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Fourteenth Edition in SI Units

R. C. Hibbeler

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Fourteenth Edition in SI Units



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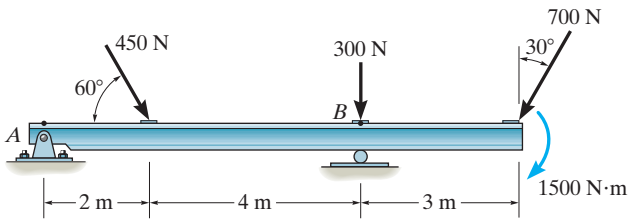
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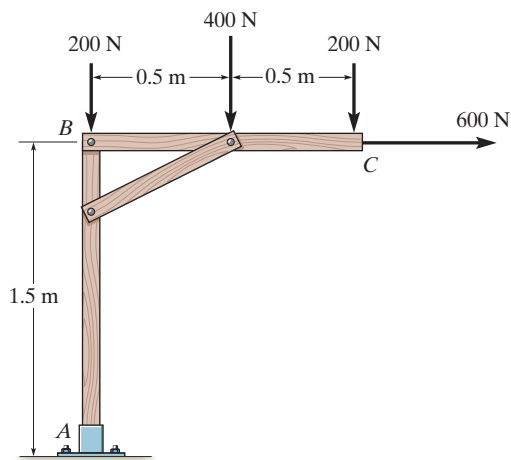
4-121. Replace the loading acting on the beam by a single resultant force. Specify where the force acts, measured from end A .

4-122. Replace the loading acting on the beam by a single resultant force. Specify where the force acts, measured from B .



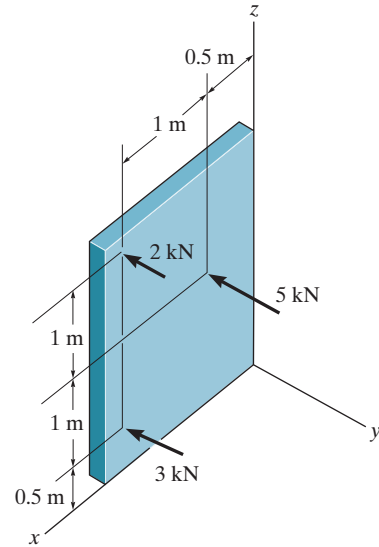
Probs. 4-121/122

4-123. Replace the loading on the frame by a single resultant force. Specify where its line of action intersects a vertical line along member AB , measured from A .



Prob. 4-123

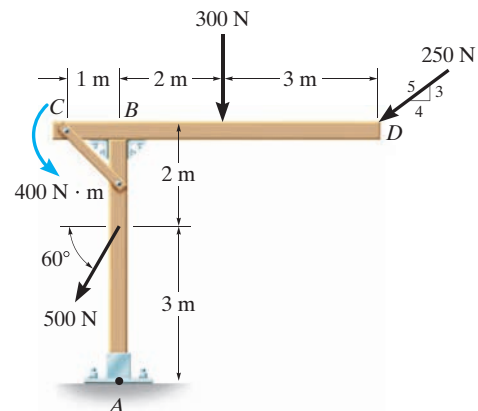
***4-124.** Replace the parallel force system acting on the plate by a resultant force and specify its location on the x - z plane.



Prob. 4-124

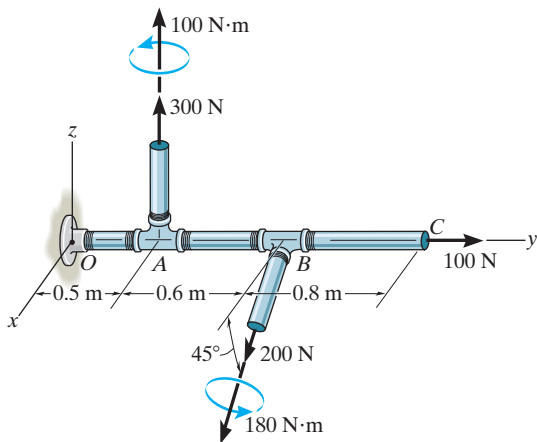
4-125. Replace the loading on the frame by a single resultant force. Specify where its line of action intersects member AB , measured from A .

