduli of elasticity in the longitudinal and transverse directions are 33 GPa and 3.65 GPa, respectively. If the volume fraction of fibers is 0.30, determine the moduli of elasticity of fiber and matrix phases. Derive the relation used for modulus of elasticity in transverse direction.

[20 marks]

→ E long. = 33 GPa.

E transverse = 3.65 GPa

volume fraction = 0.3 = V

Do not write in this margin

(b) What is hardening of materials? Briefly explain different types of case hardening process used in heat treatment.

[20 marks]

(c) During turning a steel rod of 180 mm diameter by a carbide tool of geometry 0°, –12°, 7°, 5°, 30°, 60°, 0 (mm) at a speed of 600 rpm, feed of 0.32 mm/rev and 4 mm depth of cut, the following observations were made:

Tangential component of the cutting force, $F_z = 1000$ N

Radial component of the cutting force, $F_y = 200$ N

Chip thickness (after cut), $t_2 = 0.8$ mm

For the above machining conditions, determine:

(i) Friction force, F and normal force, N acting at the chip-tool interface.

(ii) Yield shear strength of the work material under this machining condition.

(iii) Cutting power consumption in kW.

[20 marks]

Do not write in this margin

Section B : SOM & Mechanics - 1, Fluid Mechanics and Turbo Machinery - 2

(a) The velocity field of a flow is described by $\vec{V} = (4x)\vec{i} + (5y+3)\vec{j} + (3t^2)\vec{k}$. What is the pathline of a particle at a location (1 m, 2 m, 4 m) at time $t = 1$ s?

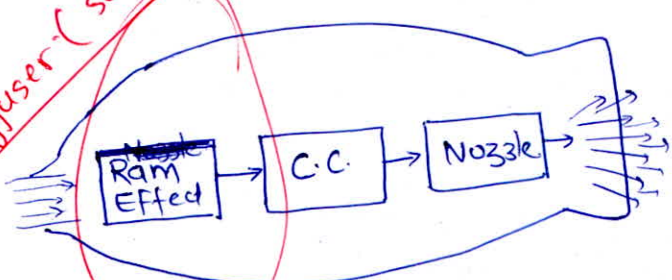
[12 marks]

⇒ $\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$ (Equation of streamline)

00

Q.5 (b) With the aid of a neat diagram, explain the working principle of a Ramjet engine. Also write its advantages.

[12 marks]



- Ram Jet Engine is a air breathing engine that doesn't use any compressor to compressor the inlet air. Rather it increases the pressure using the Ram Effect.
- A Diffuser is used to genrate the ram effect by allowing the conversion of high inlet air velocity to come to stagnation and hence increasing the pressure.

- Once the High pressure air is generated it enters the combustion chamber where the fuel is mixed with the air and burnt.
- The exhaust of the combustion chamber is then passed through nozzle and high velocity exhaust gas is genrated which is thrown out of Engine. This produces the required thrust.

Advantages:-

(1) The efficiency of the Ram Jet increases as the engine speed increases.

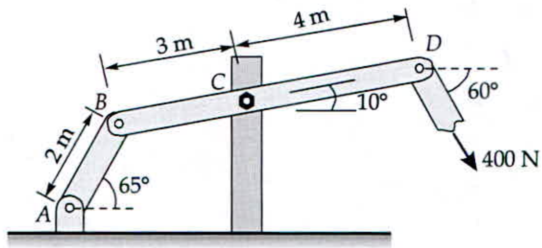
(2) These are suitable for the missiles which are carried forward by another Engine and hence providing the required speed.

(3) Because of Ram Effect these are best suitable for ~~Long~~ Short Range.

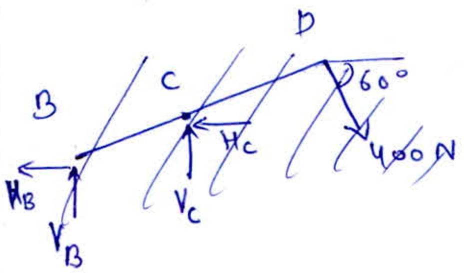
(4) They are light in weight as the compressors are not present. and neighter are turbines present.

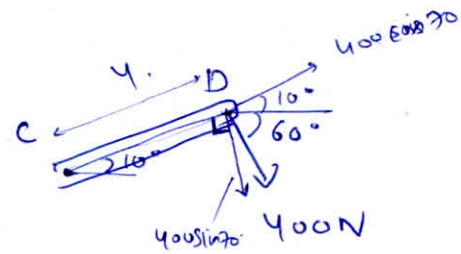
07

Q.5 (c) Member BD is hinged to a fixed support with the help of a bolt of diameter 2 cm. Member BD is 10 cm wide and 5 cm thick. Determine the shear stress in the bolt and bearing stress at *C* in member *BD*.



