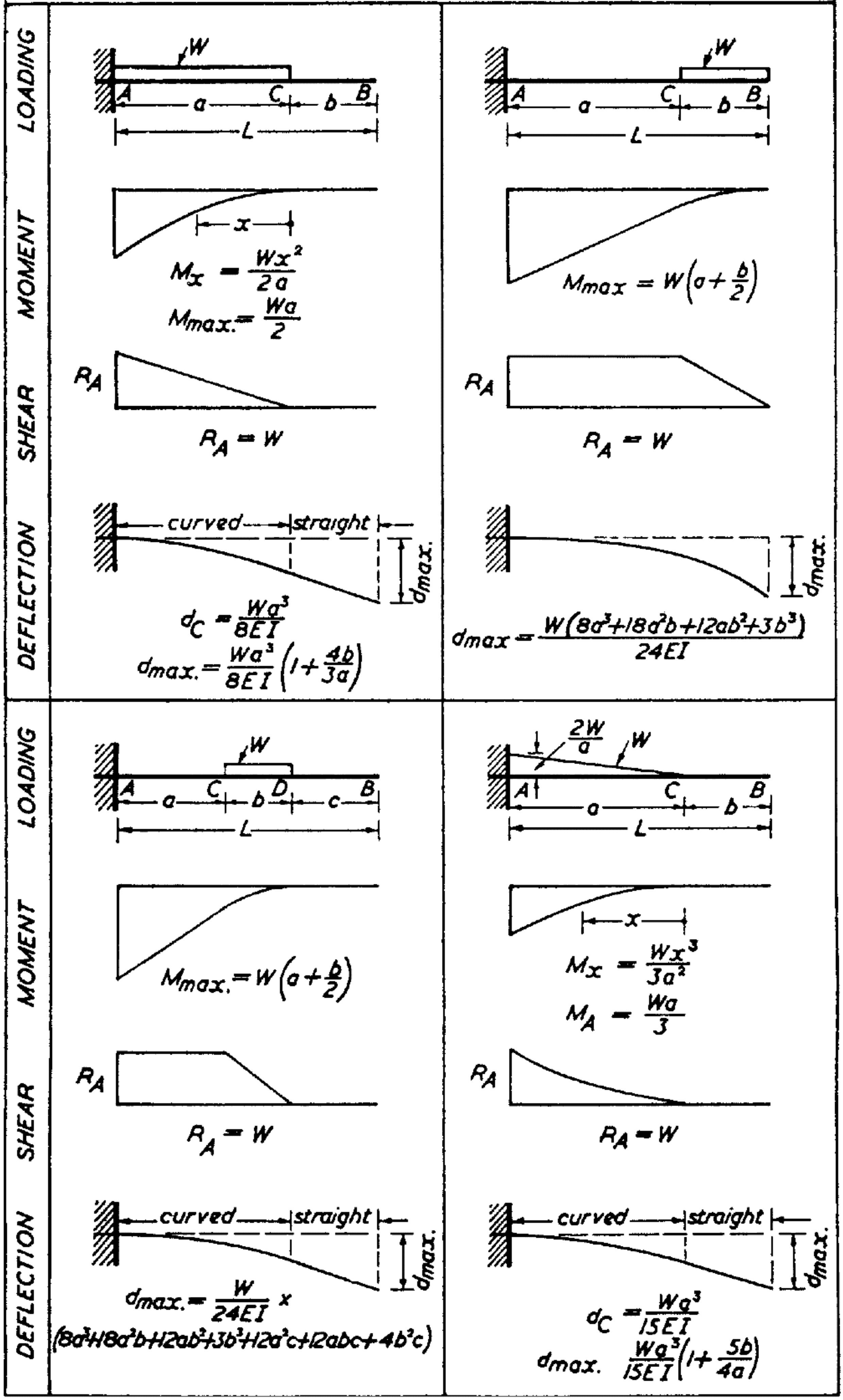
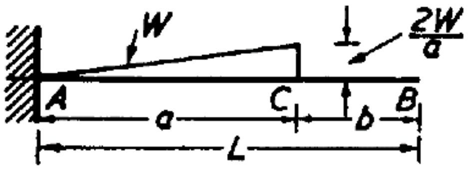
CANTILEVERS



CANTILEVERS

Case 1

LOADING

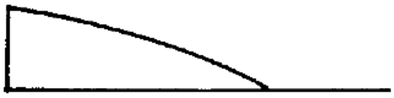


MOMENT

$$M_x = \frac{Wa}{3}\left[\left(\frac{x}{a}\right)^3 - \frac{3x}{a} + 2\right]$$

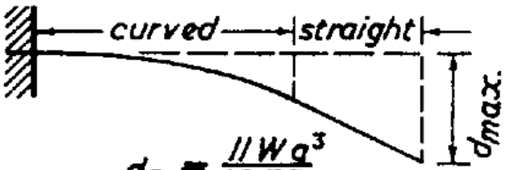
$$M_A = \frac{2Wa}{3}$$

SHEAR



$$R_A = W$$

DEFLECTION

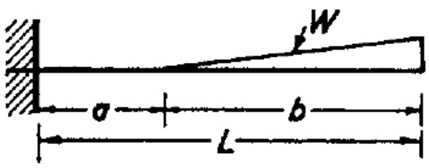


$$d_C = \frac{11Wa^3}{60EI}$$

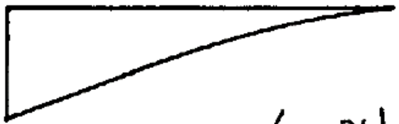
$$d_{max.} = \frac{11Wa^3}{60EI}\left(1 + \frac{15b}{11a}\right)$$

Case 2

LOADING



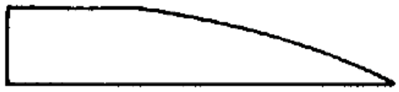
MOMENT



$$M_{max.} = W\left(a + \frac{2b}{3}\right)$$

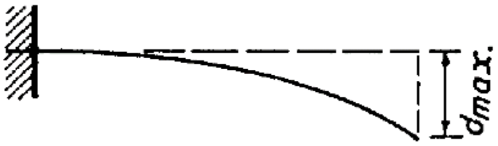
SHEAR

R_A



$$R_A = W$$

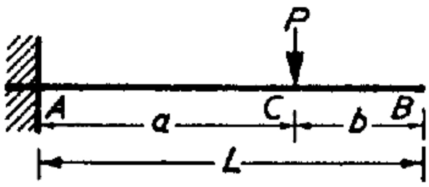
DEFLECTION



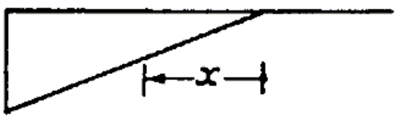
$$d_{max.} = \frac{W(20a^3 + 50a^2b + 40ab^2 + 11b^3)}{60EI}$$

Case 3

LOADING



MOMENT

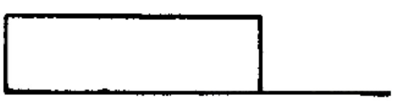


$$M_x = P.x$$

$$M_{max} = P.a$$

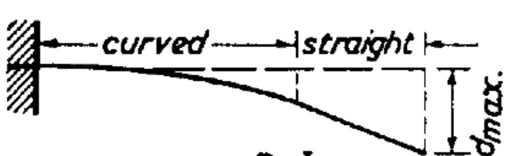
SHEAR

R_A



$$R_A = P$$

DEFLECTION

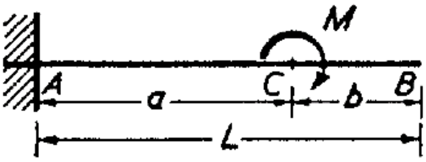


$$d_C = \frac{Pa^3}{3EI}$$

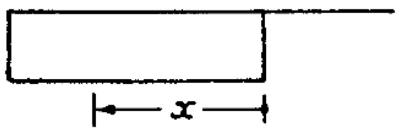
$$d_{max.} = \frac{Pa^3}{3EI}\left(1 + \frac{3b}{2a}\right)$$

Case 4

LOADING



MOMENT



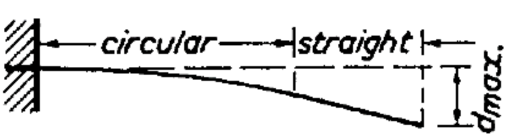
$$M_{max.} = M_x = M_C$$

SHEAR

No shears

N.B. For anti-clockwise moments the deflection is upwards.

