PE Naval Architecture & Marine Engineering Reference Handbook (2022)

ERRATA SHEET

Updates through July 2023

1.2 Properties of Materials

1.2.3 Properties of Water at Standard Conditions

Original:

Specific heat, c_p: In I-P units: $\frac{1\ \text{Btu}}{\text{lb-°F}}$ at 68°F In SI units: $\frac{4.180\ \text{kJ}}{\text{kg} \cdot \text{K}}$ at 20°C

Density at standard conditions: $\frac{1{,}000\ \text{kg}}{\text{m}^3} = \frac{62.4\ \text{lbm}}{\text{ft}^3}$

Specific weight at standard conditions: $\frac{9{,}810\ \text{N}}{\text{m}^3} = \frac{9{,}810\ \text{kg}}{\text{m}^2 \cdot \text{s}^2} = \frac{62.4\ \text{lbf}}{\text{ft}^3}$

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Density at standard conditions: $\frac{1{,}000\ \text{kg}}{\text{m}^3} = \frac{62.4\ \text{lbm}}{\text{ft}^3}$ (fresh water)

$\frac{1026\ \text{kg}}{\text{m}^3} = \frac{64.0\ \text{lbm}}{\text{ft}^3}$ (sea water)

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Original:

Schedule 80 Steel Pipe

Nominal Pipe Size	Wall Thickness	Inside Diameter	Flow Area	Pipe Wt. per L.F.	Gallons per L.F.	Water Wt. per L.F.	Total Wt. per L.F.	Moment of Inertia	Section Modulus	Radius of Gyration
in.	in.	in.	in^2	lb		lb	lb	in^4	in^3	in.
0.5	0.147	0.546	0.234	1.09	0.012	0.10	1.19	0.020	0.048	0.250
0.75	0.154	0.742	0.432	1.47	0.022	0.19	1.66	0.045	0.085	0.321
1	0.179	0.957	0.719	2.17	0.044	0.37	2.54	0.106	0.161	0.407
1.25	0.191	1.278	1.282	3.00	0.067	0.56	3.56	0.242	0.291	0.524
1.5	0.200	1.500	1.766	3.63	0.106	0.88	4.51	0.391	0.412	0.605
2	0.218	1.939	2.951	5.02	0.174	1.46	6.48	0.868	0.731	0.766
2.5	0.276	2.323	4.236	7.66	0.220	1.84	9.50	1.920	1.340	0.924
3	0.300	2.900	6.602	10.25	0.383	3.20	13.45	3.890	2.230	1.140
4	0.337	3.826	11.491	14.98	0.660	5.51	20.49	9.610	4.270	1.480
5	0.375	4.813	18.185	20.78	0.945	7.89	28.67	20.700	7.430	1.840
6	0.432	5.761	26.053	28.57	1.499	12.51	41.08	40.500	12.200	2.190
8	0.500	7.625	45.640	43.39	2.598	21.69	65.08	106.000	24.500	2.880
10	0.593	9.564	71.804	54.74	4.085	34.10	88.84	212.000	39.400	3.630
12	0.687	11.376	101.590	65.42	5.810	48.50	113.92	362.000	56.700	4.330

Double Extra Strong XX Steel Pipe

Nominal Pipe Size	Wall Thickness	Inside Diameter	Flow Area	Pipe Wt. per L.F.	Gallons per L.F.	Water Wt. per L.F.	Total Wt. per L.F.	Moment of Inertia	Section Modulus	Radius of Gyration
in.	in.	in.	in^2	lb		lb	lb	in^4	in^3	in.
2	0.436	1.503	1.773	9.03	0.174	1.46	10.49	1.310	1.100	0.703
2.5	0.552	1.771	2.462	13.69	0.128	1.07	14.76	2.870	2.000	0.844
3	0.600	2.300	4.153	18.58	0.383	3.20	21.78	5.990	3.420	1.050
4	0.674	3.152	7.799	27.54	0.660	5.51	33.05	15.300	6.790	1.370
5	0.750	4.063	12.959	38.55	0.674	5.62	44.17	33.600	12.100	1.720
6	0.864	4.897	18.825	53.16	1.499	12.51	65.67	66.300	20.000	2.060
8	0.875	6.875	37.104	72.42	2.598	21.69	94.11	162.000	37.600	2.760

Updated:

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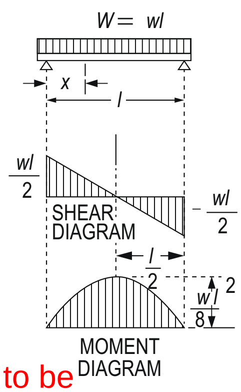
Original:

Bending Moment, Vertical Shear, and Deflection of Beams of Uniform Cross Section, Under Various Conditions of Loading

P = concentrated loads, in lb	**I = moment of inertia, in in^4**
R_1, R_2 = reactions, in lb	**V_x = vertical shear at any section, in lb**
w = uniform load per unit of length, in lb per in.	**V = maximum vertical shear, in lb**
W = total uniform load on beam, in lb	**M_x = bending moment at any section, in lb-in.**
l = length of beam, in in.	**M = maximum bending moment, in lb-in.**
x = distance from support to any section, in in.	**y = maximum deflection, in in.**
E = modulus of elasticity, in psi	**k = fraction of l to P**

Simple Beam: Uniform Load



$$R_1 = R_2 = \frac{wl}{2}$$

$$V_x = \frac{wl}{2} - wx$$

$$V = \pm \frac{wl}{2} \left(\text{when} \begin{cases} x = 0 \\ x = l \end{cases} \right)$$

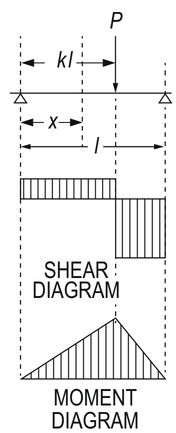
$$M_x = \frac{wlx}{2} - \frac{wx^2}{2}$$

$$M = \frac{wl^2}{8} \left(\text{when } x = \frac{l}{2} \right)$$

$$y = \frac{5Wl^4}{384EI} \text{ (at center of span)}$$

Needs to be lowercase w, not W

Simple Beam: Concentrated Load at Any Point



$$R_1 = P(1-k)$$

$$R_2 = Pk$$

$$V_x = R_1 \quad (\text{when } x < kl)$$

$$= R_2 \quad (\text{when } x > kl)$$

$$V = P(1-k) \quad (\text{when } k < 0.5)$$

$$= -Pk \quad (\text{when } k > 0.5)$$

$$M_x = Px(1-k) \quad (\text{when } x < kl)$$

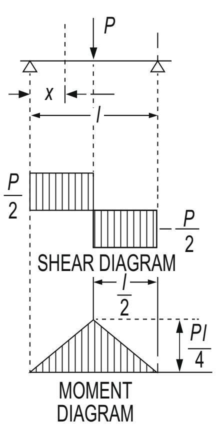
$$= Pk(l-x) \quad (\text{when } x > kl)$$

$$M = Pkl(1-k) \, (\text{at point of load})$$

$$y = \frac{Pl^3}{3EI}(1-k) \times \left(\frac{2}{3}k - \frac{1}{3}k^2 \right)^{\frac{3}{2}}$$

$$\left(\text{at } x = l\sqrt{\frac{2}{3}k - \frac{1}{3}k^2} \right)$$

Simple Beam: Concentrated Load at Center



$$R_1 = R_2 = \frac{P}{2}$$

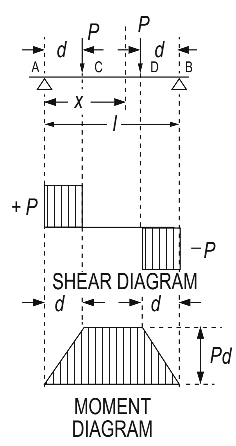
$$V_x = V = \pm \frac{P}{2}$$

$$M_x = \frac{Px}{2}$$

$$M = \frac{Pl}{4} \left(\text{when } x = \frac{l}{2} \right)$$

$$y = \frac{Pl^3}{48EI} \text{ (at center of span)}$$

Simple Beam: Two Equal Concentrated Loads at Equal Distances from Supports



$$R_1 = R_2 = P$$

$$V_x = P \quad (\text{for } AC)$$

$$= 0 \quad (\text{for } CD)$$

$$= -P \quad (\text{for } DB)$$

$$V = \pm P$$

$$M_x = Px \quad (\text{for } AC)$$

$$= Pd \quad (\text{for } CD)$$

$$= P(l-x) \quad (\text{for } DB)$$

$$M = Pd$$

$$y = \frac{Pd}{24EI}(3l^2 - 4d^2)$$

$$(\text{at center of span})$$

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P = concentrated loads, in lb	I = moment of inertia, in in^4
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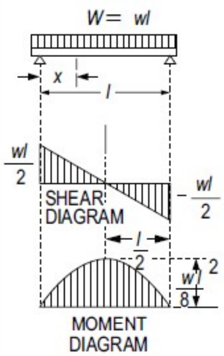