[12 marks]





Bending Moment at C = 400 sin70 × 4

= 1503.508 Nm

Shear force at C = 400 N.

shear stress in Bolt :- $= \frac{F}{A} = \frac{400}{\frac{\pi}{4} \times 0.02^2} = 1.273$ MPa

Bending stress in BD at C $= \frac{6M}{bd^2}$

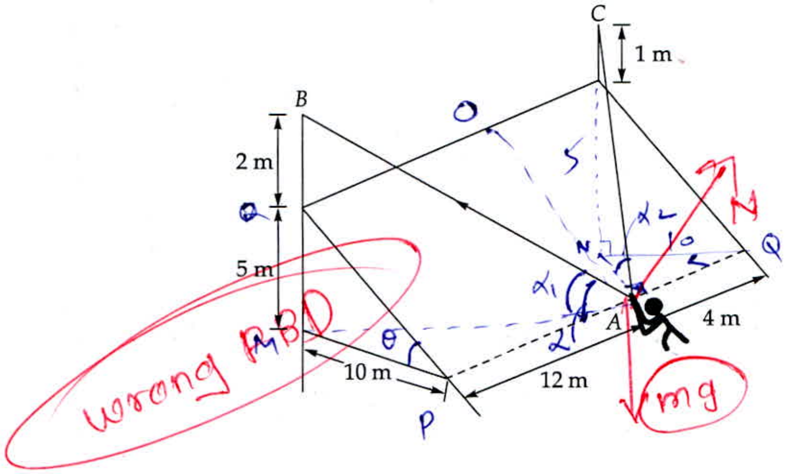
$= \frac{6 \times 1503.508}{0.10 \times 0.05^2}$

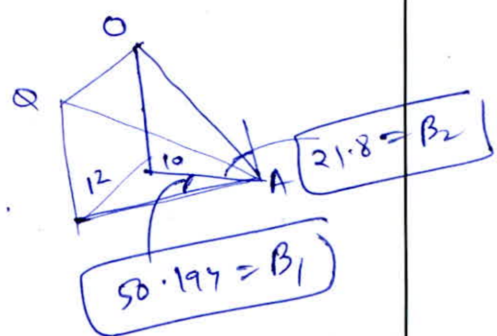
= 36.08 MPa.

conceptual error

00

(d) In trying to move across a slippery icy surface, a 75 kg man uses two ropes, *AB* and *AC*. Knowing that the force exerted on the man by the icy surface is perpendicular to the icy surface, determine the tension in each rope.





[12 marks]

$AM = \sqrt{PM^2 + AP^2} = 15.6204$

$AN = \sqrt{NQ^2 + AQ^2} = 10.77$

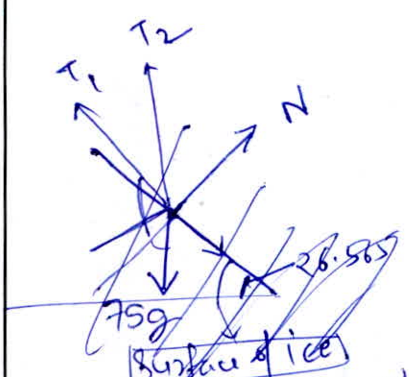
in ΔBMA $AB = \sqrt{BM^2 + MA^2} = 17.117$ $NC = 6m$

Similarly in ΔCNA, $AC = \sqrt{NC^2 + AN^2} = 12.3285$

$\alpha_1 = \tan^{-1}\left(\frac{7}{15.6204}\right) = 24.138$ ~~$\tan^{-1}(\theta) = \tan^{-1}\left(\frac{5}{10}\right)$~~

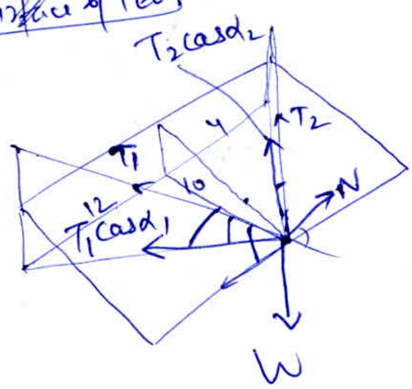
$\alpha_2 = \tan^{-1}\left(\frac{6}{10.77}\right) = 29.122$

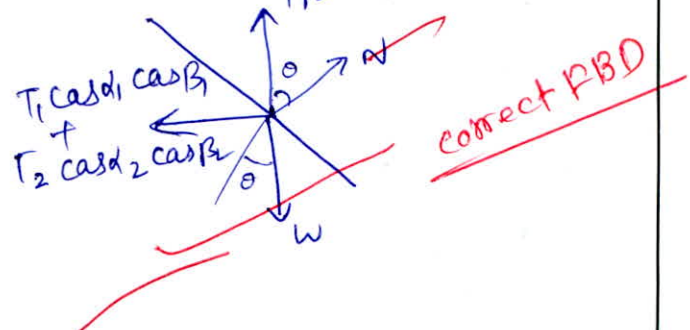
$\theta = \tan^{-1}\left(\frac{5}{10}\right) = 26.565$