DEFLECTION



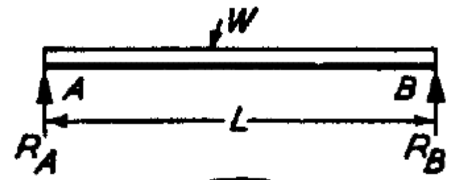
$$d_C = \frac{M.a^2}{2EI}$$

$$d_{max.} = \frac{M.a^2}{2EI}\left(1 + \frac{2b}{a}\right)$$

SIMPLY SUPPORTED BEAMS

Uniformly distributed load W over span L

LOADING

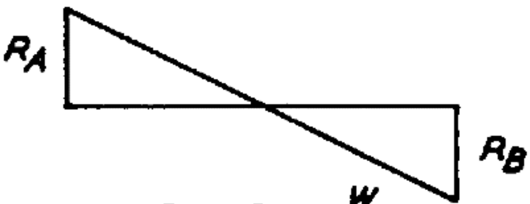


MOMENT

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

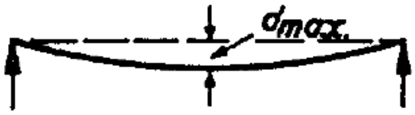
$$M_{max.} = \frac{WL}{8}$$

SHEAR



$$R_A = R_B = \frac{W}{2}$$

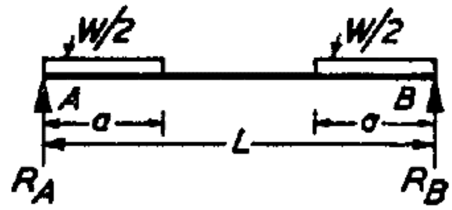
DEFLECTION



$$d_{max.} = \frac{5}{384}\cdot\frac{WL^3}{EI}$$

Two loads W/2 distributed over length a at each end

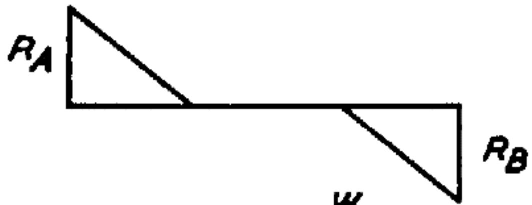
LOADING



MOMENT

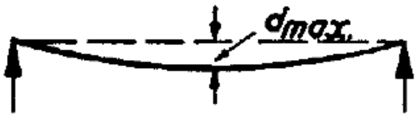
$$M_{max.} = \frac{Wa}{4}$$

SHEAR



$$R_A = R_B = \frac{W}{2}$$

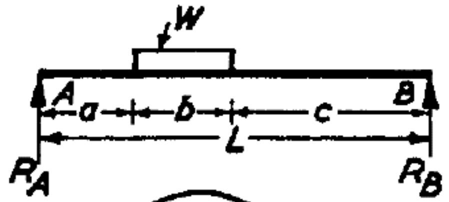
DEFLECTION



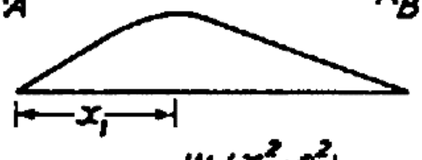
$$d_{max.} = \frac{Wa\,(3L^2-2a^2)}{96EI}$$

Load W distributed over length b

LOADING



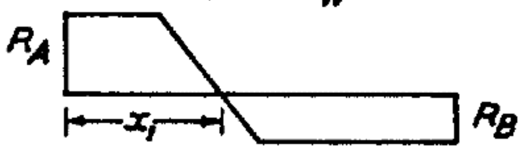
MOMENT



$$M_{max.} = \frac{W}{b}\left(\frac{x_1^2-a^2}{2}\right)$$

when $x_1 = a + \frac{R_A b}{W}$

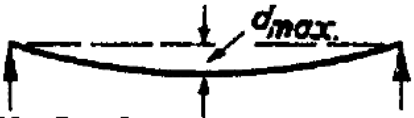
SHEAR



$$R_A = \frac{W}{L}\left(\frac{b}{2}+c\right)$$

$$R_B = \frac{W}{L}\left(\frac{b}{2}+a\right)$$

DEFLECTION

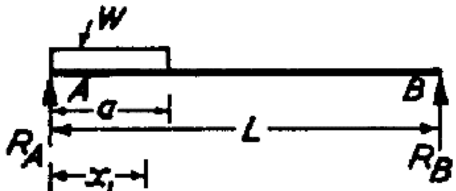


When $a = c$

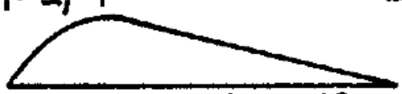
$$d_{max.} = \frac{W}{384EI}\left(8L^3-4Lb^2+b^3\right)$$

Load W distributed over length a at one end

LOADING



MOMENT



$$M_{max.} = \frac{W}{2}a\left(1-\frac{a}{2L}\right)^2$$

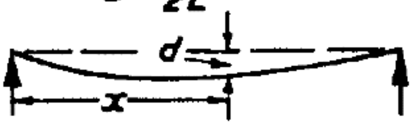
when $x_1 = a\left(1-\frac{a}{2L}\right)$

SHEAR

$$R_A = W\left(1-\frac{a}{2L}\right)$$

$$R_B = \frac{Wa}{2L}$$

DEFLECTION



When $x \le a$,

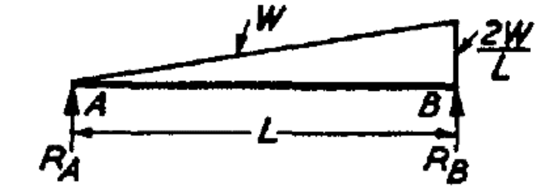
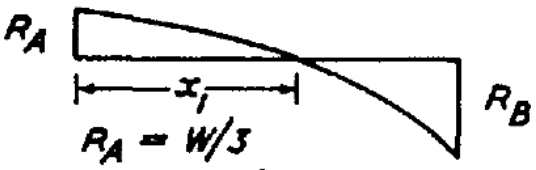
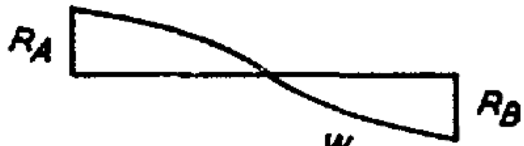
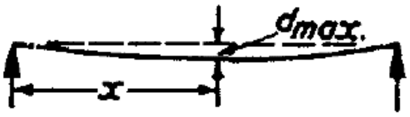
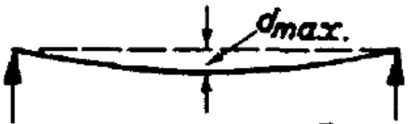
$$d = \frac{WL^4}{24aEI}\left[m^4-2n(2-n)m^3+n^2(2-n)^2m\right]$$

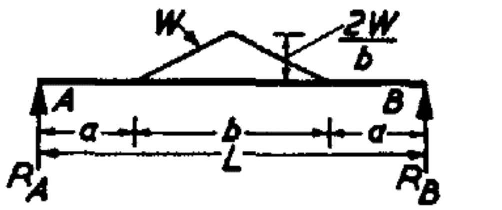
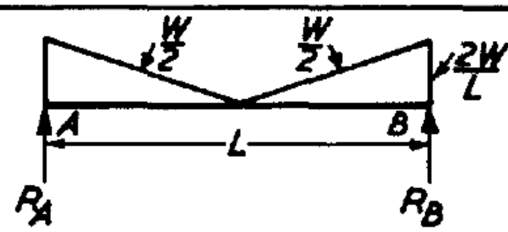
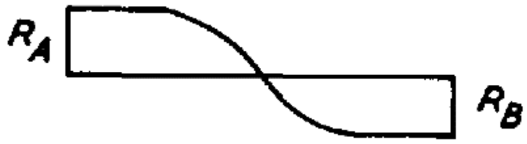
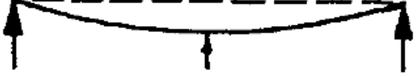
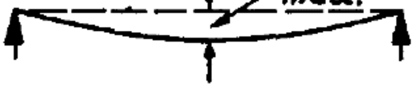
When $x > a$,

$$d = \frac{WL^4}{24aEI}\cdot n^2\left[2m^3-6m^2+m(4+n^2)-n^2\right]$$

where $m = x/L$ and $n = a/L$

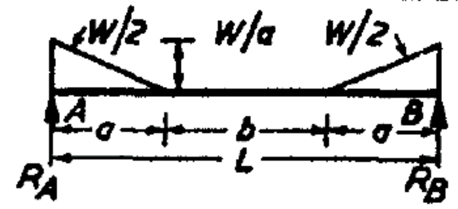
SIMPLY SUPPORTED BEAMS

LOADING		
MOMENT	 $M_x = \frac{Wx}{3}\left(1 - \frac{x^2}{L^2}\right)$ $M_{max.} = 0 \cdot 128WL$ when $x_1 = 0 \cdot 5774L$	 $M_x = Wx\left(\frac{1}{2} - \frac{2x^2}{3L^2}\right)$ $M_{max.} = WL/6$
SHEAR	 $R_A = W/3$ $R_B = 2W/3$	 $R_A = R_B = \frac{W}{2}$
DEFLECTION	 $d_{max.} = \frac{0 \cdot 01304WL^3}{EI}$ when $x = 0 \cdot 5193L$	 $d_{max.} = \frac{WL^3}{60EI}$

LOADING		
MOMENT	 $M_{max.} = \frac{W}{4}\left(L - \frac{b}{3}\right)$	 $M_x = Wx\left(\frac{1}{2} - \frac{x}{L} + \frac{2x^2}{3L^2}\right)$ $M_{max.} = WL/12$
SHEAR	 $R_A = R_B = W/2$	 $R_A = R_B = \frac{W}{2}$
DEFLECTION	 $d_{max.} = \frac{W}{480EI}(8L^3 + 7aL^2 - 4a^2L - 4a^3)$	 $d_{max.} = \frac{3WL^3}{320EI}$

SIMPLY SUPPORTED BEAMS

LOADING



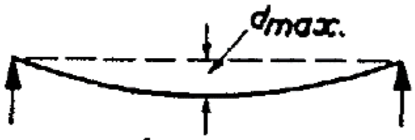
MOMENT

$M_{max.} = \frac{Wa}{6}$

SHEAR

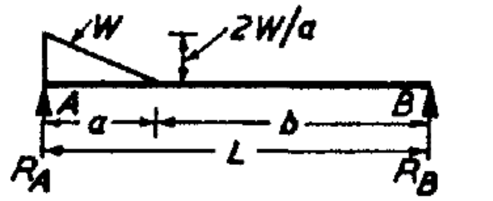
$R_A = R_B = W/2$

DEFLECTION



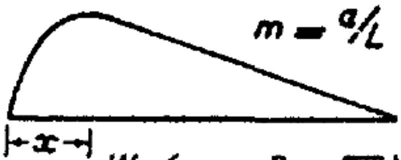
$d_{max.} = \frac{Wa}{240EI}\left(18a^2 + 20ab + 5b^2\right)$

