Engineering Mechanics: Statics Tenth Edition

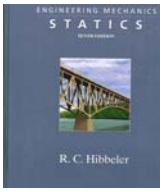
CHAPTER

FORCE SYSTEM RESULTANTS

UMBC

4e

•College of Engineering •Department of Mechanical Engineering



by
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SPRING 2007

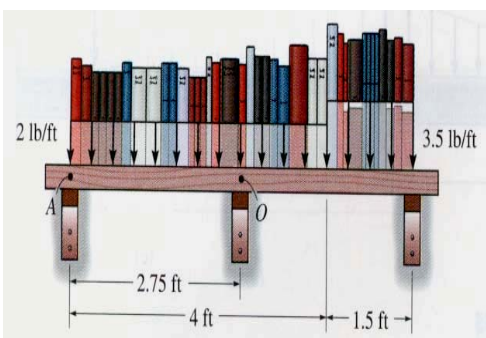
ENES 110 – Statics

Department of Mechanical Engineering
University of Maryland, Baltimore County

Reduction of Distributed Loading

Lecture's Objectives:

Students will be able to determine an equivalent force for a distributed load.



In-Class Activities:

- Submit Homework #4
- Reading quiz
- Applications
- Equivalent force
- Concept quiz
- Problem solving (Ex. 1)
- Attention quiz

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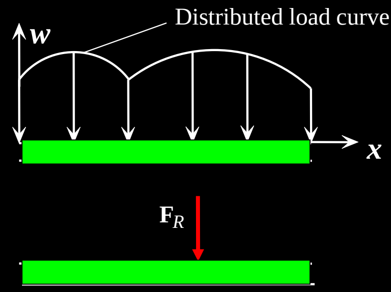
Reading Quiz



1. The resultant force ($\mathbf{F}_R$) due to a distributed load is equivalent to the _____ under the distributed loading curve, $w = w(x)$.

   A) centroid B) arc length

   C) area D) volume

2. The line of action of the distributed load's equivalent force passes through the ______ of the distributed load.

   A) centroid B) mid-point

   C) left edge D) right edge

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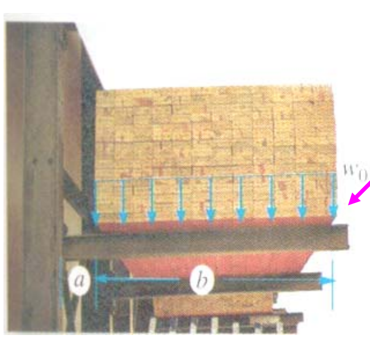
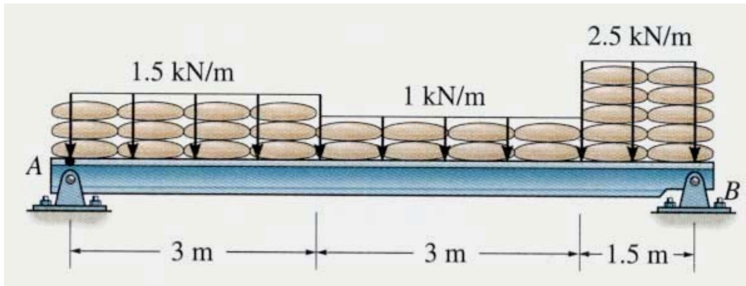
Applications



A distributed load on the beam exists due to the weight of the lumber.

Is it possible to reduce this force system to a single force that will have the same external effect? If yes, how?

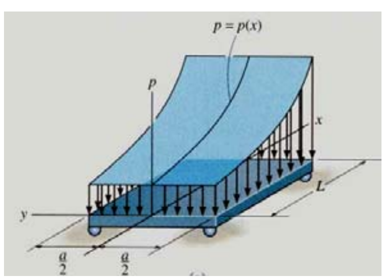
Applications (cont’d)

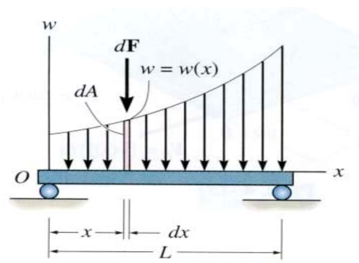


The sandbags on the beam create a distributed load.