Normal Component of Tension will be in the ~~direction~~ opposite W

$T_1 \sin\alpha_1$ and $T_2 \sin\alpha_2$





$N \sin\theta = T_1 \cos\alpha_1 \cos\beta_1 + T_2 \cos\alpha_2 \cos\beta_2$

$N \cos\theta + T_1 \sin\alpha_1 + T_2 \sin\alpha_2 = W = 75g.$

$T_1 \cos\alpha_1 \sin\beta_1 = T_2 \cos\alpha_2 \sin\beta_2$

$\alpha_1 = 24.138$
$\alpha_2 = 29.122$
$\beta_1 = 50.194$
$\beta_2 = 21.8$
$\theta = 26.565$

$T_1 = 0.4627 T_2$

$$\tan\theta = \frac{T_1(0.5842) + T_2 0.811}{75 \times 9.81 - 0.4089 T_1 - 0.4866 T_2} = 0.5$$

$T_2(1.0813) + T_2(0.3378) = 367.875$

$T_2 = 259.23$ N

$T_1 = 119.94$ N

11

Q.5 (e) (i) Allowable stress is determined from ultimate strength after considering factor of safety. State the rationale behind considering factor of safety.

(ii) The principal strains at a point loaded biaxially in a strained material are $\epsilon_1 = +500 \times 10^{-6}$, $\epsilon_2 = +300 \times 10^{-6}$. If $E = 200$ kN/mm^2, $\nu = 0.3$, what are principal stresses?

[6 + 6 marks]

(i) During the derivation of various strength of material formulaes there are various assumptions take and these assumptions are not valid under each and every condition. Because of this and various other factor like:-

(a) Environment condition like Temperature can change dimensions.

(b) Human Errors cannot be avoided as mistakes by mannual working are always are present.

(c) Machine Errors like Systematic errors, short period errors.

(d) Even some Random Erractic Errors can result in magnified stresses in the workpiece.

For all these factors, we reduce the maximum possible stress that we allow in the components. and design the dimensions. accordingly.
So this helps to avoid failure

(ii) $\varepsilon_1 = 500 \times 10^{-6}$ $\varepsilon_2 = 300 \times 10^{-6}$.

$$\sigma_1 = \frac{E(\varepsilon_1 + \mu \varepsilon_2)}{1-\mu^2}$$

$$= \frac{200 \times 10^3 \times (500 + 0.3 \times 300)}{1 - 0.3^2}$$

$$= 129.67 \text{ MPa}$$

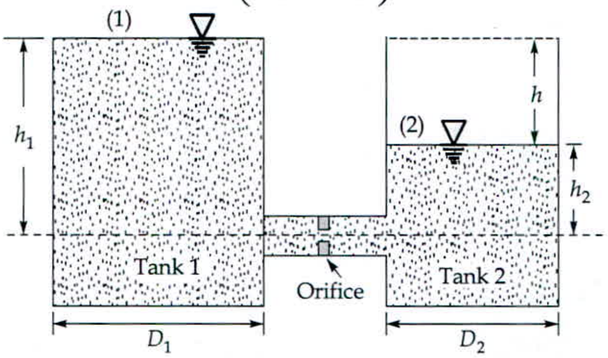
$$\sigma_2 = \frac{E(\varepsilon_2 + \mu \varepsilon_1)}{1-\mu^2} = 98.9 \text{ MPa}.$$

4+6=

10

Q.6 (a) A system that consists of two interconnected cylindrical tanks with diameter D_1 and diameter D_2 is to be used to determine the discharge coefficient of a short diameter (D_0) orifice. At the beginning ($t = 0$ second), the fluid heights in the tanks are (h_1) and (h_2) as shown in figure. If it takes 't_f' second for the fluid levels in the two tanks to equalize and the flow to stop, then show that the discharge coefficient (C_d) of the orifice is:

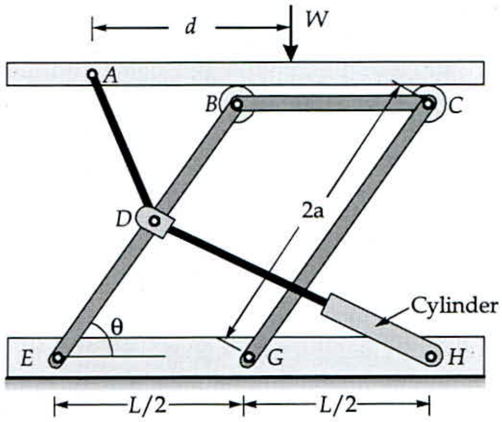
$$C_d = \frac{2\sqrt{(h_1 - h_2)}}{\left(\frac{D_0^2}{D_2^2} + \frac{D_0^2}{D_1^2}\right) \times t_f \times \sqrt{2g}}$$



Assume that the fluid is incompressible, and losses other than that associated with flow through the orifice are negligible.