LOADING



MOMENT

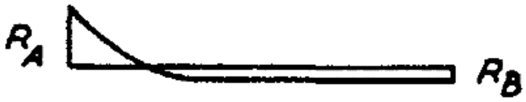
$m = a/L$



$M_{max.} = \frac{Wa}{3}\left(1 - m + \frac{2m}{3}\sqrt{\frac{m}{3}}\right)$

when $x = a\left(1 - \sqrt{\frac{m}{3}}\right)$

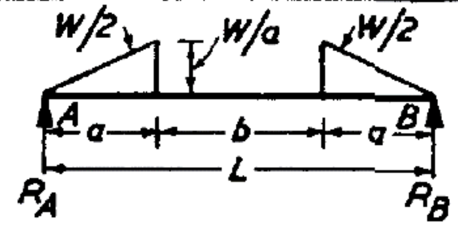
SHEAR



$R_A = W\left(1 - \frac{m}{3}\right)$

$R_B = \frac{Wm}{3}$

LOADING



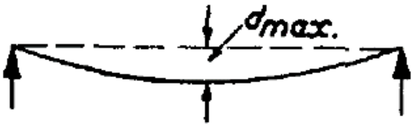
MOMENT

$M_{max.} = \frac{Wa}{3}$

SHEAR

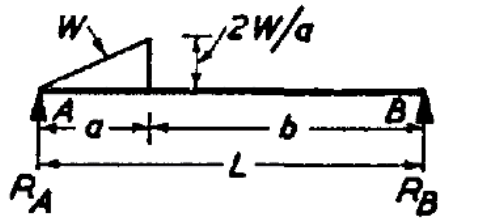
$R_A = R_B = W/2$

DEFLECTION

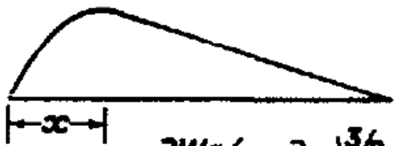


$d_{max.} = \frac{Wa}{120EI}\left(16a^2 + 20ab + 5b^2\right)$

LOADING



MOMENT



$M_{max.} = \frac{2Wa}{3}\left(1 - \frac{2m}{3}\right)^{3/2}$

when $x = a\sqrt{1 - \frac{2m}{3}}$

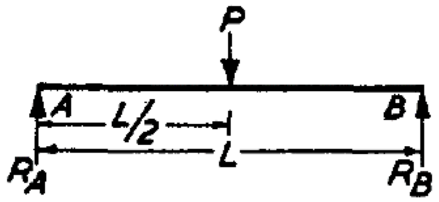
SHEAR

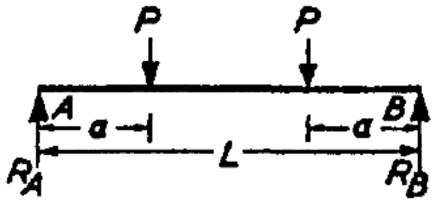
$R_A = W\left(1 - \frac{2m}{3}\right)$

$R_B = \frac{2Wm}{3}$

SIMPLY SUPPORTED BEAMS

LOADING



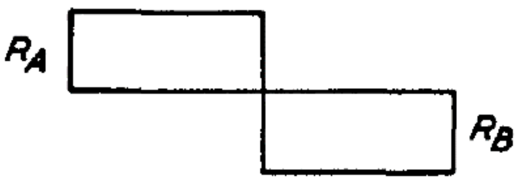


MOMENT

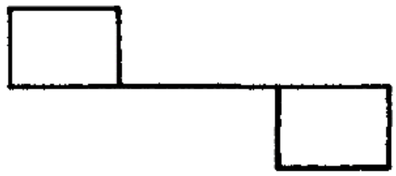
$$M_{max.} = \frac{PL}{4}$$

$$M_{max.} = Pa$$

SHEAR

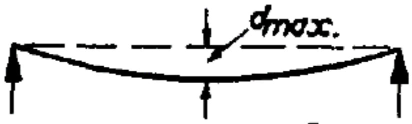


$$R_A = R_B = \frac{P}{2}$$

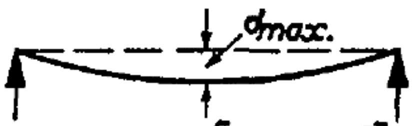


$$R_A = R_B = P$$

DEFLECTION

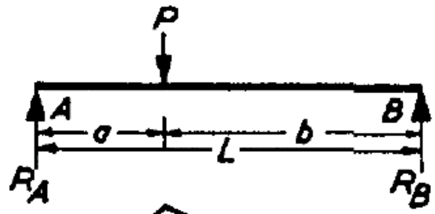


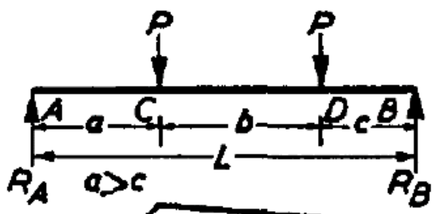
$$d_{max.} = \frac{PL^3}{48EI}$$



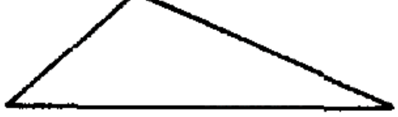
$$d_{max.} = \frac{PL^3}{6EI}\left[\frac{3a}{4L} - \left(\frac{a}{L}\right)^3\right]$$

LOADING





MOMENT



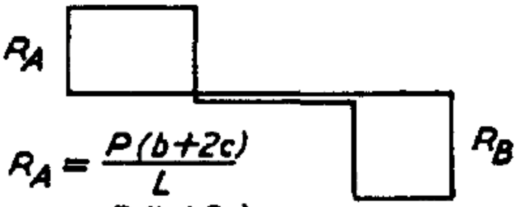
$$M_{max.} = \frac{Pab}{L}$$

$$M_C = \frac{Pa(b+2c)}{L}$$

$$M_D = \frac{Pc(b+2a)}{L}$$

SHEAR

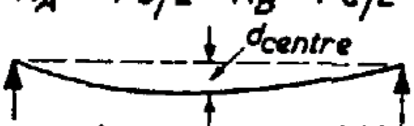
$R_A = Pb/L \quad R_B = Pa/L$



$$R_A = \frac{P(b+2c)}{L}$$

$$R_B = \frac{P(b+2a)}{L}$$

DEFLECTION



$d_{max.}$ always occurs within 0·0774 L of the centre of the beam. When $b \geqslant a$,

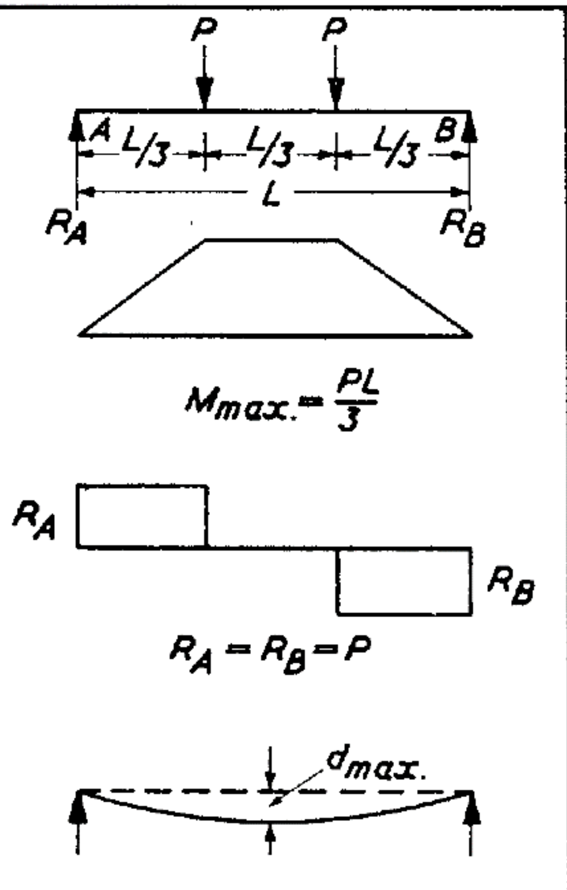
$$d_{centre} = \frac{PL^3}{48EI}\left[\frac{3a}{L} - 4\left(\frac{a}{L}\right)^3\right]$$

This value is always within 2·5% of the maximum value.

For central deflection add the values for each P derived from the formula in the adjacent diagram.

