Key Solution

Exam # 2

by

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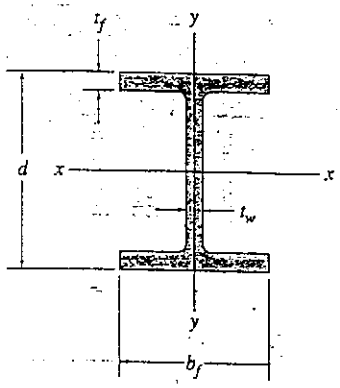
STRUCTURAL MECHANICS I
(CE 203)

Exam # 2
(2 hours)

(Spring, 2005)

Name : Key

ID. No. : _____



Wide-Flange Sections or W Shapes

Designation	Area	Depth	Web thickness	Flange width	Flange thickness	x–x axis			y–y axis		
	A	d	t_w	b_f	t_f	I	S	r	I	S	r
in. × lb/ft	in^2	in.	in.	in.	in.	in^4	in^3	in.	in^4	in^3	in.
W12 × 87	25.6	12.53	0.515	12.125	0.810	740	118	5.38	241	39.7	3.07
W12 × 50	14.7	12.19	0.370	8.080	0.640	394	64.7	5.18	56.3	13.9	1.96
W12 × 45	13.2	12.06	0.335	8.045	0.575	350	58.1	5.15	50.0	12.4	1.94
W12 × 26	7.65	12.22	0.230	6.490	0.380	204	33.4	5.17	17.3	5.34	1.51
W12 × 22	6.48	12.31	0.260	4.030	0.425	156	25.4	4.91	4.66	2.31	0.847
W12 × 16	4.71	11.99	0.220	3.990	0.265	103	17.1	4.67	2.82	1.41	0.773
W12 × 14	4.16	11.91	0.200	3.970	0.225	88.6	14.9	4.62	2.36	1.19	0.753
W10 × 100	29.4	11.10	0.680	10.340	1.120	623	112	4.60	207	40.0	2.65
W10 × 54	15.8	10.09	0.370	10.030	0.615	303	60.0	4.37	103	20.6	2.56
W10 × 45	13.3	10.10	0.350	8.020	0.620	248	49.1	4.32	53.4	13.3	2.01
W10 × 39	11.5	9.92	0.315	7.985	0.530	209	42.1	4.27	45.0	11.3	1.98
W10 × 30	8.84	10.47	0.300	5.810	0.510	170	32.4	4.38	16.7	5.75	1.37
W10 × 19	5.62	10.24	0.250	4.020	0.395	96.3	18.8	4.14	4.29	2.14	0.874
W10 × 15	4.41	9.99	0.230	4.000	0.270	68.9	13.8	3.95	2.89	1.45	0.810
W10 × 12	3.54	9.87	0.190	3.960	0.210	53.8	10.9	3.90	2.18	1.10	0.785
W8 × 67	19.7	9.00	0.570	8.280	0.935	272	60.4	3.72	88.6	21.4	2.12
W8 × 58	17.1	8.75	0.510	8.220	0.810	228	52.0	3.65	75.1	18.3	2.10
W8 × 48	14.1	8.50	0.400	8.110	0.685	184	43.3	3.61	60.9	15.0	2.08
W8 × 40	11.7	8.25	0.360	8.070	0.560	146	35.5	3.53	49.1	12.2	2.04
W8 × 31	9.13	8.00	0.285	7.995	0.435	110	27.5	3.47	37.1	9.27	2.02
W8 × 24	7.08	7.93	0.245	6.495	0.400	82.8	20.9	3.42	18.3	5.63	1.61
W8 × 15	4.44	8.11	0.245	4.015	0.315	48.0	11.8	3.29	3.41	1.70	0.876
W6 × 25	7.34	6.38	0.320	6.080	0.455	53.4	16.7	2.70	17.1	5.61	1.52
W6 × 20	5.87	6.20	0.260	6.020	0.365	41.4	13.4	2.66	13.3	4.41	1.50
W6 × 16	4.74	6.28	0.260	4.030	0.405	32.1	10.2	2.60	4.43	2.20	0.966
W6 × 15	4.43	5.99	0.230	5.990	0.260	29.1	9.72	2.56	9.32	3.11	1.46
W6 × 12	3.55	6.03	0.230	4.000	0.280	22.1	7.31	2.49	2.99	1.50	0.918
W6 × 9	2.68	5.90	0.170	3.940	0.215	1.64	5.56	2.47	2.19	1.11	0.905