[20 marks]

b) A hydraulic lift table is used to raise a 1000 kg crate. Member EB and GC are equal. Cylinder apply force in the direction DH. D is at mid point of EB. Determine the force exerted by the cylinder in raising the crate for $\theta = 60°$, $a = 0.7$ m, $L = 3.2$ m and $d = 1$ m.



[20 marks]

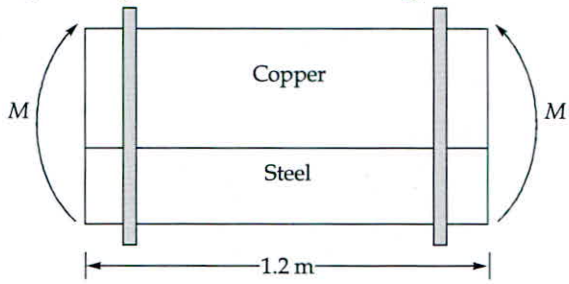
Do not write in this margin

(c) A helicopter gas turbine requires an overall compressor pressure ratio of 12 : 1. This is to be obtained using a two-spool layout consisting of a four stage axial compressor followed by a single stage centrifugal compressor. The polytropic efficiency of the axial compressor is 92% and that of the centrifugal compressor is 83%. The axial compressor is having a stage temperature rise of 32 K, using a 50 percent reaction design with a stator outlet angle of 25°. If mean diameter of each stage is 25.0 cm and each stage is identical, calculate the required rotational speed. Assume a work done factor of 0.85 and a constant axial velocity of 160 m/s.

Assuming an axial velocity at the eye of the impeller, an impeller diameter of 35.0 cm, a slip factor of 0.92 and power input factor of 1.04, calculate the rotational speed required for the centrifugal compressor. Ambient conditions are 1.01 bar and 288 K. Take $c_p = 1.005$ kJ/kgK and $\gamma = 1.4$.

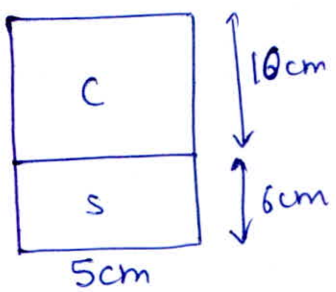
[20 marks]

Q.7 (a) Two beams are clamped together as shown in figure:



Both are of equal length and both have 5 cm width. Height of copper beam is 10 cm and that of steel beam is 6 cm. What could maximum moment that can be allowed without any failure of $E_{Cu} = 120$ GPa, $(\sigma_{allowable})_{Cu} = 150$ MPa, $E_{St} = 200$ GPa and $(\sigma_{allowable})_{St} = 250$ MPa?

[20 marks]



Since the beams are clamped.
Both will be having Same radius of Curvature

$$\frac{M}{I} = \frac{E}{R}. \qquad \boxed{R = \frac{EI}{M}}$$

$$\frac{E_c I_c}{M_c} = \frac{E_s I_s}{M_s}$$

$$I_c = \frac{5 \times 10^3}{12} = \frac{1250}{3} \text{ cm}^4 \qquad E_{cu} = 120$$

$$I_s = \frac{5 \times 6^3}{12} = 90 \text{ cm}^4. \qquad E_{st} = 200$$

$$\frac{M_c}{M_s} = \frac{E_{cu} I_{cu}}{E_s I_s} = \frac{120 \times \frac{1250}{3}}{200 \times 90}$$

$$\frac{M_c}{M_s} = \frac{25}{9}$$

also $M_s + M_c = M$

if (σ_{cu}) reaches first $= 150$ MPa.

$M_{cu} = \frac{bd^2}{6} \times \sigma_{cu} = \frac{5 \times 10^2}{6} \times 10^{-6} \times 150 \times 10^6$

$M_{cu} = 12500$ Nm.

then
$M_s = \frac{9}{25} \times 12500 = 4500$

$\sigma_s = \frac{6 \cdot M_s}{bd^2} = \frac{6 \times 4500 \times 10^6}{5 \times 6^2}$

$= 150$ MPa.

$\sigma_s \leq (\sigma_s)$ allowable

So this is possible

$M_{cu} = 12500$
$M_s = 4500$

$M = 17000$ Nm

19

Q.7 (b) **(i)** For a multi-stage steam turbine having same stage efficiency for all stages. Prove that, $\eta_{internal}$ = R.F. × η_{stage}

(ii) A 20 stage 50% reaction turbine develops a diagram power of 14 MW. The total isentropic enthalpy drop is 900 kJ/kg. The stage efficiency is 76% and the reheat factor is 1.05. The exit angle of blades is 20° and the blade velocity ratio is 0.7.