SIMPLY SUPPORTED BEAMS

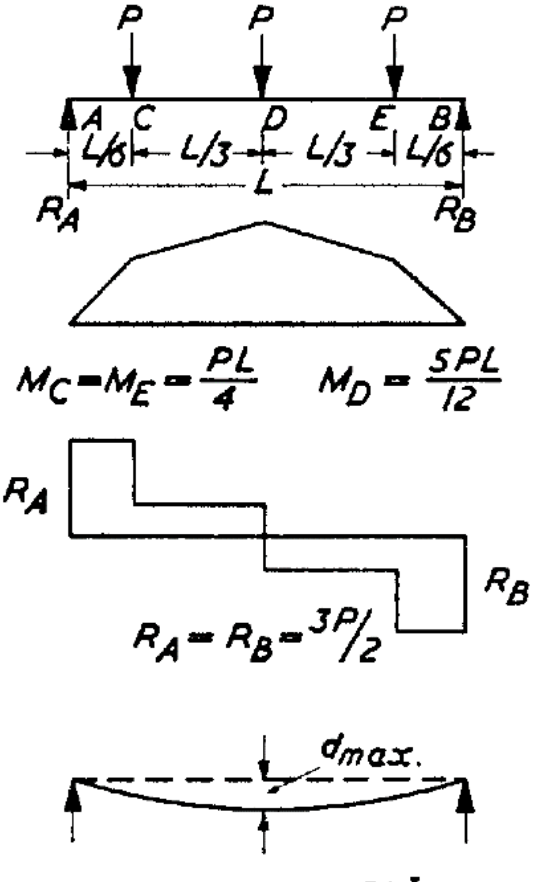
LOADING / MOMENT / SHEAR / DEFLECTION



$M_{max.} = \frac{PL}{3}$

$R_A = R_B = P$

$d_{max.} = \frac{23PL^3}{648EI}$

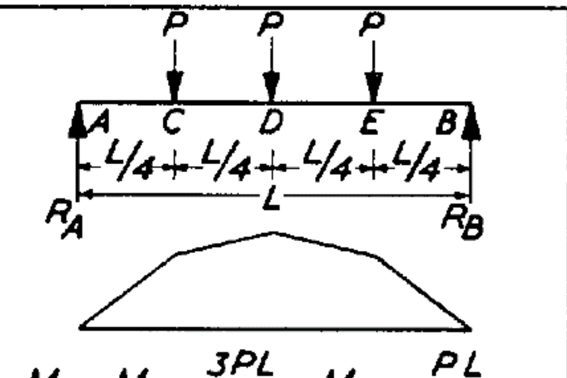


$M_C = M_E = \frac{PL}{4} \quad M_D = \frac{5PL}{12}$

$R_A = R_B = 3P/2$

$d_{max.} = \frac{53PL^3}{1296EI}$

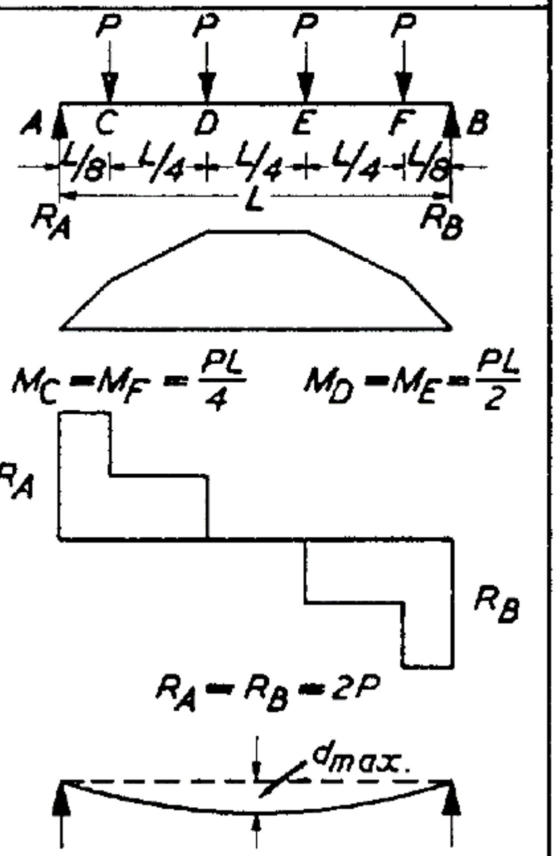
LOADING / MOMENT / SHEAR / DEFLECTION



$M_C = M_E = \frac{3PL}{8} \quad M_D = \frac{PL}{2}$

$R_A = R_B = 3P/2$

$d_{max.} = \frac{19PL^3}{384EI}$



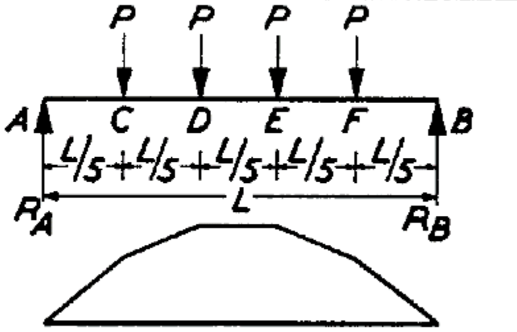
$M_C = M_F = \frac{PL}{4} \quad M_D = M_E = \frac{PL}{2}$

$R_A = R_B = 2P$

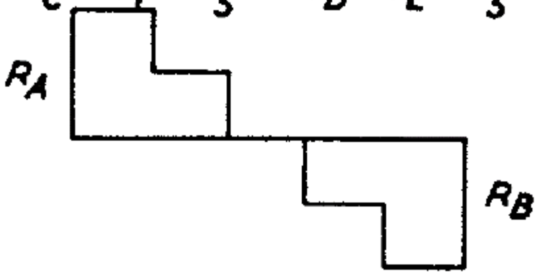
$d_{max.} = \frac{41PL^3}{768EI}$

SIMPLY SUPPORTED BEAMS

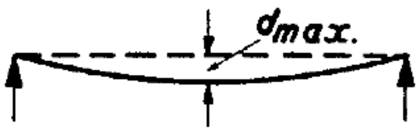
LOADING — MOMENT — SHEAR — DEFLECTION



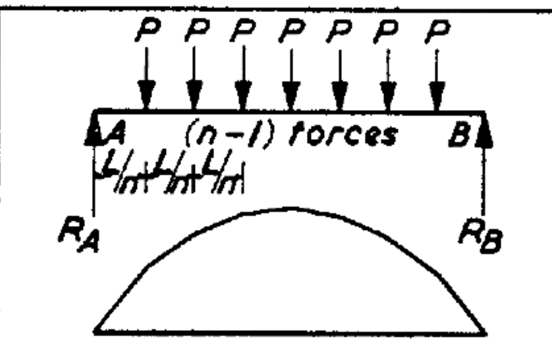
$M_C = M_F = \frac{2PL}{5}$ $M_D = M_E = \frac{3PL}{5}$



$R_A = R_B = 2P$



$d_{max.} = \frac{63PL^3}{1000EI}$



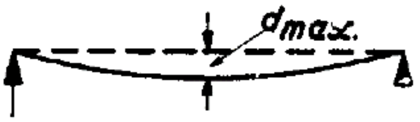
When n is odd,

$M_{max.} = \frac{(n^2-1)\,PL}{8n}$

When n is even,

$M_{max.} = n.PL/8$

$R_A = R_B = (n-1)P/2$



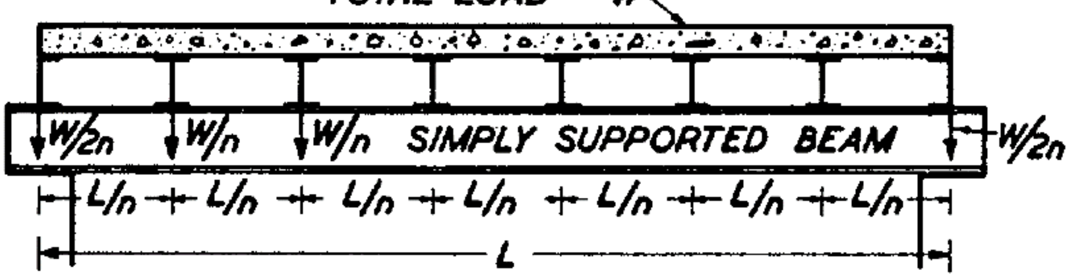
When n is odd

$d_{max.} = \frac{PL^3}{192EI}\left[n-\frac{1}{n}\right]\left[3-\frac{1}{2}\left(1-\frac{1}{n^2}\right)\right]$

When n is even

$d_{max.} = \frac{PL^3}{192EI}\cdot n\left[3-\frac{1}{2}\left(1+\frac{4}{n^2}\right)\right]$

TOTAL LOAD = W



When $n > 10$, consider the load uniformly distributed

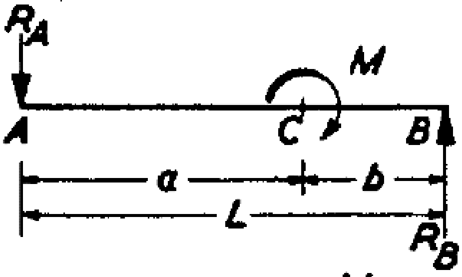
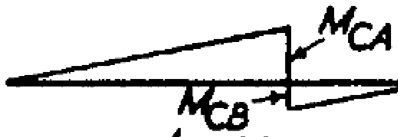
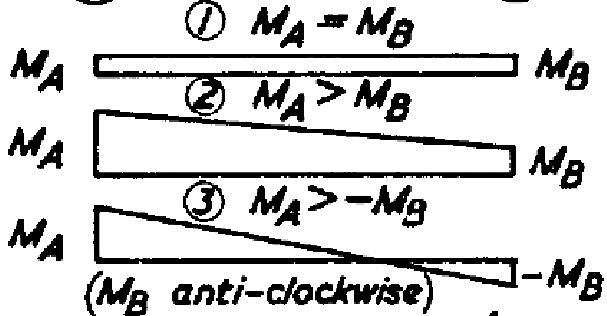
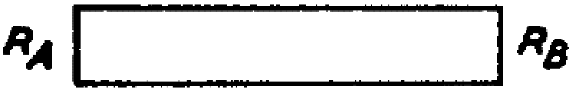
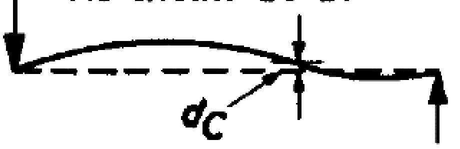
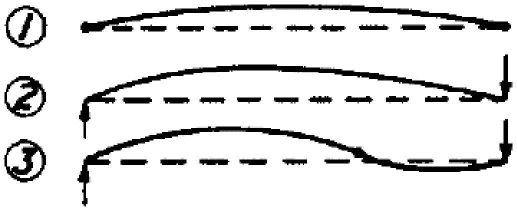
The reaction at the supports = W/2, but the maximum S.F at the ends of the beam $= \frac{W(n-1)}{2n} = A.W$