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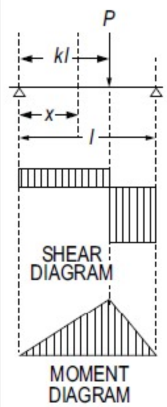

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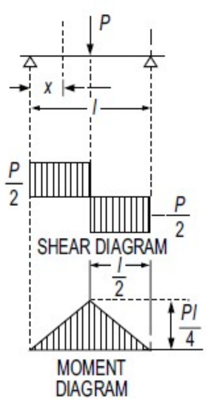

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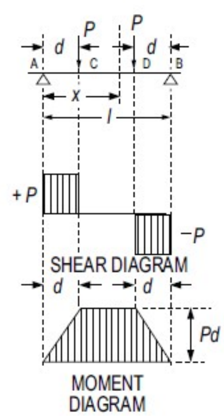

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l = length of beam, in in.	M = maximum bending moment, in lb-in.
x = distance from support to any section, in in.	y = maximum deflection, in in.
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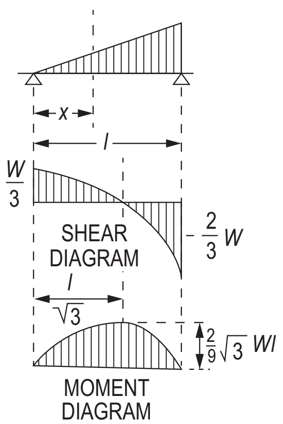
Simple Beam: Load Increasing Uniformly from One Support to the Other



$R_1 = \frac{W}{3};\ R_2 = \frac{2}{3}W$

$V_x = W\left(\frac{1}{3} - \frac{x^2}{l^2}\right)$

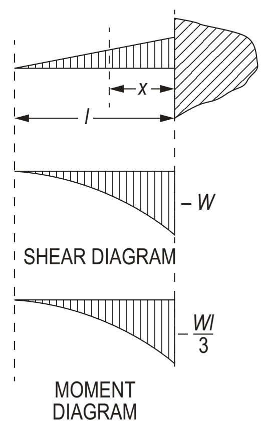
$V = -\frac{2}{3}W \text{ (when } x = l)$

$M_x = \frac{Wx}{3}\left(1 - \frac{x^2}{l^2}\right)$

$M = \frac{2}{9\sqrt{3}}Wl \left(\text{when } x = \frac{l}{\sqrt{3}}\right)$

$y = \frac{0.01304}{EI}Wl^3$

Cantilever Beam: Load Increasing Uniformly from Free End to Support



$R = W$

$V_x = -W\frac{(l-x)^2}{l^2}$

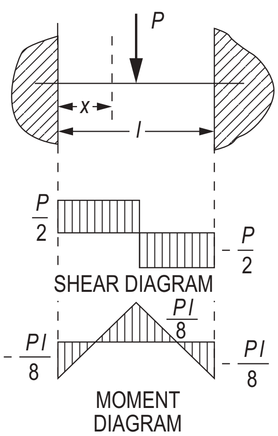
$V = -W \text{ (when } x = 0)$

$M_x = -\frac{W}{3}\frac{(l-x)^3}{l^2}$

$M = -\frac{Wl}{3} \text{ (when } x = 0)$

$y = \frac{Wl^3}{15EI}$

Fixed Beam: Concentrated Load at Center of Span



$R_1 = R_2 = \frac{P}{2}$

$V_x = V = \pm\frac{P}{2}$

$M_x = P\left(\frac{x}{2} - \frac{l}{8}\right)$

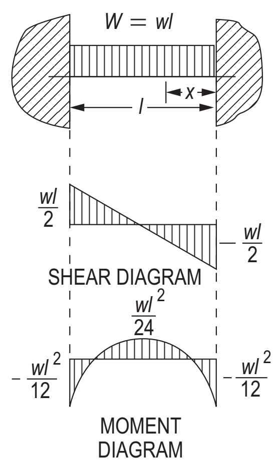
$M_x = -\frac{Pl}{8}\left(\text{when } \begin{cases} x = 0 \\ x = l \end{cases}\right)$

$M = +\frac{Pl}{8} \text{ (at center of span)}$

$y = \frac{Wl^3}{192EI}$

Should be a P, not a W

Fixed Beam: Uniform Load



$R_1 = R_2 = \frac{wl}{2} = \frac{W}{2}$

$V_x = \frac{wl}{2} - wx$

$V = \pm\frac{wl}{2} \text{ (at ends)}$

$M_x = -\frac{wl^2}{2}\left(\frac{1}{6} - \frac{x}{l} + \frac{x^2}{l^2}\right)$

$M = -\frac{1}{12}wl^2\left(\text{when } \begin{cases} x = 0 \\ x = l \end{cases}\right)$