Problem # 1 (30%)

Define the following:

(1) torque

torque : twisting moment

(2) angle of twist

angle through which a shaft rotates when subjected to twisting

(3) power

the time rate of change of work

(4) frequency

number of revolutions or cycles per second.

(5) angular velocity

the angle that a rotating shaft covers per second

(6) shear modulus of elasticity

the ratio of shear stress to shear strain for linearly elastic materials

(7) load diagram

A drawing of the structure showing all loads (actions and reactions) known and placed in the right directions

(8) bending stress

stress produced by a bending moment

(9) ~~shear flow~~

shear flow is $q = \tau t$ where τ is shear stress and t is the section thickness.

(10) neutral surface

surface at which bending stress is zero. It passes through the centroid of the cross section.

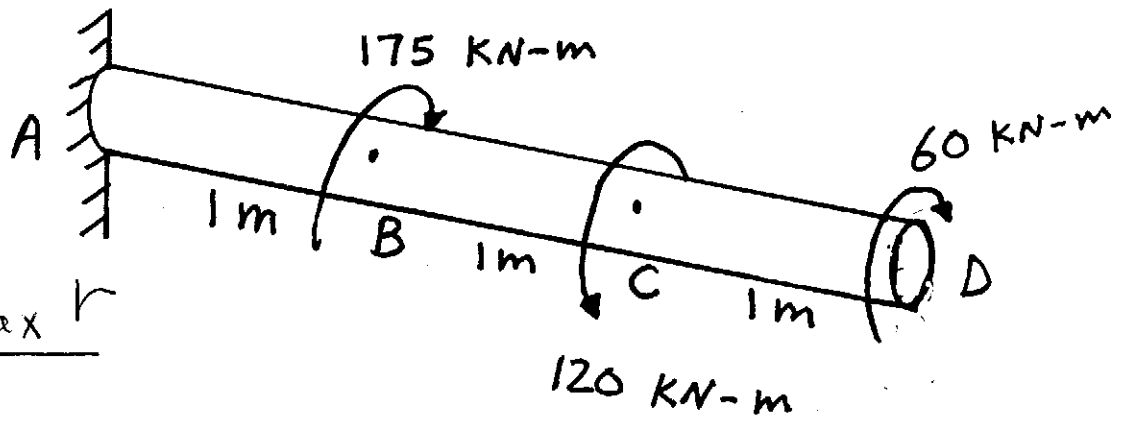
(4)

Problem # 2 (20%)

(a) The shaft shown below was designed by a junior engineer. Is the shaft safe?

$\tau_{allow} = 80$ MPa , $\phi_{allow} = 2^\circ$

diameter $d = 0.2$ m , $G = 10$ GPa , $J = 1.57 \times 10^{-4}$ m^4



$$\tau_{max} = \frac{T_{max}\, r}{J}$$

$$= \frac{115 \times 10^3 \times 0.1}{1.57 \times 10^{-4}} = 73 \text{ MPa} < \tau_{allow} \quad \text{OK}$$

$$\phi_D = \int_0^1 \frac{115\, dz}{GJ} - \int_0^1 \frac{60\, dz}{GJ} + \int_0^1 \frac{60}{GJ}\, dz$$