The value of the maximum bending moment = C.WL

The value of the deflection at the centre of the span $= k.\frac{WL^3}{EI}$

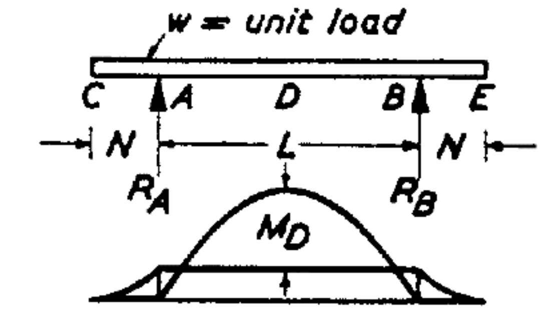
Value of n	A	C	k
2	0·2500	0·1250	0·0105
3	0·3333	0·1111	0·0118
4	0·3750	0·1250	0·0124
5	0·4000	0·1200	0·0126
6	0·4167	0·1250	0·0127
7	0·4286	0·1224	0·0128
8	0·4375	0·1250	0·0128
9	0·4444	0·1236	0·0129
10	0·4500	0·1250	0·0129

SIMPLY SUPPORTED BEAMS

LOADING		
MOMENT	 $M_{CA} = M \cdot a/L$ $M_{CB} = M \cdot b/L$	
SHEAR	 $R_A = R_B = M/L$	Shear diagram when $M_A \neq M_B$  $R_A = -R_B = \frac{M_A - M_B}{L}$
DEFLECTION	As shown $a > b$.  $d_C = \frac{M \cdot ab}{3EI}\left(\frac{a}{L} - \frac{b}{L}\right)$ For anti-clockwise moments the deflections are reversed.	 When $M_A = M_B$, $d_{max} = -\frac{ML^2}{8EI}$

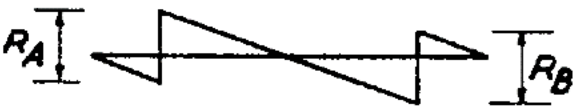
SIMPLY SUPPORTED BEAMS

LOADING / MOMENT



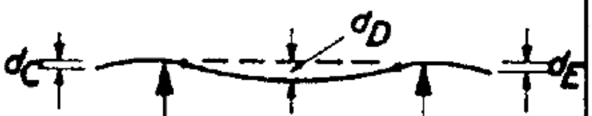
$M_A = M_B = -\frac{wN^2}{2}$ $M_D = \frac{wL^2}{8} + M_A$

SHEAR



$R_A = R_B = w\left(N + \frac{L}{2}\right)$

DEFLECTION

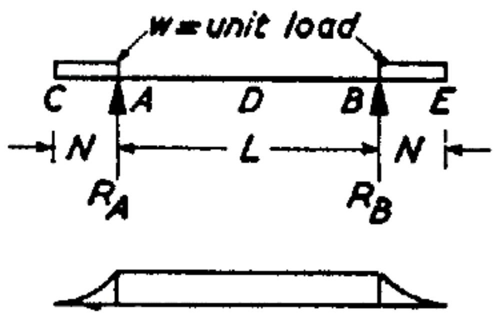


$d_C = d_E = \frac{wL^3 N}{24EI}\left(3n^3 + 6n^2 - 1\right)$

$d_D = \frac{wL^4}{384EI}\left(5 - 24n^2\right)$

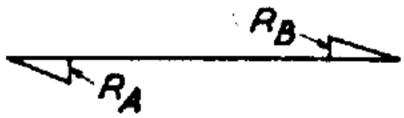
Where $n = N/L$

LOADING / MOMENT



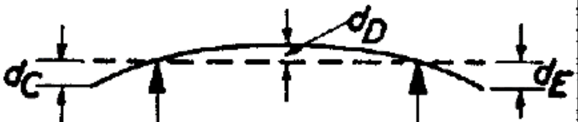
$M_A = M_B = -\frac{wN^2}{2}$

SHEAR



$R_A = R_B = wN$

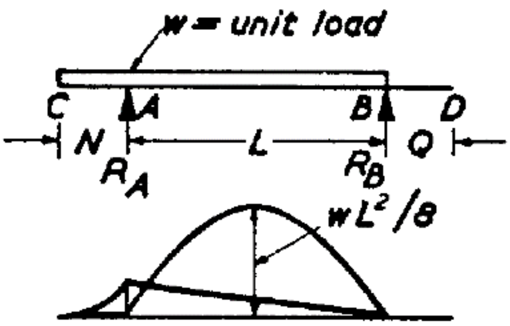
DEFLECTION



$d_C = d_E = \frac{wLN^3}{8EI}\left(2 + \frac{N}{L}\right)$

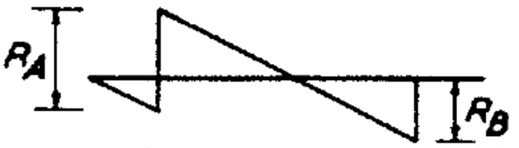
$d_D = -\frac{wL^2 N^2}{16EI}$

LOADING / MOMENT



$M_A = -\frac{wN^2}{2}$

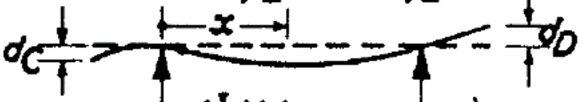
SHEAR



$R_A = \frac{w(N+L)^2}{2L}$ $R_B = \frac{w(L+N)(L-N)}{2L}$

DEFLECTION

$m = x/L$ $n = N/L$

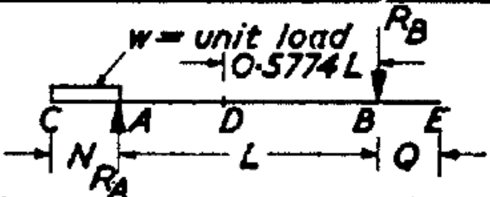


$d_C = \frac{wL^3 N}{24EI}\left(3n^3 + 4n^2 - 1\right)$

$d_x = \frac{wL^4}{24EI}\left[m^4 - 2m^3\left(1-n^2\right) + m\left(1-2n^2\right)\right]$

$d_D = -\frac{wL^3 Q}{24EI}\left(2n^2 - 1\right)$

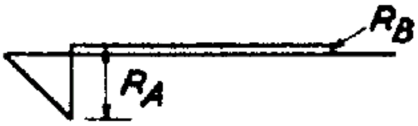
LOADING / MOMENT



Max. upward deflection is at D.