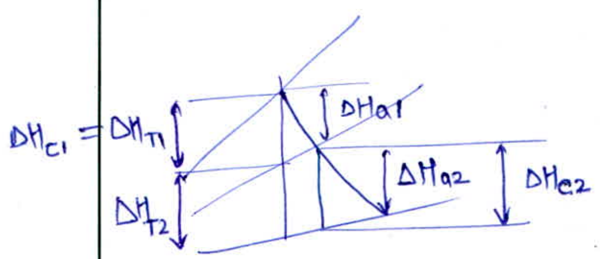
Calculate:

(p) Flow rate of steam required (in kg per hour) if all the stages develop equal work.

(q) Blade velocity

[10 + 10 marks]

(i) Reheat factor = $\frac{\text{Cumulative Isentropic drop}}{\text{Total Isentropic Drop}}$



Cumulative Isentropic drop $= \Delta H_{C1} + \Delta H_{C2}$

Total $\Delta H = \Delta H_{T1} + \Delta H_{T2}$

$$RF = \frac{\Delta H_{C1} + \Delta H_{C2}}{\Delta H_{T1} + \Delta H_{T2}}$$

$\frac{\Delta H_{a1}}{\Delta H_{c1}} = \eta_{stage\,1}$

$\frac{\Delta H_{a2}}{\Delta H_{c2}} = \eta_{stage\,2}$

for same stage efficiency

$$RF = \frac{\frac{\Delta H_{a1}}{\eta_s} + \frac{\Delta H_{a2}}{\eta_s}}{\Delta H_{T1} + \Delta H_{T2}} = \frac{1}{\eta_s}\left(\frac{\Delta H_{a1} + \Delta H_{a2}}{\Delta H_T}\right)$$

$$\frac{\Delta H_{a1} + \Delta H_{a2}}{\Delta H_T} = \eta_{internal}$$

So $\frac{1}{\eta_s}(\eta_{internal}) = RF$

$$\boxed{\eta_{int} = \eta_s \cdot R.F.}$$

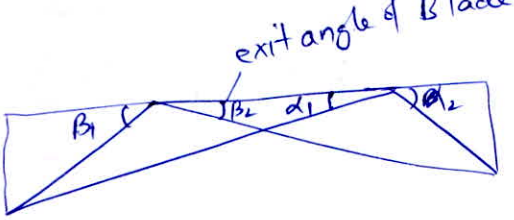
(ii) 20 stage 50% Reaction turbine

$P_1 = \frac{14}{20} \times 10^6 = 700\,kW$

$\eta_{internal} = 0.76 \times 1.05 = 0.798.$

Do not write in this margin

$\frac{P_{act}}{P_{theo}} = \eta_{int} = 0.798$ $P_{theo} = 877.19$ kW



$\frac{u}{V} = 0.7$

$\beta_2 = \alpha_1$ = 50% turbine.

$V = 44.74\sqrt{\frac{\Delta H}{2}}$ for reaction turbine.

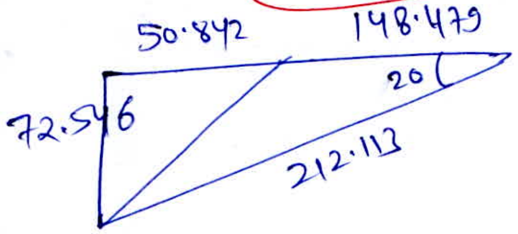
$\Delta H_1 = \frac{900}{20} = 45$ kJ/kg.

$V = 44.74\sqrt{\frac{\Delta H_1}{2}} = 4.743$ m/s $\times 44.72$

$V = 212.113$ m/s

$u = 148.479$. — Blade velocity.

Calculation error



$m(V_{w1} + V_{w2})u = P_{theo}$.

$m(250 - 163)(148.479) = 877.19 \times 10^3$

$m = 23.615$ kg/sec

$m = 85017.44$ kg/hr

13

Q.7 (c) Air enters a 10 m long section of a rectangular duct cross section 15 cm × 20 cm made of commercial steel at 1 atm and 35°C at an average velocity of 7 m/s. Disregarding the entrance effects. Determine the fan power needed to overcome the pressure losses in this section of the duct. Assume the flow is steady and incompressible. Consider the air properties at 1 atm and 35°C.

Density, $\rho = 1.145\ \text{kg/m}^3$

Dynamic viscosity, $\mu = 1.895 \times 10^{-5}\ \text{kg/m-s}$

kinematic viscosity, $\nu = 1.655 \times 10^{-5}\ \text{m}^2/\text{s}$

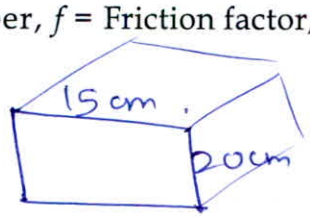
The roughness of commercial steel surfaces, $\varepsilon = 0.000045$ m.