4-126. Replace the loading on the frame by a single resultant force. Specify where its line of action intersects member CD , measured from end C .



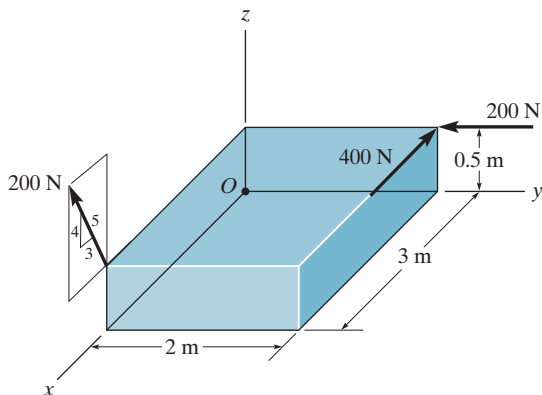
Probs. 4-125/126

4-127. Replace the two wrenches and the force, acting on the pipe assembly, by an equivalent resultant force and couple moment at point O .



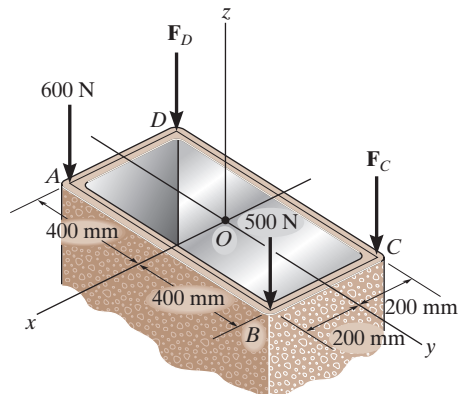
Prob. 4-127

***4-128.** Replace the force system by a wrench and specify the magnitude of the force and couple moment of the wrench and the point where the wrench intersects the x - z plane.



Prob. 4-128

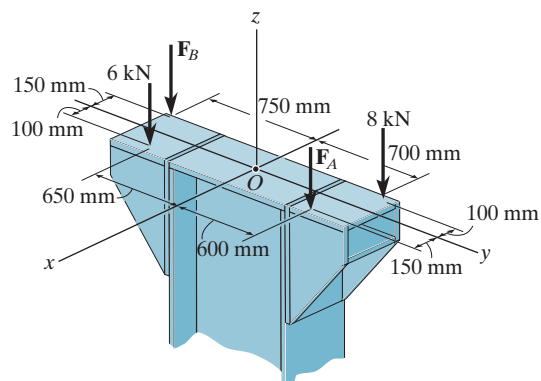
4-129. The tube supports the four parallel forces. Determine the magnitudes of forces $\mathbf{F}_C$ and $\mathbf{F}_D$ acting at C and D so that the equivalent resultant force of the force system acts through the midpoint O of the tube.



Prob. 4-129

4-130. If $F_A = 7$ kN and $F_B = 5$ kN, represent the force system acting on the corbels by a resultant force, and specify its location on the x - y plane.

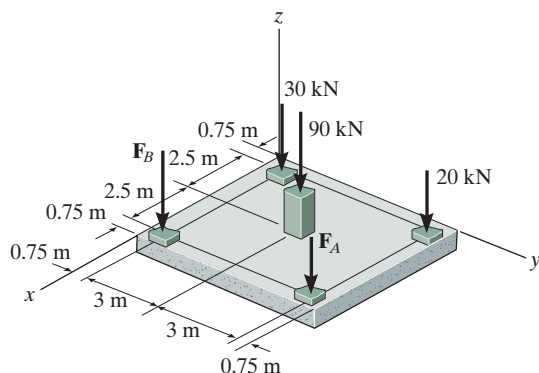
4-131. Determine the magnitudes of $\mathbf{F}_A$ and $\mathbf{F}_B$ so that the resultant force passes through point O of the column.



Probs. 4-130/131

***4-132.** If $F_A = 40$ kN and $F_B = 35$ kN, determine the magnitude of the resultant force and specify the location of its point of application (x, y) on the slab.