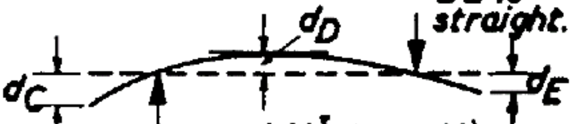
$M_A = -\frac{wN^2}{2}$

SHEAR



$R_A = \frac{wN(2L+N)}{2L}$ $R_B = \frac{wN^2}{2L}$

DEFLECTION



$d_C = \frac{wLN^3}{24EI}\left(4 + 3\frac{N}{L}\right)$

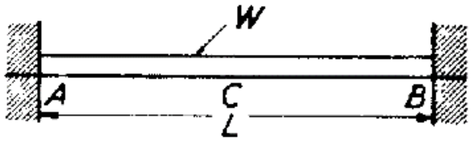
$d_D = -\frac{0.032\,wL^2 N^2}{EI}$

$d_E = \frac{wLN^2 Q}{12EI}$

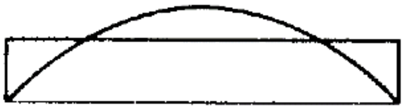
BUILT — IN BEAMS

Uniformly distributed load W over span L

LOADING



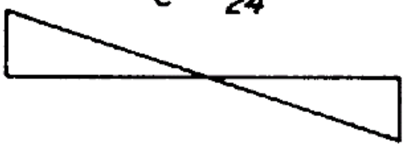
MOMENT

M_A  M_B

$$M_A = M_B = -\frac{WL}{12}$$

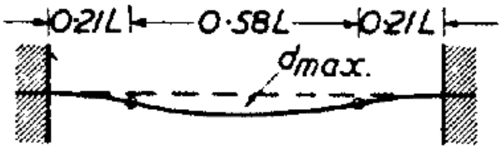
$$M_C = \frac{WL}{24}$$

SHEAR

R_A  R_B

$$R_A = R_B = W/2$$

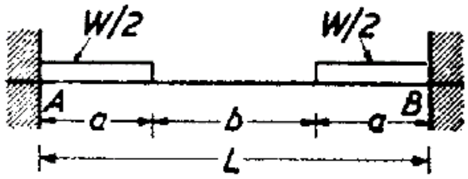
DEFLECTION



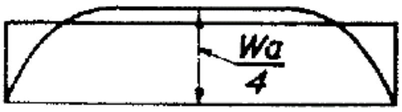
$$d_{max.} = \frac{WL^3}{384EI}$$

Two loads W/2 distributed over end lengths a

LOADING

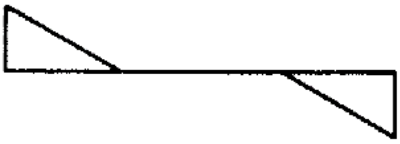


MOMENT



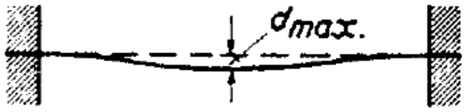
$$M_A = M_B = -\frac{Wa}{12L}(3L-2a)$$

SHEAR

R_A  R_B

$$R_A = R_B = W/2$$

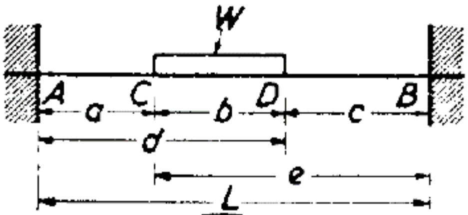
DEFLECTION



$$d_{max.} = \frac{Wa^2}{48EI}(L-a)$$

Load W distributed over length b

LOADING



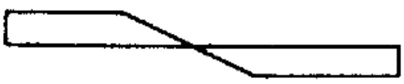
MOMENT

M_A  M_B

$$M_A = \frac{-W}{12L^2b}\left[e^3(4L-3e) - c^3(4L-3c)\right]$$

$$M_B = \frac{-W}{12L^2b}\left[d^3(4L-3d) - a^3(4L-3a)\right]$$

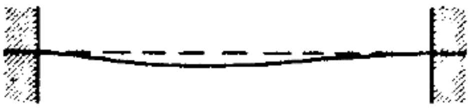
SHEAR

R_A  R_B

When r is the simple support reaction

$$R_A = r_A + \frac{M_A - M_B}{L} \qquad R_B = r_B + \frac{M_B - M_A}{L}$$

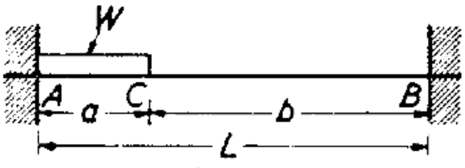
DEFLECTION



When $a = c$, $d_{max.} = \frac{W}{384EI}(L^3 + 2L^2a + 4La^2 - 8a^3)$

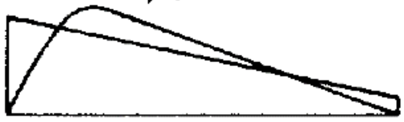
Load W distributed over length a from A

LOADING



$a/L = m$

MOMENT

M_A  M_B

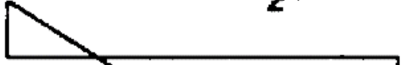
$$M_A = -\frac{WL}{12}\cdot m\,(3m^2 - 8m + 6)$$

$$M_B = -\frac{WL}{12}\cdot m^2(4-3m)$$

$$+M_{max.} = \frac{WL}{12}m^2\left(-\frac{3}{2}m^5 + 6m^4 - 6m^3 - 6m^2 + 15m - 8\right)$$

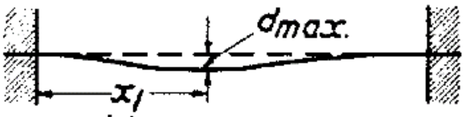
When $x = \frac{a}{2}(m^3 - 2m^2 + 2)$

SHEAR

R_A  R_B

$$R_A = \frac{W(m^3 - 2m^2 + 2)}{2} \qquad R_B = \frac{W.m^3(2-m)}{2m}$$

DEFLECTION



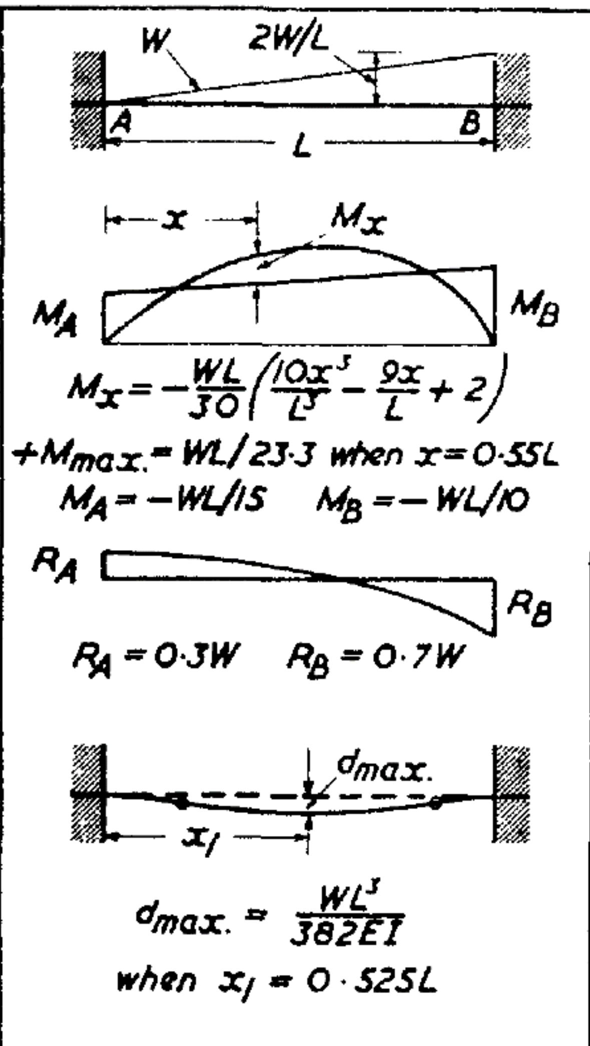
When $a = L/2$ and $x_1 = 0{\cdot}445L$

$$d_{max.} = \frac{WL^3}{333EI}$$

$$d_C = \frac{WL^3}{384EI}$$

BUILT-IN BEAMS

LOADING / MOMENT / SHEAR / DEFLECTION



$$M_x = -\frac{WL}{30}\left(\frac{10x^3}{L^3} - \frac{9x}{L} + 2\right)$$

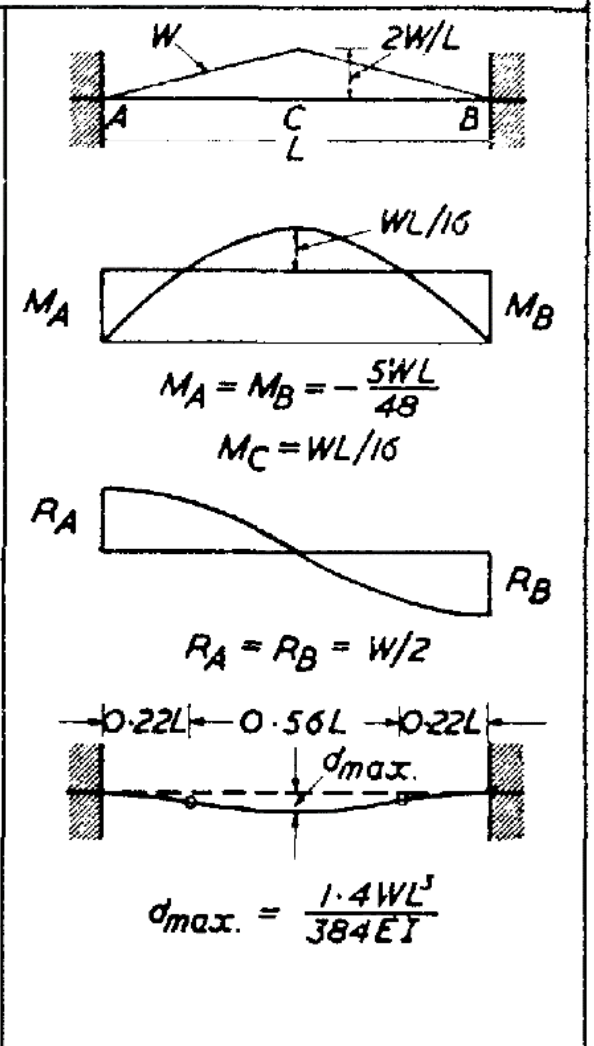
$+M_{max.} = WL/23{\cdot}3$ when $x = 0{\cdot}55L$