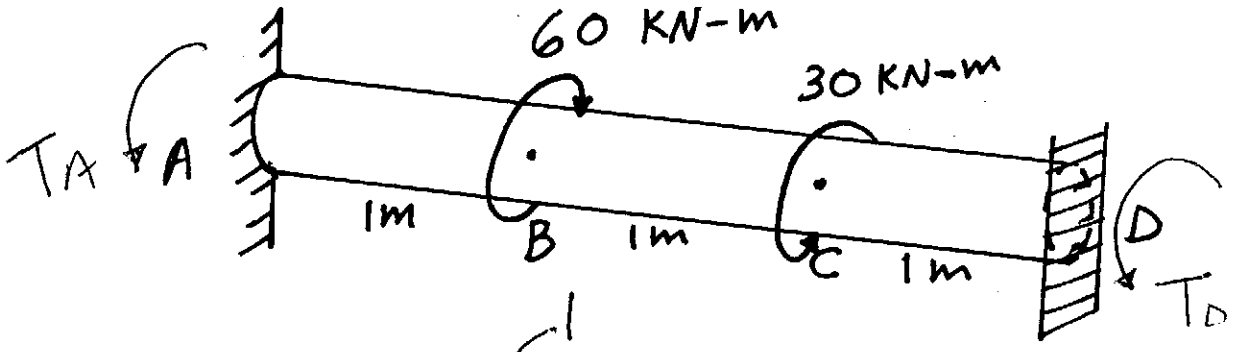
$$= \frac{115}{GJ} = \frac{115 \times 10^3}{1.57 \times 10^{-4} \times 10 \times 10^9}$$

$$= 7.32 \times 10^{-2} \text{ rad}$$

$$= 4.2^\circ > \phi_{allow}$$

not safe

(b) The shaft shown is fixed between two rigid walls. Calculate the reactions.



$$\phi_D - \phi_A = \int_0^1 \frac{T_A}{GJ}\,dz + \int_0^1 \frac{(T_A - 60)}{GJ}\,dz + \int_0^1 \frac{T_D\,dz}{GJ}$$