How can we determine a single equivalent resultant force and its location?

Distributed Loading



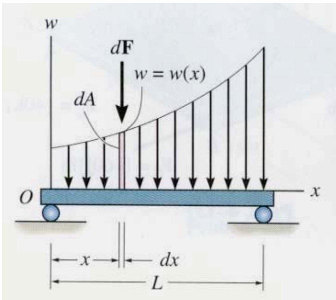


In many situations a surface area of a body is subjected to a distributed load. Such forces are caused by winds, fluids, or the weight of items on the body’s surface.

We will analyze the most common case of a distributed pressure loading. This is a uniform load along one axis of a flat rectangular body.

In such cases, w is a function of x and has units of force per length.

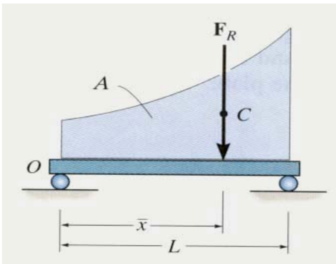
Magnitude of Resultant Force



Consider an element of length dx.

The force magnitude dF acting on it is given as

$$dF = w(x)\,dx$$

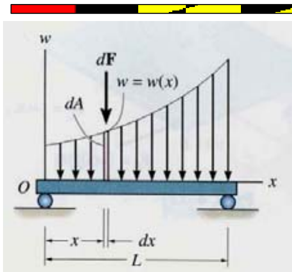


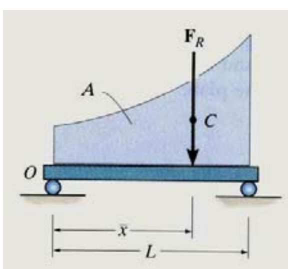
The net force on the beam is given by

$$+\downarrow\ F_R = \int_L dF = \int_L w(x)\,dx = A$$

Here *A* is the area under the loading curve *w*(*x*).

Location of Resultant Force





The force dF will produce a moment of $(x)(dF)$ about point O.

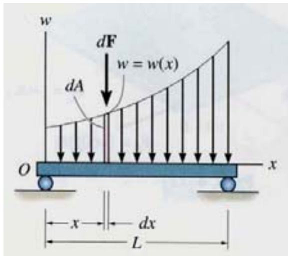
The total moment about point O is given as

$$\circlearrowleft +\ M_{RO} = \int_L x\,dF = \int_L x\,w(x)\,dx$$

Assuming that F_R acts at $\bar{x}$, it will produce the moment about point O as

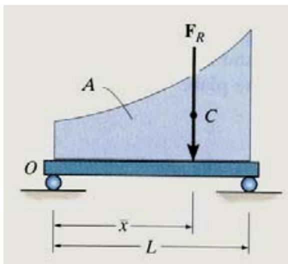
$$\circlearrowleft +\ M_{RO} = (\bar{x})\,(F_R) = \bar{x}\int_L w(x)\,dx$$

Location of Resultant Force (cont'd)



Comparing the last two equations, we get

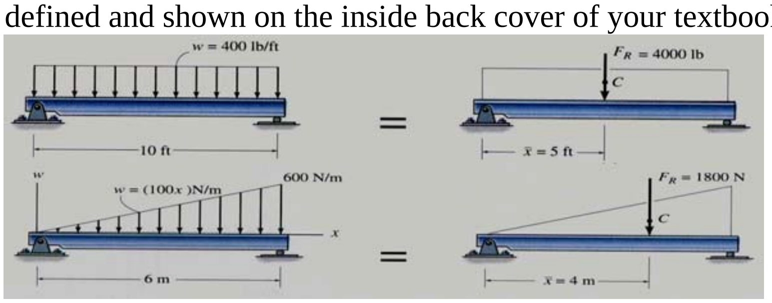
$$\bar{x} = \frac{\int_L x\,w(x)\,dx}{\int_L w(x)\,dx} = \frac{\int_A x\,dA}{\int_A dA}$$



You will learn later that F_R acts through a point "*C*," which is called the geometric center or centroid of the area under the loading curve *w*(*x*).