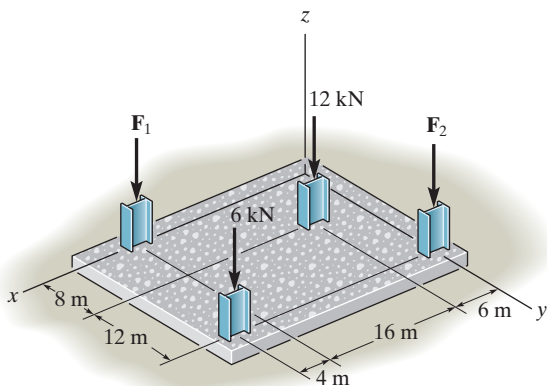
4-133. If the resultant force is required to act at the center of the slab, determine the magnitude of the column loadings F_A and F_B and the magnitude of the resultant force.



Probs. 4-132/133

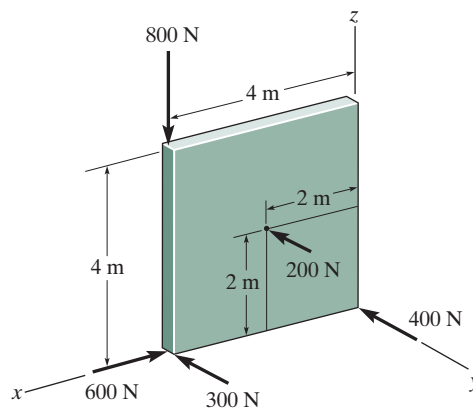
4-134. The building slab is subjected to four parallel column loadings. Determine the equivalent resultant force and specify its location (x, y) on the slab. Take $F_1 = 8$ kN and $F_2 = 9$ kN.

4-135. The building slab is subjected to four parallel column loadings. Determine F_1 and F_2 if the resultant force acts through point (12 m, 10 m).



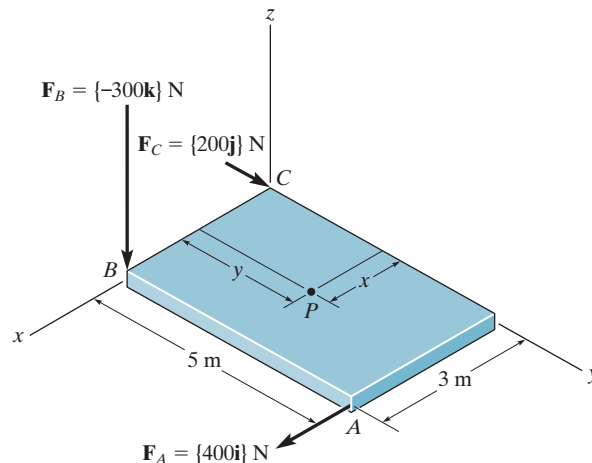
Probs. 4-134/135

***4-136.** Replace the five forces acting on the plate by a wrench. Specify the magnitude of the force and couple moment for the wrench and the point $P(x, z)$ where the wrench intersects the x - z plane.

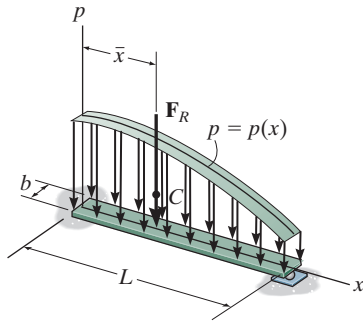


Prob. 4-136

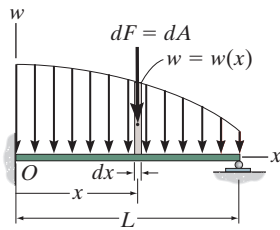
4-137. Replace the three forces acting on the plate by a wrench. Specify the magnitude of the force and couple moment for the wrench and the point $P(x, y)$ where the wrench intersects the plate.