$$0 = T_A + T_A - 60 + T_D$$

$$0 = 2T_A + T_D - 60 \quad \text{---} (1)$$

Equilibrium $\Rightarrow$

$$T_A + T_D = 30 \quad \text{---} (2)$$

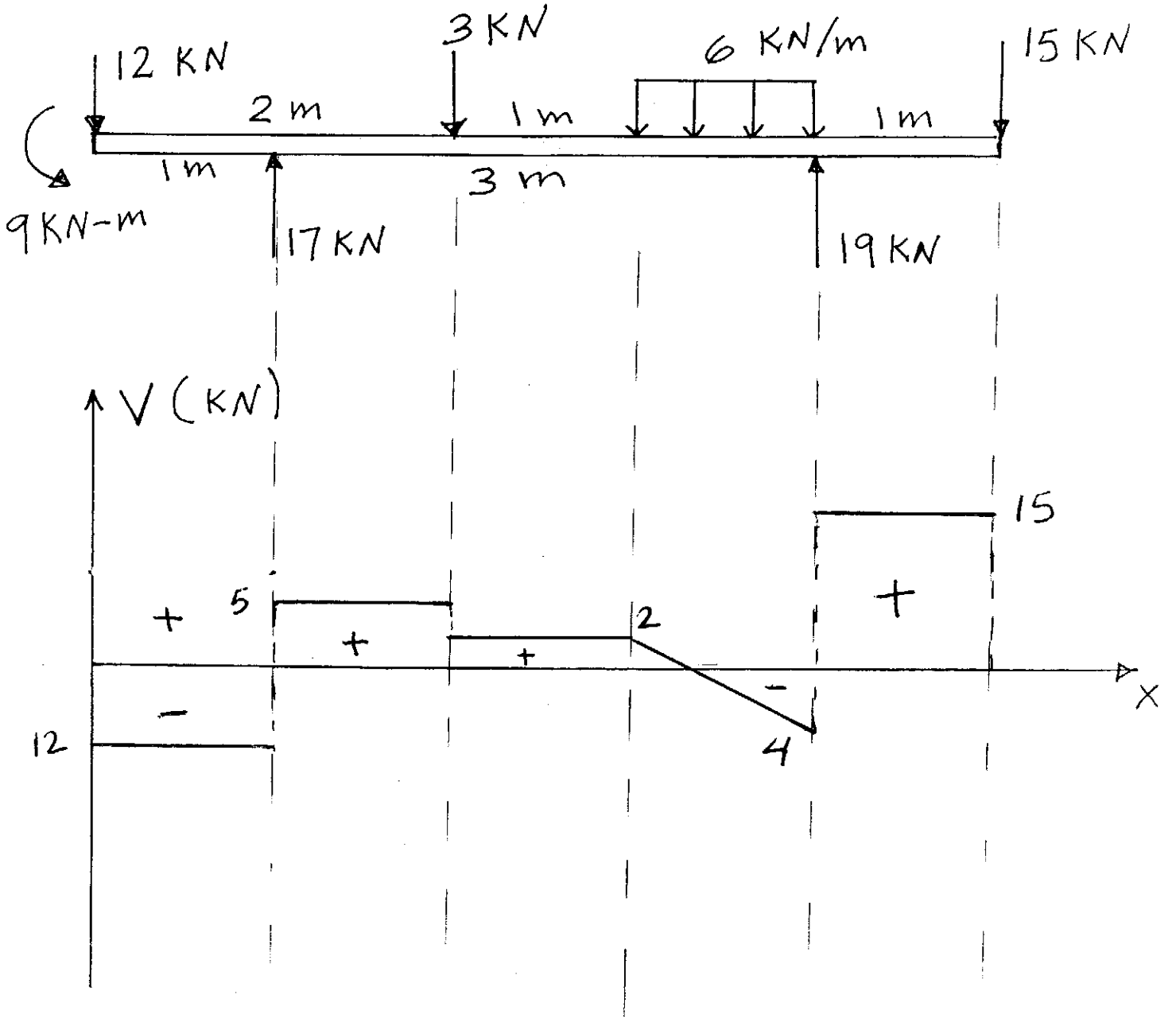
Solving (1) + (2)