For the friction factor, the governing equation is Colebrook equation:

$$\frac{1}{\sqrt{f}} = -2.0\log_{10}\left(\frac{\frac{\varepsilon}{D_h}}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$$

where, ε = Roughness of surface, D_h = Hydraulic diameter, Re = Reynolds number, f = Friction factor, $\frac{\varepsilon}{D_f}$ = Relative roughness

[20 marks]



$V = 7\ \text{m/s}$ $L = 10\ \text{m}$

$D_h = \frac{4A}{P} = \frac{4 \times 15\text{cm} \times 20\text{cm}}{2(35\ \text{cm})} = 17.1428\ \text{cm}$ = hydraulic dia.

$Re = \frac{7 \times 0.17428}{1.655 \times 10^{-5}} = 73713.59 = \frac{\rho V D}{\mu} = \left(\frac{VD}{\nu}\right)$

check calcul

$$\frac{1}{\sqrt{f}} = -2.0 \log_{10}\left(\frac{0.000045}{0.04633} + \frac{2.51}{73713.55\sqrt{f}}\right)$$

using Calculator:-

$$f = 0.029$$

Pressure losses due to friction:- (assuming other minor losses.)

$$h_L = \frac{fLV^2}{2gd_h} = \frac{0.029 \times 10 \times 7^2}{2 \times 9.81 \times 0.171428}$$

$$h_L = 4.2248 \text{ m.}$$

Power required = $\Delta P \cdot Q$.

$$= \rho g h_L \times Q$$

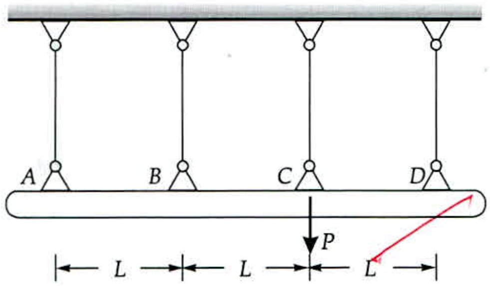
$$= (1.145 \times 9.81 \times 4.2248) \times (0.15 \times 0.2 \times 7)$$

$$= 9.9655 \text{ Watt.}$$

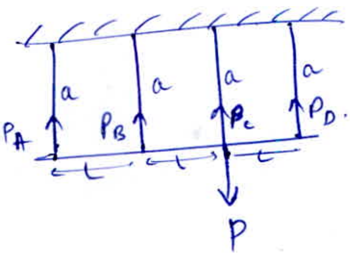
Check calculation ?

07

(4) The rigid rod *ABCD* is hinged with the help of 4 wires of equal length and cross-section area. Determine tension in each wire if force *P* is applied at *C* in downward direction. All the wires have same Young's modulus.



[20 marks]



a – area } of wires.
e – length }

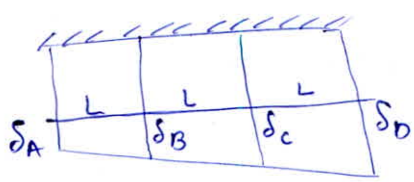
Applying static Equilibrium

$\Sigma F_y = 0$

$$P_A + P_B + P_c + P_D = P \quad \text{——— (1)}$$

$\Sigma M_C = 0$ $\quad P_A \times 2L + P_B L = P_D \times L$

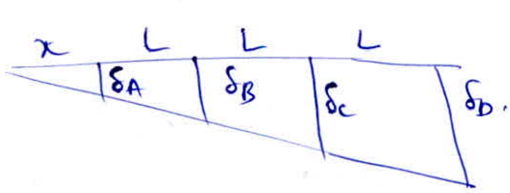
$$2P_A + P_B = P_D \quad \text{——— (2)}$$



$\delta_A = \dfrac{P_A e}{aE}$ $\quad$ let $k = \dfrac{e}{aE}$ = const. for all.

$\delta_B = P_B k$

$\delta_c = P_c k$ $\quad \delta_D = P_D k$.



$$\frac{\delta_A}{x} = \frac{\delta_B}{x+L} = \frac{\delta_c}{x+2L} = \frac{\delta_D}{x+3L}$$

$$\frac{\delta_B}{\delta_A} = 1 + \frac{L}{x}$$

$$\frac{P_B}{P_A} - 1 = \frac{L}{x}$$

$$x = \frac{L \cdot P_A}{P_B - P_A} \quad \text{— (3)}$$

using eq-3

$$\frac{\delta_B}{\delta_c} = \frac{P_B}{P_c} = \frac{\frac{P_A L}{P_B - P_A} + L}{\frac{P_A L}{P_B - P_A} + 2L}$$

$$\frac{P_B}{P_c} = \frac{P_B L}{(2P_B - P_A)L}$$

$$\frac{P_B}{P_c} = \frac{P_B}{2P_B - P_A}$$

$$P_c = 2P_B - P_A \quad \text{— (4)}$$

also $\dfrac{\delta_B}{\delta_D} = \dfrac{x+L}{x+3L}$

$$\frac{P_B}{P_D} = \frac{\frac{P_B L}{P_B - P_A}}{\frac{(3P_B - 2P_A)L}{P_B - P_A}}$$

$$P_D = 3P_B - 2P_A \quad \text{— (5)}$$

from ① and ② $\boxed{3P_A + 2P_B + P_c = P}$ — (M)

Putting Eqⁿ ⑤ in ②

$2P_A + P_B = 3P_B - 2P_A$

$4P_A = 2P_B$

$\boxed{2P_A = P_B}$ — (A_1)

Eq – 4

$\boxed{P_c = 2P_B - P_A}$ — (A_2)

Putting (A_1) and (A_2) in (M)

$3P_A + 2(2P_A) + 2(2P_A) - P_A = P$.