$M_A = -WL/15 \quad M_B = -WL/10$

$R_A = 0{\cdot}3W \quad R_B = 0{\cdot}7W$

$$d_{max.} = \frac{WL^3}{382EI}$$

when $x_1 = 0{\cdot}525L$

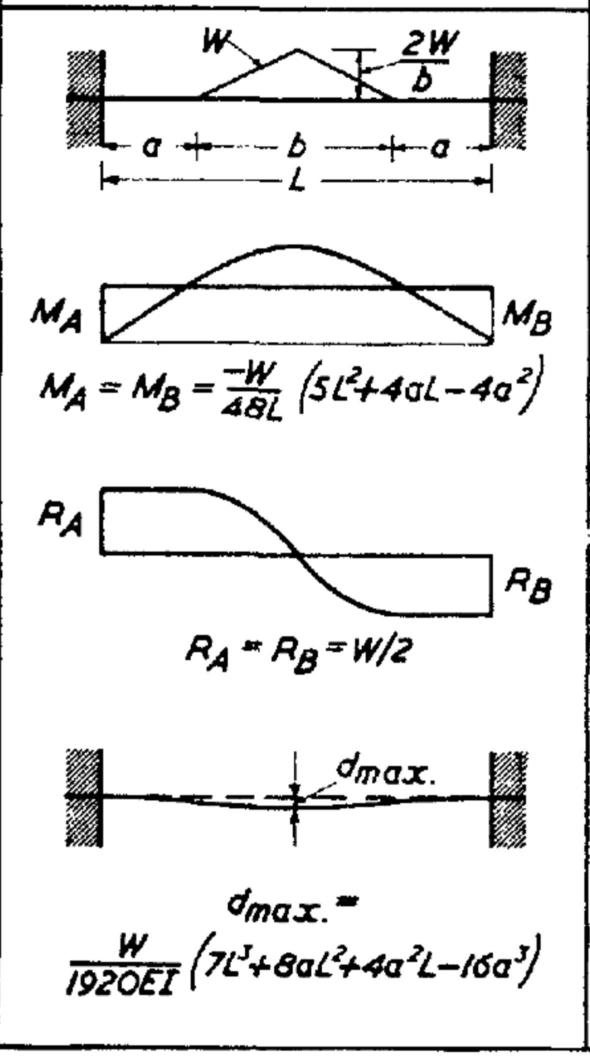


$$M_A = M_B = -\frac{5WL}{48}$$

$M_C = WL/16$

$R_A = R_B = W/2$

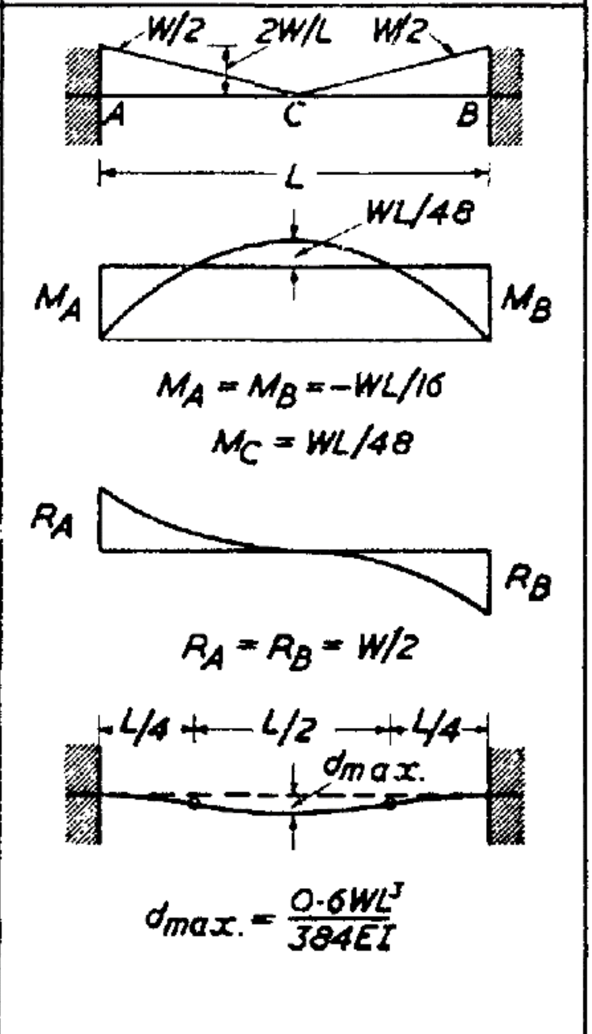
$$d_{max.} = \frac{1{\cdot}4WL^3}{384EI}$$



$$M_A = M_B = \frac{-W}{48L}\left(5L^2 + 4aL - 4a^2\right)$$

$R_A = R_B = W/2$

$$d_{max.} = \frac{W}{1920EI}\left(7L^3 + 8aL^2 + 4a^2L - 16a^3\right)$$



$M_A = M_B = -WL/16$

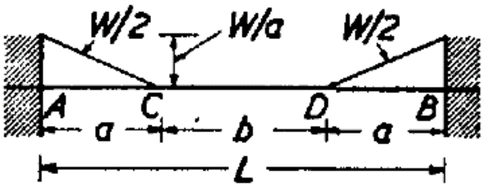
$M_C = WL/48$

$R_A = R_B = W/2$

$$d_{max.} = \frac{0{\cdot}6WL^3}{384EI}$$

BUILT-IN BEAMS

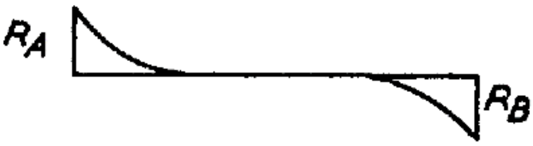
LOADING



MOMENT

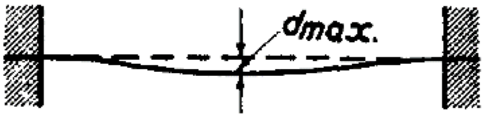
$$M_A = M_B = -\frac{Wa}{12L}(2L-a)$$

SHEAR



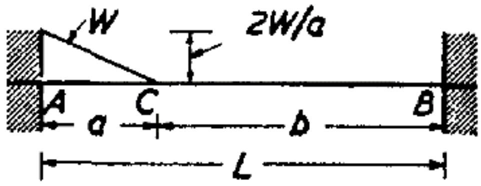
$$R_A = R_B = W/2$$

DEFLECTION

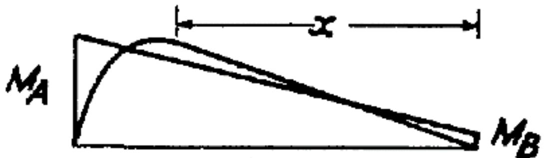


$$d_{max.} = \frac{Wa^2}{480EI}(5L-4a)$$

LOADING



MOMENT



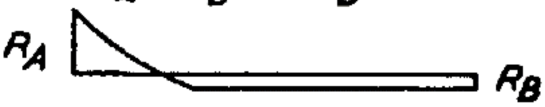
$$M_A = -\frac{Wa}{30L^2}(3a^2+10bL)$$

$$M_B = -\frac{Wa^2}{30L^2}(5L-3a)$$

In AC. $M_x = R_B.x + M_B - \frac{2W(x-b)^3}{6ab}$

In CB. $M_x = R_B.x + M_B$

SHEAR



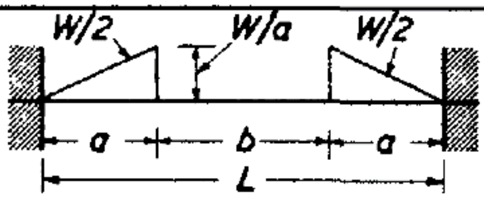
$$R_A = \frac{W}{10L^3}(10L^3-5La^2+2a^3)$$