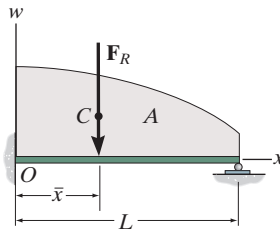
Prob. 4-137



(a)



(b)



(c)

Fig. 4-48

4.9 Reduction of a Simple Distributed Loading

Sometimes, a body may be subjected to a loading that is distributed over its surface. For example, the pressure of the wind on the face of a sign, the pressure of water within a tank, or the weight of sand on the floor of a storage container, are all **distributed loadings**. The pressure exerted at each point on the surface indicates the intensity of the loading. It is measured using pascals Pa (or N/m^2) in SI units.

Loading Along a Single Axis. The most common type of distributed loading encountered in engineering practice can be represented along a single axis.* For example, consider the beam (or plate) in Fig. 4-48a that has a constant width and is subjected to a pressure loading that varies only along the x axis. This loading can be described by the function $p = p(x) \text{ N/m}^2$. It contains only one variable x , and for this reason, we can also represent it as a *coplanar distributed load*. To do so, we multiply the loading function by the width b m of the beam, so that $w(x) = p(x)b \text{ N/m}$, Fig. 4-48b. Using the methods of Sec. 4.8, we can replace this coplanar parallel force system with a single equivalent resultant force $\mathbf{F}_R$ acting at a specific location on the beam, Fig. 4-48c.

Magnitude of Resultant Force. From Eq. 4-17 ($F_R = \Sigma F$), the magnitude of $\mathbf{F}_R$ is equivalent to the sum of all the forces in the system. In this case integration must be used since there is an infinite number of parallel forces $d\mathbf{F}$ acting on the beam, Fig. 4-48b. Since $d\mathbf{F}$ is acting on an element of length dx , and $w(x)$ is a force per unit length, then $dF = w(x) dx = dA$. In other words, the magnitude of $d\mathbf{F}$ is determined from the colored differential area dA under the loading curve. For the entire length L ,

$$+\downarrow F_R = \Sigma F; \quad F_R = \int_L w(x) dx = \int_A dA = A \quad (4-19)$$

Therefore, the magnitude of the resultant force is equal to the area A under the loading diagram, Fig. 4-48c.

*The more general case of a surface loading acting on a body is considered in Sec. 9.5.

Location of Resultant Force. Applying Eq. 4-17 ($M_{R_O} = \Sigma M_O$), the location $\bar{x}$ of the line of action of $\mathbf{F}_R$ can be determined by equating the moments of the force resultant and the parallel force distribution about point O (the y axis). Since $d\mathbf{F}$ produces a moment of $x dF = xw(x) dx$ about O , Fig. 4-48b, then for the entire length, Fig. 4-48c,

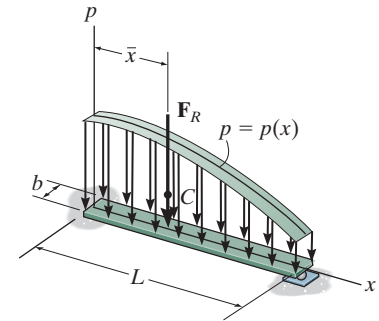
$$\zeta + (M_R)_O = \Sigma M_O; \quad -\bar{x}F_R = -\int_L xw(x) dx$$

Solving for $\bar{x}$, using Eq. 4-19, we have

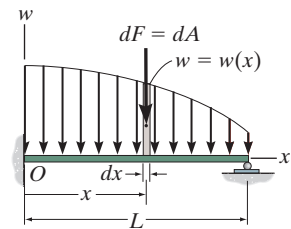
$$\bar{x} = \frac{\int_L xw(x) dx}{\int_L w(x) dx} = \frac{\int_A x dA}{\int_A dA} \quad (4-20)$$

This coordinate $\bar{x}$, locates the geometric center or **centroid** of the area under the distributed loading. *In other words, the resultant force has a line of action which passes through the centroid C (geometric center) of the area under the loading diagram*, Fig. 4-48c. Detailed treatment of the integration techniques for finding the location of the centroid for areas is given in Chapter 9. In many cases, however, the distributed-loading diagram is in the shape of a rectangle, triangle, or some other simple geometric form. The centroid location for such common shapes does not have to be determined from the above equation but can be obtained directly from the tabulation given on the inside back cover.