$10 P_A = P$

$\boxed{P_A = \frac{P}{10}}$

$\boxed{P_B = \frac{2P}{10}}$

$\boxed{P_C = \frac{3P}{10}}$

$\boxed{P_D = \frac{4P}{10}}$

20

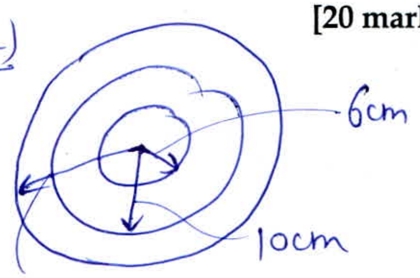
19

Do not write in this margin

) A compound cylinder is formed by shrinking one cylinder onto the other, the final dimensions become inner diameter of 12 cm, external diameter of 24 cm and junction diameter of 20 cm. After shrinking of outer cylinder over inner cylinder the radial pressure at common surface is 20 N/mm². Calculate the necessary difference in diameters of the two cylinders at the common surface. Take E = 200 GPa, ν = 0.3 for inner cylinder and E = 100 GPa and ν = 0.32 for outer cylinder. What is the minimum temperature through which the outer cylinder should be heated before it can be slipped on?
$\alpha = 11 \times 10^{-6}/°C$ for outer cylinder,

[20 marks]

⇒ for compound Cylinders (thick)



$\sigma_r = \frac{B}{r^2} - A$

Inner

$\sigma_r = 0$ at $r = 6$ cm

$\sigma_r = 20$ at $r = 10$ cm.

$\frac{B_1}{10^2} - A_1 = 20$

$\frac{B_1}{(6^2)} - A_1 = 0$

$B_1 = \frac{-20 \times (10^2 \times 6^2)}{10^2 - 6^2}$

$B_1 = -1125$ (MPa × cm²)

$A_1 = -31.25$ MPa.

$\sigma_h = \frac{B_1}{r^2} + A_1$

$\sigma_{h_{r=10}} = \frac{-1125}{10^2} + 31.25$

$= 42.5$ MPa.

$\sigma_{hi} = 42.5$ MPa

Outer

$\frac{B_2}{10^2} - A = 20$

$\frac{B_2}{12^2} - A_2 = 0$

$B_2 = 6545.45$

$A_2 = 45.45$

$\sigma_h = \frac{B_2}{r^2} + A_2$

at $r = 10$

$\sigma_{ho} = 110.9045$ MPa.

$$\left(\frac{dr}{r}\right)_i = -\frac{(\sigma_{hi_0} + \mu_i \sigma_{ri_0})}{E} = -\left(\frac{42.5 + 0.3(20)}{200}\right) \times 10^{-3}$$

$$dr_i = -0.2425 \times 10cm \times 10^{-3}$$

$$|dr_i| = +2.425\,cm \times 10^{-3}$$

Similary for outer cylinder

$$\left|\frac{dr_o}{r}\right| = \frac{\sigma_{hoi} + \mu_o \sigma_{roi}}{E_o} = \left(\frac{110.9045 + 0.32 \times 20}{100}\right) \times 10^{-3}$$

$$dr_o = 1.173 \times 10 \times 10^{-3}$$

$$|dr_o| = (11.73\,cm \times 10^{-3})$$

$$\Delta r = |dr_i| + |dr_o| = 14.155\,cm \times 10^{-3} = 0.01415\,cm$$

minimum temperature for outer cylinder

$\varepsilon_{90} = \varepsilon_2$ due to thermal.

procedure ok

$$\left(\frac{dr_o}{r_m}\right) = 1.173 \times 10^{-3} = \alpha\Delta T$$

$$\Delta T = 1.173 \times$$

$$\frac{(1.173 \times 10^{-3})}{11 \times 10^{-6}} = \Delta T$$

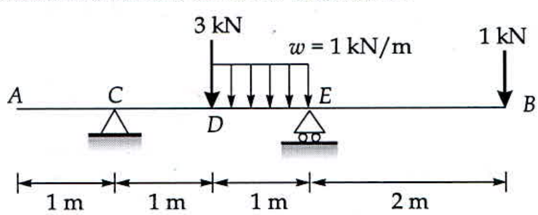
Check calculation

$$\Delta T = 106.63^\circ C$$

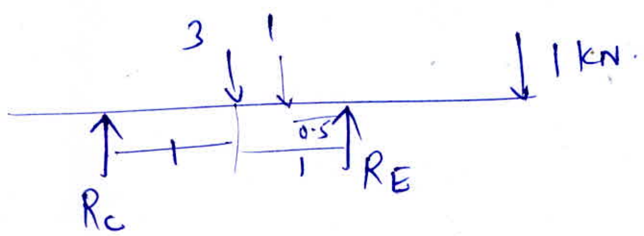
11

Do not write in this margin

c) A beam is loaded as shown in figure. Determine the distance of point of contraflexure from point *A* and maximum moment and its location.