$M = \frac{wl^2}{24}\left(\text{when } x = \frac{l}{2}\right)$

$y = \frac{Wl^3}{384EI}$

Updated:

Bending Moment, Vertical Shear, and Deflection of Beams of Uniform Cross Section, Under Various Conditions of Loading (cont'd)

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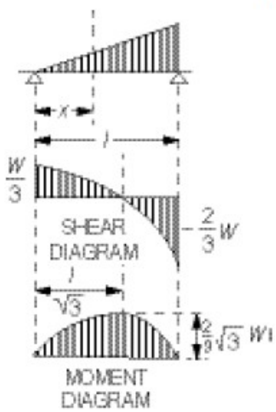
Simple Beam: Load Increasing Uniformly from One Support to the Other



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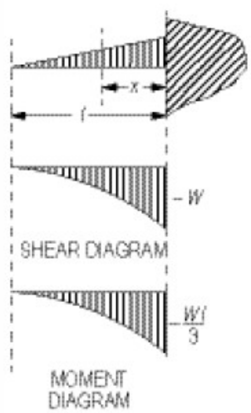
$$M_x = \frac{Wx}{3}\left(1 - \frac{x^2}{l^2}\right)$$

$$M = \frac{2}{9\sqrt{3}}Wl \left(\text{when } x = \frac{l}{\sqrt{3}}\right)$$

$$y = \frac{0.01304}{EI}Wl^3$$

Cantilever Beam: Load Increasing Uniformly from Free End to Support



$$R = W$$

$$V_x = -W\frac{(l-x)^2}{l^2}$$

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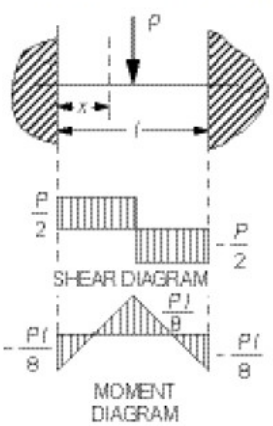
$$y = \frac{Wl^3}{15EI}$$

Fixed Beam: Concentrated Load at Center of Span



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$$V_x = V = \pm\frac{P}{2}$$

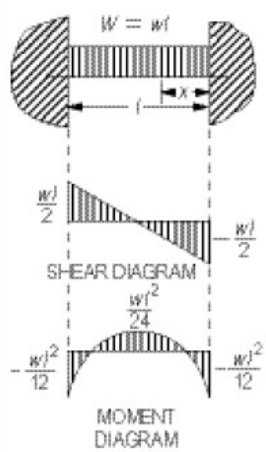
$$M_x = P\left(\frac{x}{2} - \frac{l}{8}\right)$$

$$M_x = -\frac{Pl}{8}\left(\text{when } \begin{cases} x = 0 \\ x = l \end{cases}\right)$$

$$M = +\frac{Pl}{8} \text{ (at center of span)}$$

$$y = \frac{Pl^3}{192EI}$$

Fixed Beam: Uniform Load



$$R_1 = R_2 = \frac{wl}{2} = \frac{W}{2}$$

$$V_x = \frac{wl}{2} - wx$$

$$V = \pm\frac{wl}{2} \text{ (at ends)}$$

$$M_x = -\frac{wl^2}{2}\left(\frac{1}{6} - \frac{x}{l} + \frac{x^2}{l^2}\right)$$

$$M = -\frac{1}{12}wl^2\left(\text{when } \begin{cases} x = 0 \\ x = l \end{cases}\right)$$

$$M = \frac{wl^2}{24}\left(\text{when } x = \frac{l}{2}\right)$$

$$y = \frac{Wl^3}{384EI}$$

New Section Added:

1.22 Sound Decibel Addition: Decibels are logarithmic ratios, two decibel values cannot be added directly together to obtain their sum. Instead, the total level can be calculated by determining the difference between the two levels and adding a correction to the larger of the two using the equation below.

$$\Sigma\ (L_1 + L_2) = L_1 + 10\ \log_{10}(1 + 10 - \frac{\Delta L}{10})$$

where

L_1 = higher decibel level

L_2 = lower decibel level

$\Delta L = L_1 - L_2$

Original:

Moment to Change Trim One CM

SI units:

$$MTcm\ \frac{\Delta\,BM_L}{100L} = \frac{0.01025\,I_L}{L} \quad \text{(salt water)}$$

$$MTcm\ \frac{\Delta\,BM_L}{100L} = \frac{I_L}{L} \quad \text{(fresh water)}$$

Updated:

Moment to Change Trim One CM

SI units:

$$MTcm\ \frac{\Delta\,BM_L}{100L} = \frac{0.01025\,I_L}{L} \quad \text{(salt water)}$$

$$MTcm\ \frac{\Delta\,BM_L}{100L} = \frac{I_L}{L} \quad \text{(fresh water)}$$

Should be $0.01I_L$

Original:

6.3.5 Darcy-Weisbach Equation

$$h_L = f\,\frac{L}{D}\,\frac{v^2}{2g}$$

where

should be hL, not h_f

h_f = head loss

f = friction factor, dimensionless

D = internal diameter of the pipe

L = length over which the head loss occurs

$\boldsymbol{v}$ = fluid velocity

$\boldsymbol{g}$ = acceleration of gravity

Updated:

$$h_L = f\,\frac{L}{D}\,\frac{v^2}{2g}$$

where

hL = head loss

f = friction factor, dimensionless

D = internal diameter of the pipe

L = length over which the head loss occurs

v = fluid velocity

g = acceleration of gravity

Original:

6.3.15 Pilot Tubes

Updated:

6.3.15 Pitot Tubes

Added Section 6.3.20 Hydraulic Cylinders

6.3.20 Hydraulic Cylinders

Hydraulic cylinder systems with 2 or more cylinders obey the following laws of similitude that maintain constant pressure and volume (for incompressible fluid):

$F_1*A_1 = F_2*A_2$

Where F = force input/output by a hydraulic cylinder and A = cross-sectional area of the hydraulic cylinder.

$S_1*A_1 = S_2*A_2$

Where S = stroke of the hydraulic cylinder.

Original:

Internal Combustion Engines

The *mean effective pressure* equals net work divided by volumetric displacement. Horsepower is derived from

$$\text{hp} = (\text{MEP})\frac{Lan}{K}$$

where

MEP = mean effective pressure, in $\frac{\text{lb}}{\text{in}^2}$ or kPa

L = stroke, in ft or m

a = total piston area, in in^2 or m^2

n = number of cycles completed per min

K = 33,000 for I-P units or 0.4566 for SI units

Should be 0.04472

$$r_v = \text{compression ratio} = \frac{V_1}{V_2} = \frac{V_4}{V_3}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \qquad \frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{k-1}$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{k} \qquad \frac{P_3}{P_4} = \left(\frac{V_4}{V_3}\right)^{k}$$

Updated:

Internal Combustion Engines

The *mean effective pressure* equals net work divided by volumetric displacement. Horsepower is derived from

$$\text{hp} = (\text{MEP})\frac{Lan}{K}$$

where

MEP = mean effective pressure, in $\frac{\text{lb}}{\text{in}^2}$ or kPa

L = stroke, in ft or m

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$$r_v = \text{compression ratio} = \frac{V_1}{V_2} = \frac{V_4}{V_3}$$

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$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{k} \qquad \frac{P_3}{P_4} = \left(\frac{V_4}{V_3}\right)^{k}$$

Added Bearing Force Equation

7.11 Bearing Force

Bearing Force for rotating shaft with weight spread equally between bearings:

$$F_B = 0.5W_R(1+(r\,\omega^2)/g)$$

where

F_B = Bearing Force

W_R = Rotating Shaft Weight

r = off-center distance from rotational axis to center of mass

ω = rate of rotation (rad/sec)

g = acceleration due to gravity

Added a new equation under Gear Pitch
Original:

7.13 Gears

7.13.1 Gear Pitch

$$P = \frac{N}{d}$$

$$F_c = \frac{T}{P}$$

where

P = Diametral Pitch

N = Number of teeth

d = Pitch diameter

F_c = Gear contact or tangential force

T = Torque

Updated:

7.14 Gears

7.14.1 Gear Pitch

$$P = \frac{N}{d}$$

$$F_c = \frac{T}{P}$$

P = Diametral Pitch

N = Number of teeth

d = Pitch diameter

F_c = Gear contact or tangential force

T = Torque

Wt = 126050*(HP/(RPMp x d))

Where

Wt = tooth loading

RPMp = pinion RPM

d = pitch diameter of the pinion

Original:

8.4 Refrigeration

8.4.1 Compression Refrigeration Cycles

Refer to Chapter 4, Thermodynamics, for additional information on compression refrigeration cycles.

Should be Chapter 7

Updated:

8.4 Refrigeration

8.4.1 Compression Refrigeration Cycles

Refer to Chapter 7, Thermodynamics, for additional information on compression refrigeration cycles.