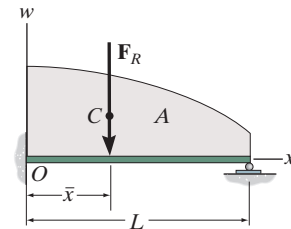
Once $\bar{x}$ is determined, $\mathbf{F}_R$ by symmetry passes through point $(\bar{x}, 0)$ on the surface of the beam, Fig. 4-48a. *Therefore, in this case the resultant force has a magnitude equal to the volume under the loading curve $p = p(x)$ and a line of action which passes through the centroid (geometric center) of this volume.*



(a)



(b)



(c)

Fig. 4-48 (Repeated)

Important Points

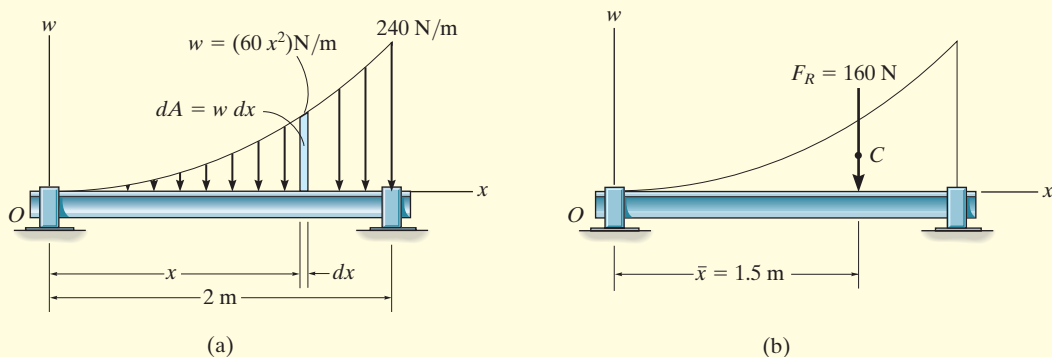
- Coplanar distributed loadings are defined by using a loading function $w = w(x)$ that indicates the intensity of the loading along the length of a member. This intensity is measured in N/m.
- The external effects caused by a coplanar distributed load acting on a body can be represented by a single resultant force.
- This resultant force is equivalent to the *area* under the loading diagram, and has a line of action that passes through the *centroid* or geometric center of this area.



The pile of brick creates an approximate triangular distributed loading on the board.

EXAMPLE 4.21

Determine the magnitude and location of the equivalent resultant force acting on the shaft in Fig. 4-49a.

**Fig. 4-49****SOLUTION**

Since $w = w(x)$ is given, this problem will be solved by integration.

The differential element has an area $dA = w dx = 60x^2 dx$. Applying Eq. 4-19,

$$+\downarrow F_R = \Sigma F;$$

$$F_R = \int_A dA = \int_0^{2\text{ m}} 60x^2 dx = 60 \left(\frac{x^3}{3} \right) \bigg|_0^{2\text{ m}} = 60 \left(\frac{2^3}{3} - \frac{0^3}{3} \right) \\ = 160 \text{ N} \quad \text{Ans.}$$

The location $\bar{x}$ of F_R measured from O , Fig. 4-49b, is determined from Eq. 4-20.

$$\bar{x} = \frac{\int_A x dA}{\int_A dA} = \frac{\int_0^{2\text{ m}} x(60x^2) dx}{160 \text{ N}} = \frac{60 \left(\frac{x^4}{4} \right) \bigg|_0^{2\text{ m}}}{160 \text{ N}} = \frac{60 \left(\frac{2^4}{4} - \frac{0^4}{4} \right)}{160 \text{ N}} \\ = 1.5 \text{ m} \quad \text{Ans.}$$

NOTE: These results can be checked by using the table on the inside back cover, where it is shown that the formula for an exparabolic area of length a , height b , and shape shown in Fig. 4-49a, is

$$A = \frac{ab}{3} = \frac{2 \text{ m}(240 \text{ N/m})}{3} = 160 \text{ N} \text{ and } \bar{x} = \frac{3}{4}a = \frac{3}{4}(2 \text{ m}) = 1.5 \text{ m}$$