[20 marks]



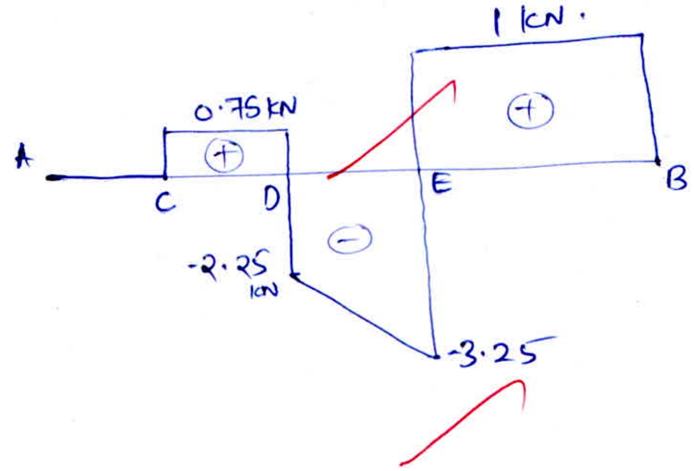
$\Sigma M_c = 0) \rightarrow (3 \times 1) + (1 \times 1.5) + (1 \times 4) = R_E \times 2$

$R_E = \frac{3 + 1.5 + 4}{2}$

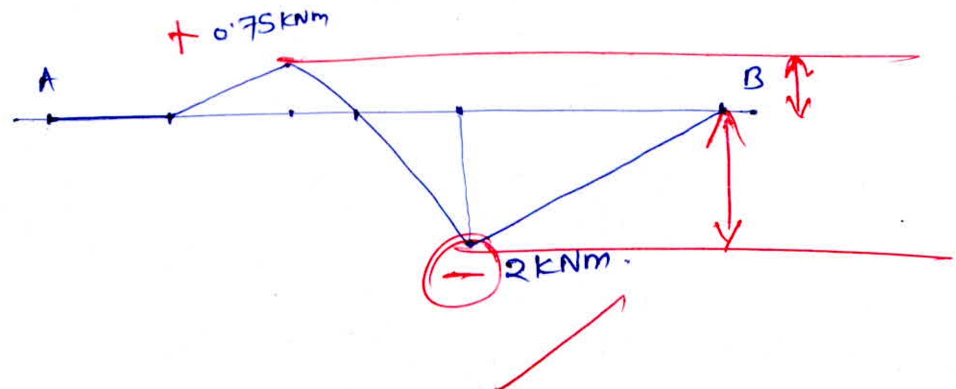
$R_E = 4.25 \text{ kN}$

$R_E + R_c = 3 + 1 + 1 = 5$ $R_c = 0.75$

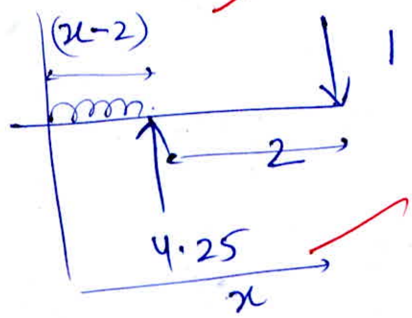
SFD



BMD



BM at x



$$M_x = 4.25(x-2) + 1x - 1\times\frac{(x-2)^2}{2}$$

$$M_x = 4.25x - 8.5 - x - \frac{(x-2)^2}{2}$$

$$= 3.25x - 8.5 - \frac{x^2+4-4x}{2}$$

$$= \frac{2(3.25x - 8.5) - (x^2+4-4x)}{2}$$

$$= \frac{6.5x - 17 - x^2 - 4 + 4x}{2}$$

$$= -\frac{1}{2}\left(x^2 - 10.5x + 21\right)$$

~~$\frac{\partial M}{\partial x}=0$~~ $M_x = 0$ gives the point of Contraflexure.

$$x^2 - 10.5x + 21 = 0$$

$$x = 2.6882\ m$$

Correct

So the point from A $= 5 - 2.6882$
$= 2.3118$ m.

Point of Maximum Bending moment

$x = 3$ m ~~from~~ (A)

and i.e. at Point E

$$M_E = 2\ kNm$$

19

■■■■

Space for Rough Work