Examples

Until you learn more about centroids, we will consider only rectangular and triangular loading diagrams whose centroids are well defined and shown on the inside back cover of your textbook.



In a rectangular loading, F_R = 400 × 10 = 4,000 lb and $\bar{x}$ = 5 ft.

In a triangular loading,

F_R = (0.5) (6000) (6) = 1,800 N and $\bar{x}$ = 6 – (1/3) 6 = 4 m.

Please note that the centroid in a right triangle is at a distance one third the width of the triangle as measured from its base.

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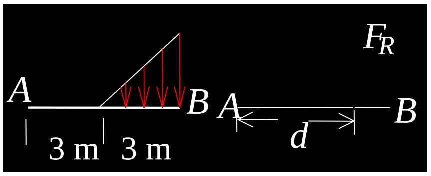
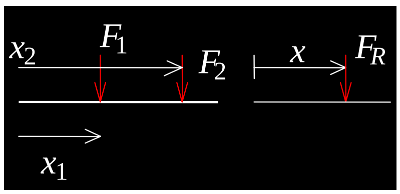
Concept Quiz



1. What is the location of F_R, i.e., the distance d?

A) 2 m B) 3 m C) 4 m

D) 5 m E) 6 m



2. If $F_1 = 1$ N, $x_1 = 1$ m, $F_2 = 2$ N and $x_2 = 2$ m, what is the location of F_R, i.e., the distance x.

A) 1 m B) 1.33 m C) 1.5 m

D) 1.67 m E) 2 m

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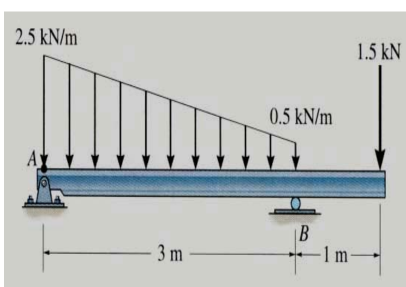
Example 1



Given: The loading on the beam as shown.

Find: The equivalent force and its location from point *A*.

Plan:

1) Consider the trapezoidal loading as two separate loads (one rectangular and one triangular).

2) Find F_R and $\bar{x}$ for each of these two distributed loads.

3) Determine the overall F_R and $\bar{x}$ for the three point loadings.

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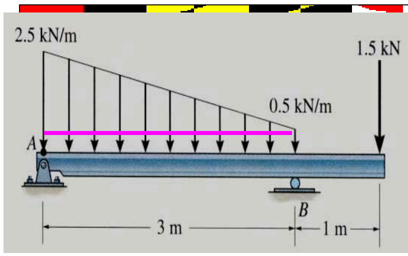
Example 1 (cont'd)



For the rectangular loading of height 0.5 kN/m and width 3 m,

F_{R1} = 0.5 kN/m × 3 m = 1.5 kN

= 1.5 m from *A*

For the triangular loading of height 2 kN/m and width 3 m,

F_{R2} = (0.5) (2 kN/m) (3 m) = 3 kN

and its line of action is at = 1 m from *A*

For the combined loading of the three forces,

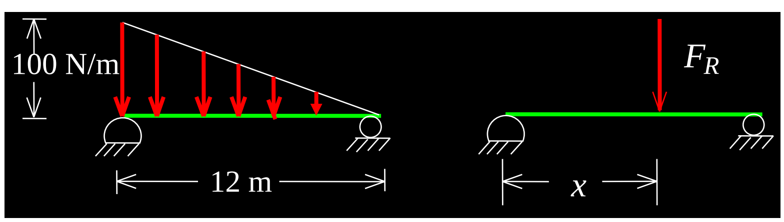
F_R = 1.5 kN + 3 kN + 1.5 kN = 6 kN

$\curvearrowleft +$ M_{RA} = (1.5) (1.5) + 3 (1) + (1.5) 4 = 11.25 kN • m

Now, $F_R\ \bar{x}$ = 11.25 kN • m

Hence, = (11.25) / (6) = 1.88 m from *A*.

Attention Quiz



1. F_R = ____________

   A) 12 N B) 100 N

   C) 600 N D) 1200 N

2. x = __________.

   A) 3 m B) 4 m

   C) 6 m D) 8 m