$$T_D = 0$$

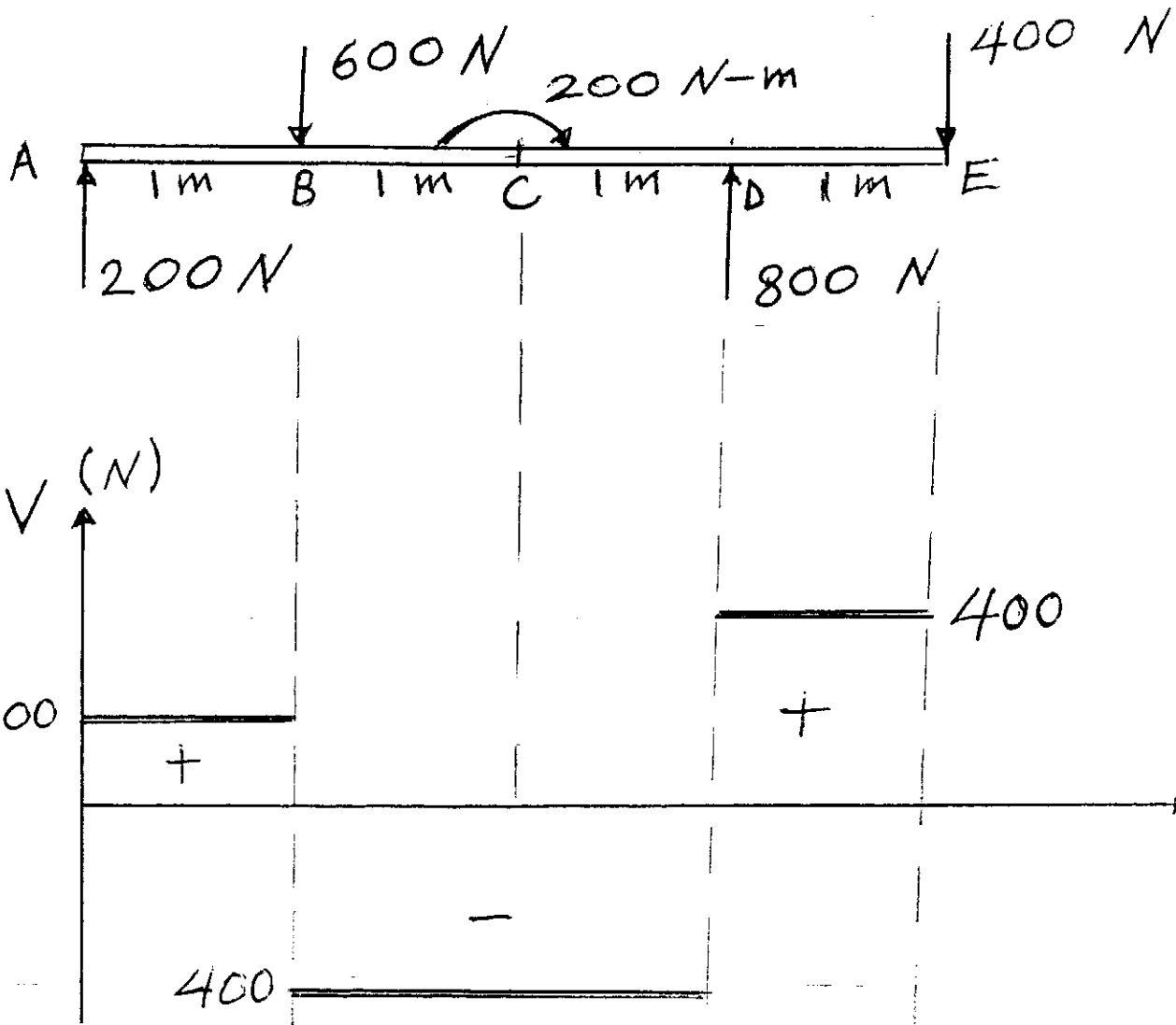
$$T_A = 30 \text{ KN-m}$$

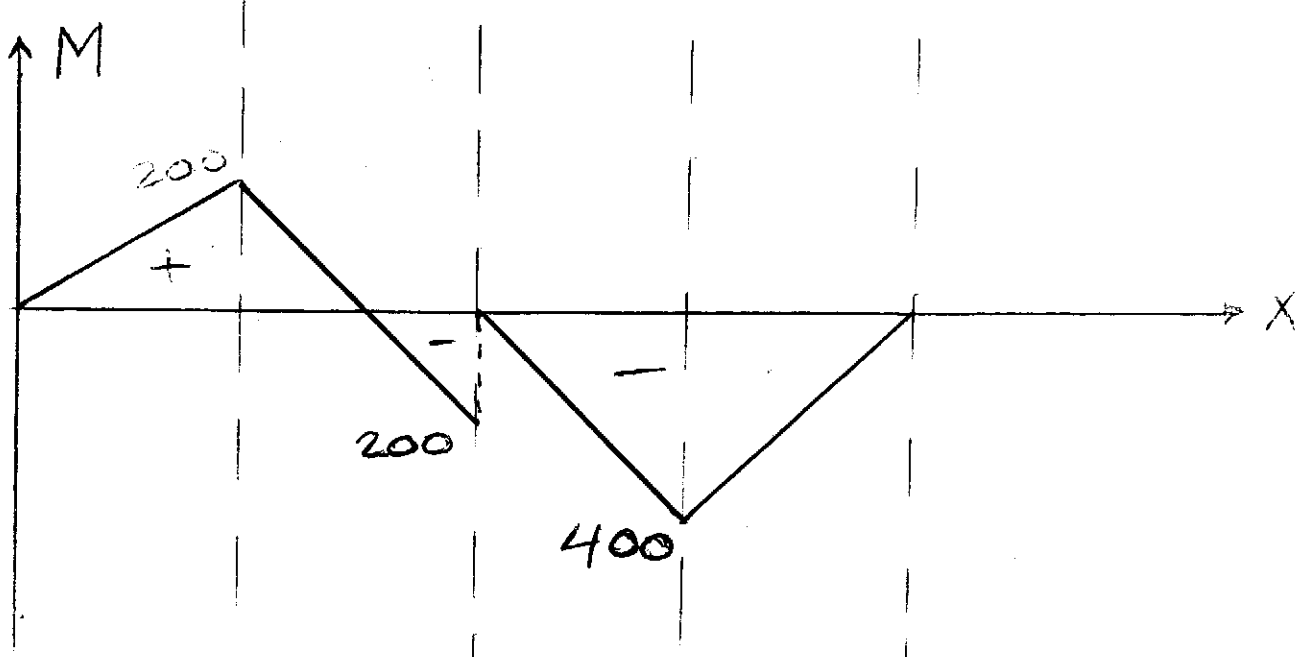
Problem # 3 (20%)