$$R_B = \frac{Wa^2}{10L^3}(5L-2a)$$

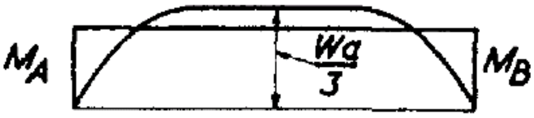
DEFLECTION

———

LOADING



MOMENT

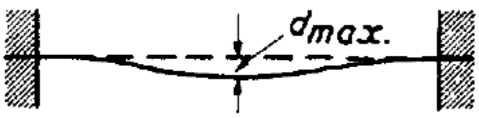


$$M_A = M_B = -\frac{Wa}{12L}(4L-3a)$$

SHEAR

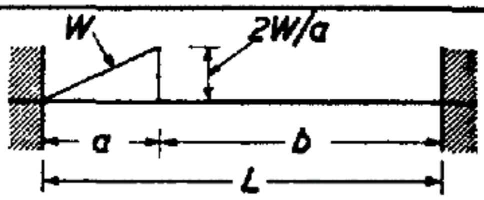
$$R_A = R_B = W/2$$

DEFLECTION

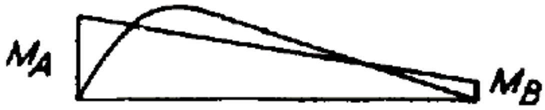


$$d_{max.} = \frac{Wa^2}{480EI}(15L-16a)$$

LOADING



MOMENT



$$M_A = -\frac{Wa}{15L^2}(10L^2-15aL+6a^2)$$

$$M_B = -\frac{Wa^2}{10L^2}(5L-4a)$$

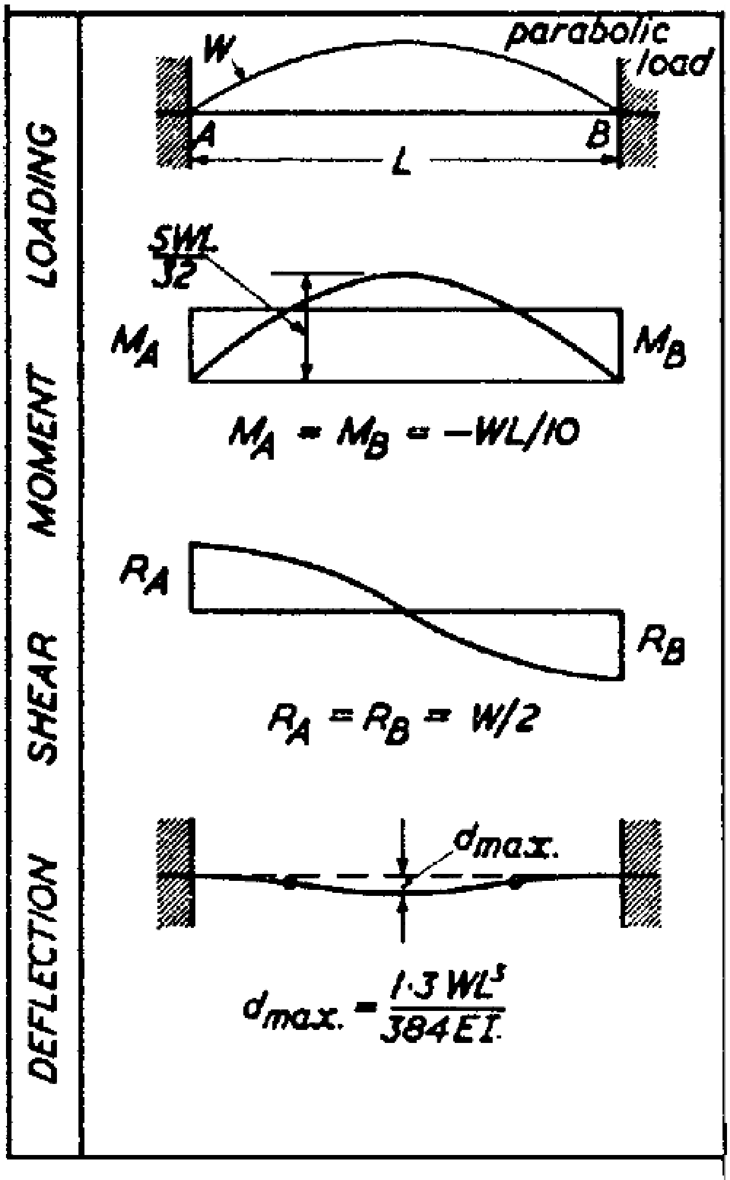
SHEAR

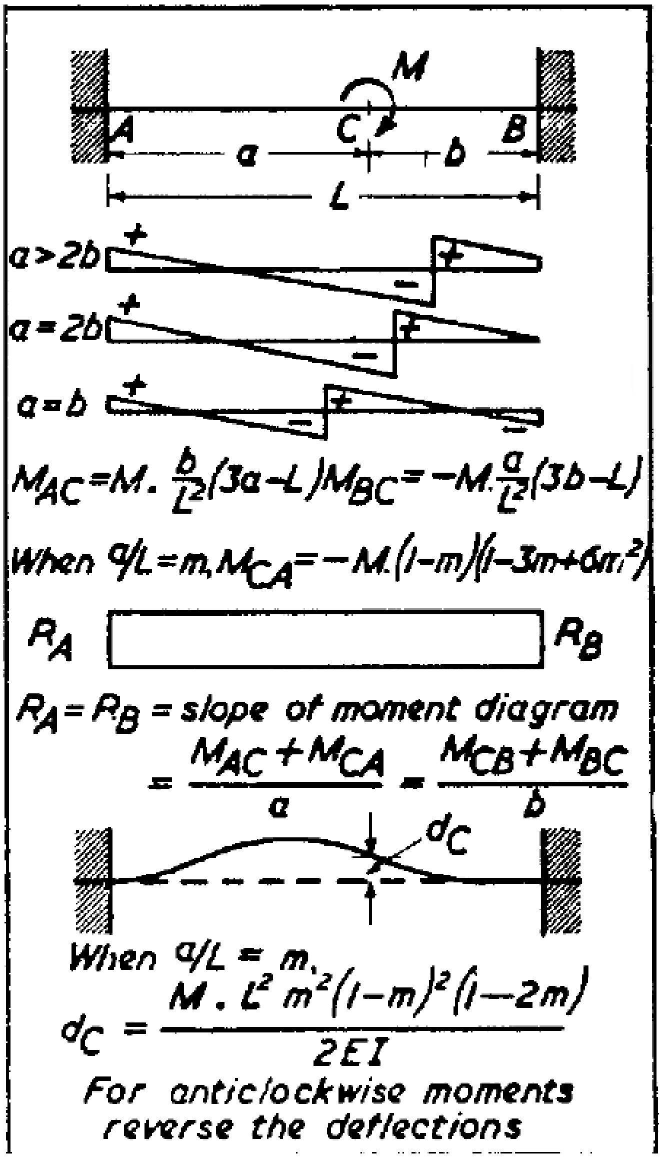
$$R_A = \frac{W}{10L^3}(10L^3-15La^2+8a^3)$$

$$R_B = \frac{Wa^2}{10L^3}(15L-8a)$$

DEFLECTION

———

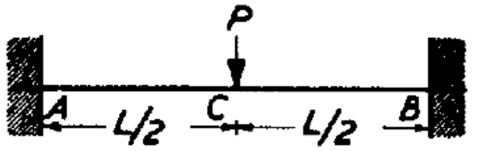

LOADING
MOMENT
SHEAR
DEFLECTION
W
parabolic load
A
B
L
$\frac{5WL}{32}$
M_A
M_B
$M_A = M_B = -WL/10$
R_A
R_B
$R_A = R_B = W/2$
$d_{max.}$
$d_{max.} = \frac{1{\cdot}3\,WL^3}{384EI}$


M
A
C
B
a
b
L
a>2b
a=2b
a=b
+
−
$M_{AC} = M.\frac{b}{L^2}(3a-L)$ $M_{BC} = -M.\frac{a}{L^2}(3b-L)$
When $a/L = m$, $M_{CA} = -M.(1-m)(1-3m+6m^2)$
R_A
R_B
$R_A = R_B =$ slope of moment diagram
$= \frac{M_{AC}+M_{CA}}{a} = \frac{M_{CB}+M_{BC}}{b}$
d_C
When $a/L = m$,
$d_C = \frac{M.L^2 m^2 (1-m)^2 (1-2m)}{2EI}$
For anticlockwise moments reverse the deflections

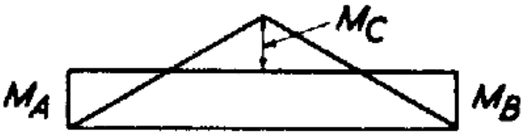
BUILT – IN BEAMS

Central point load P

LOADING

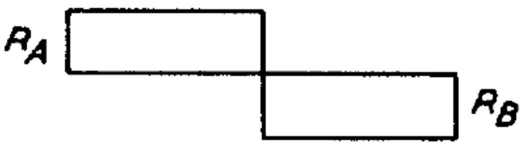


MOMENT



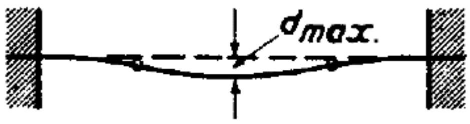
$$-M_A = -M_B = M_C = PL/8$$

SHEAR



$$R_A = R_B = P/2$$

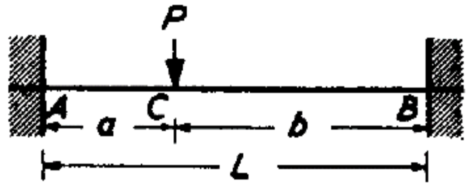
DEFLECTION



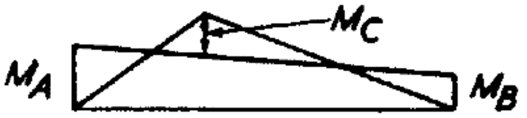
$$d_{max.} = \frac{PL^3}{192\,EI}$$

Point load P at distance a from A

LOADING



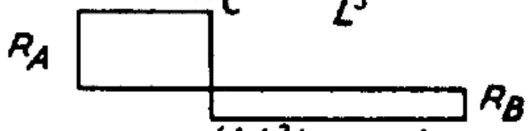
MOMENT



$$M_A = -\frac{Pab^2}{L^2} \qquad M_B = -\frac{Pba^2}{L^2}$$

$$M_C = \frac{2Pa^2b^2}{L^3}$$

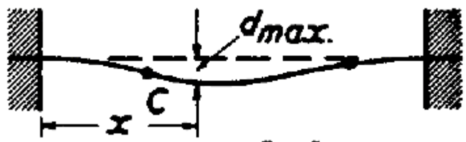
SHEAR



$$R_A = P\left(\frac{b}{L}\right)^2\left(1 + 2\,\frac{a}{L}\right)$$

$$R_B = P\left(\frac{a}{L}\right)^2\left(1 + 2\,\frac{b}{L}\right)$$

DEFLECTION

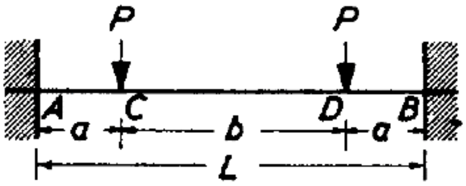


$$d_C = \frac{Pa^3b^3}{3EIL^3}$$

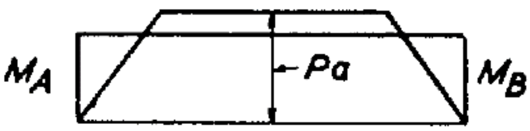
$$d_{max.} = \frac{2Pa^2b^3}{3EI(3L-2a)^2} \text{ when } x = \frac{L^2}{3L-2a}$$

Two point loads P at distance a from each end

LOADING



MOMENT



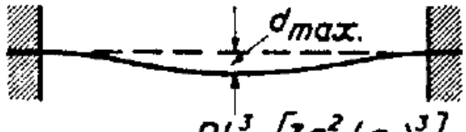
$$M_A = M_B = -\frac{Pa(L-a)}{L}$$

$$M_C = M_D = Pa^2/L$$

SHEAR

$$R_A = R_B = P$$

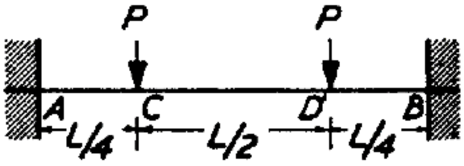
DEFLECTION



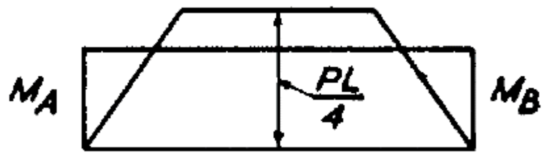
$$d_{max.} = \frac{PL^3}{6EI}\left[\frac{3a^2}{4L^2} - \left(\frac{a}{L}\right)^3\right]$$

Two point loads P at the quarter points

LOADING



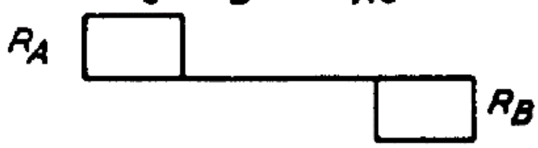
MOMENT



$$M_A = M_B = -3PL/16$$

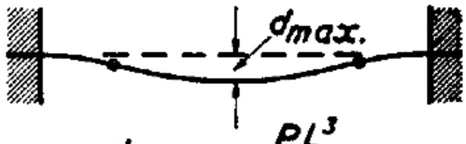
$$M_C = M_D = PL/16$$

SHEAR



$$R_A = R_B = P$$

DEFLECTION



$$d_{max.} = \frac{PL^3}{192EI}$$

BUILT — IN BEAMS