(a) Given the beam load diagram shown below, draw the shear diagram by the method of summations.



(b) Given the load and the shear diagrams shown below, draw the moment diagram by the method of summations.

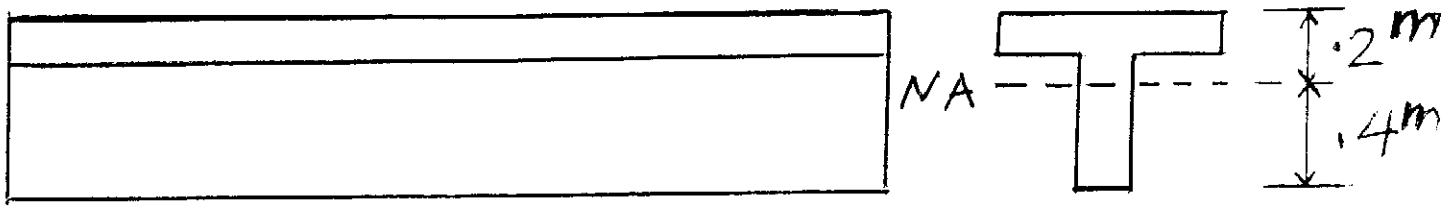


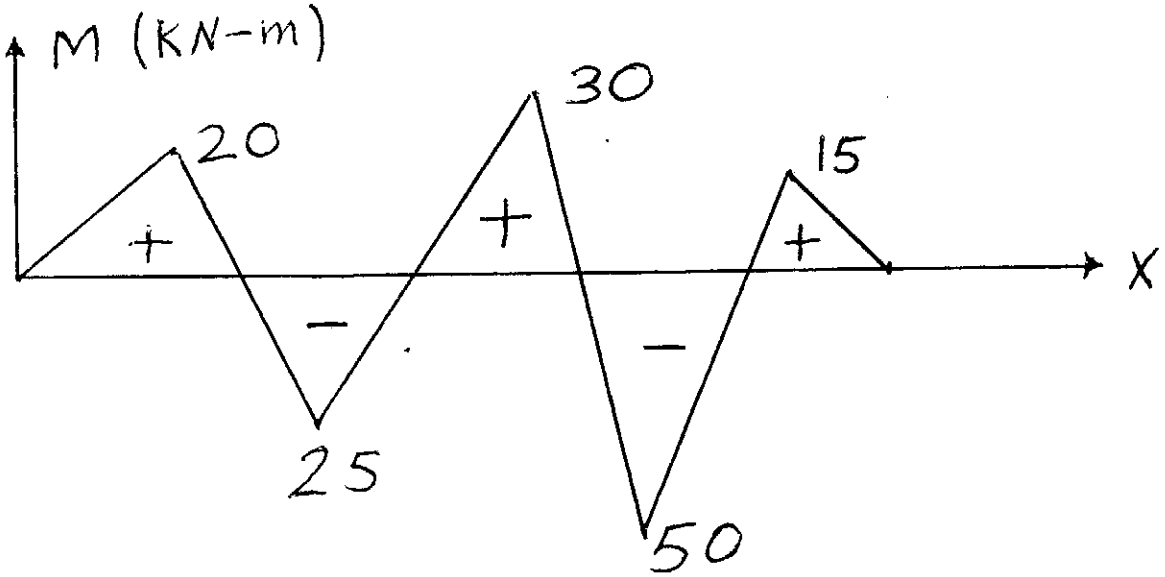


(8)

Problem # 4 (30%)

(a) A beam has the moment diagram shown below. $I = 1 \times 10^{-3}\ m^4$





(1) What is the moment that will produce maximum bending stress?

$M = -50$ KN-m

(2) What is the moment that will produce minimum bending stress?

$M = 0$

(3) Calculate the section modulus.

$$S = \frac{I}{C} = \frac{1 \times 10^{-3}}{0.4} = 2.5 \times 10^{-3}\ m^3$$

(4) Compute the maximum bending stress produced by a moment equal to 30 KN-m.

$$\sigma_{max} = -\frac{M y_{max}}{I}$$

$$= -\frac{(30 \times 10^{3})(-0.4)}{1 \times 10^{-3}}$$

$$= 12 \text{ MPa}$$

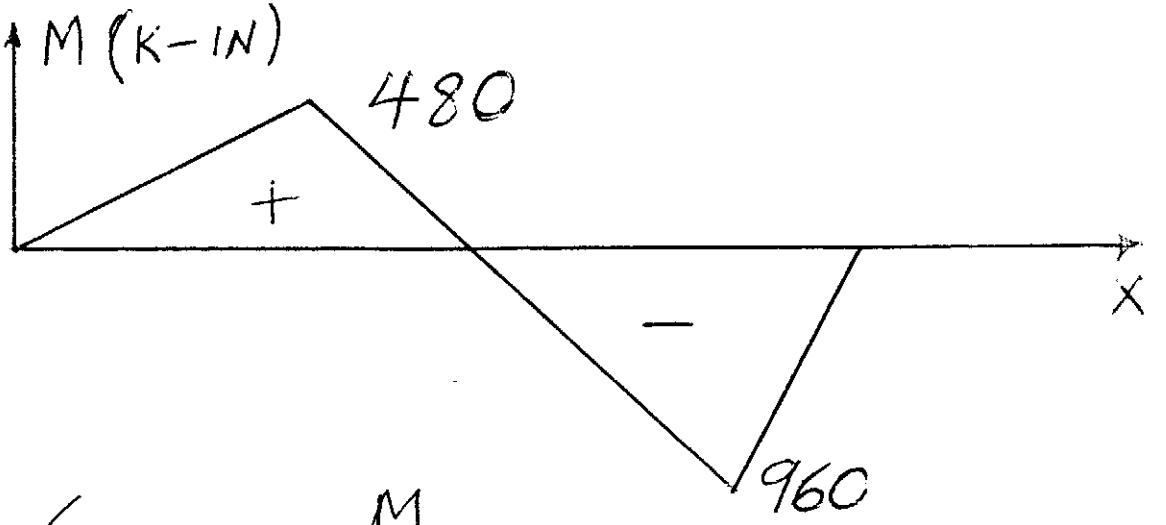
(5) If the allowable bending stress is 160 MPa, calculate the maximum moment the beam can resist.

$$\sigma = \frac{-M y}{I}$$

$$160 \times 10^{6} = \frac{-M(-0.4)}{1 \times 10^{-3}}$$

$$\text{max } M = 400 \text{ KN-m}$$

(b) Given the moment diagram shown below, select a safe wide flange section using the table provided. The allowable bending stress is 24 ksi.



$$\sigma_{max} = \frac{M}{S}$$

$$24 = \frac{960}{S}$$

$$\therefore S = 40 \text{ IN}^3$$

∴ use W 10 X 39 ($S = 42.1$)