Introduction to Statics

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Unit 1
Forces as Vectors

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Unit 1
Forces as Vectors

Frame 1-1

Introduction

The study of statics deals with the analysis of force systems acting upon bodies which have no acceleration. By making use of the principles of statics, the engineer can determine the force or load acting at any location in such a body. With this information he is then able to properly proportion or "design" the body to resist the loads safely.

You can see for yourself that statics is going to be something you will use a great deal in your engineering career.

To begin to learn it, go to the next frame.

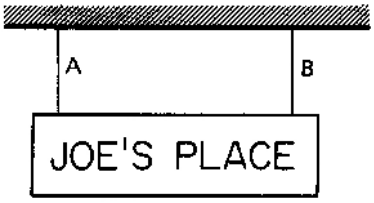
Correct response to preceding frame

No response

Frame 1-2

Example 1

Use your common sense to answer the following questions.



1. The sign weighs 200 pounds and is supported by a cable at A and one at B. How much will each carry?

2. Suppose you have in stock three grades of cable. Cable No. 1 can safely carry 75 lb. Cable No. 2 is rated at 125 lb and Cable No. 3 is rated at 150 lb. Which will you specify?

- ☐ Cable No. 1
- ☐ Cable No. 2
- ☐ Cable No. 3

Correct response to preceding frame

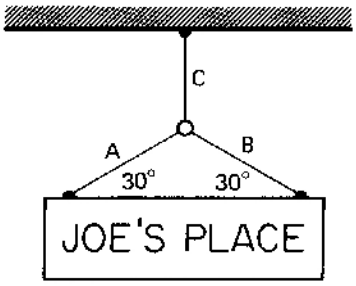
100 lb per cable

Cable No. 2 appears to be best.

Frame 1-3

Example 2

Another way of hanging the 200 pound sign is shown. It uses two cables, A and B, attached to the hanger, C.



1. What load must C be able to resist? _____ .

2. What load must A and B each be able to carry? (Make a guess) _____ .

Correct response to preceding frame

1. 200 lb

2. A and B must each be able to carry 200 pounds! (The first part of this course will be devoted to showing you why. If you guessed right either your statics or your mechanical intuition is very good. Most people miss it.)

Frame 1-4

Transition

As you just saw, intuition will get you a little way in statics but not very far. In order to evaluate loadings on the basis of information rather than intuition we need to take a close look at the things we call forces.

The next several frames will help you clarify your ideas about forces. When you are ready, go to the next frame.

Correct response to preceding frame

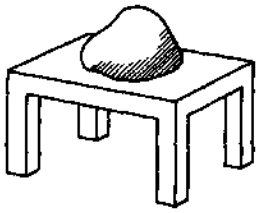
No response

Frame 1-5

Force

A force is defined as the action of one body on another which tends to cause, or retard, motion.

A rock lying on a table is acted upon by two forces.



1. First, the weight of the rock is the gravitational pull exerted by the _____ .

2. The second force (which keeps the rock from falling) is exerted on the rock by the

_____ .

Correct response to preceding frame

1. earth
2. table

Frame 1-6

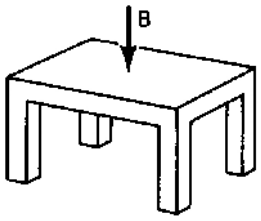
Force

The forces we described in the preceding frame are represented in the figure below, called a ***free body diagram***.

1. The weight of the block is represented by Arrow _____

2. The push of the table against the rock is represented by Arrow _____

The next figure is a partial free body diagram of the table on which the rock rests.



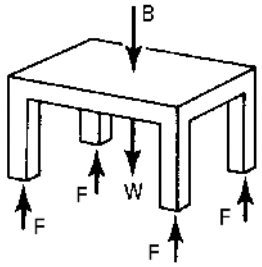
3. Complete the free body diagram by drawing the other forces exerted on it. Assume all of the legs carry equal loads.

4. What exerts these forces? _____

Correct response to preceding frame

1. A

2. B
3.



4. W, the weight of the table itself is the force exerted by the gravitational pull of the earth. The forces which I have labeled F are exerted by the floor on which the table is sitting.

Frame 1-7

Mass, Weight, and Force of Gravity

In this book forces will generally be measured in pounds or Newtons, and masses in slugs or kilograms, although we will occasionally refer to other units. You have undoubtedly seen a package something like the one pictured below.

The label clearly says “NET WT 5LB (2.26 kg)”

Some professors have argued “that label is all ***wrong***.” Why might they say that?

_____

Correct response to preceding frame

Because pounds are units of force while kilograms are units of mass, so the measures are not equivalent. (or equivalent response)

Frame 1-8

Mass, Weight, and Force of Gravity

According to many American books, “weight means force of gravity.” In American calculations this works out fine because our units for force and weight are _____ .

As people living in the real world, the strict application of this statement can give us problems.

Kilograms are units of mass. What response do you think you would get if you gave a sales associate in a Canadian grocery several tomatoes and asked her to “Mass these for me, please.”

_____ .

If you asked for the weight of the tomatoes, what units would you expect the answer to be given in? _____

Correct response to preceding frame

pounds
Perhaps she might say “Take them home and mash them yourself.” (or equivalent response)
kilograms

Frame 1-9

Mass, Weight, and Force of Gravity

Complete the top of Page 1-1 of your Notebook, then read the section “Mass, Weight, and Force of Gravity.”

The relationship between mass and gravitational force is given by the equation

$$F = m\,g$$

Using the values of $g = 32.2$ fps^2 and $g = 9.81$ mps^2, find the following, giving proper units with your answers:

1. A 1,000 pound crate has mass of _____

   and exerts a gravitational force of _____ .

2. A 500 kilogram box has mass of _____

   and exerts a gravitational force of _____ .

Correct response to preceding frame

1. mass = 31.1 slugs ... gravitational force = 1,000 pounds
2. mass = 500 kilograms ... gravitational force = 4910 Newtons

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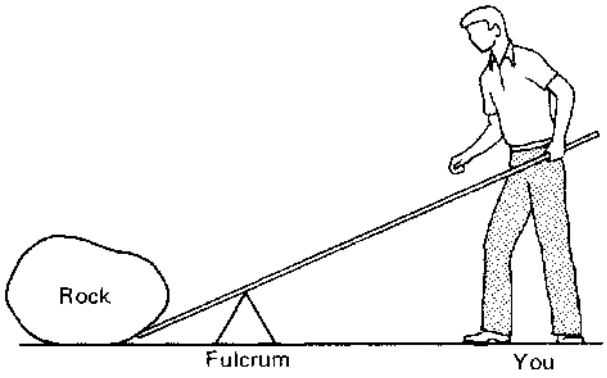
Frame 1-10

Force

You are using a lever to lift a rock.



Your hand exerts pressure on the handle. What other forces are exerted on the lever? (Ignore the weight of the lever.)

The forces in question are exerted by the _____ and the _____ .

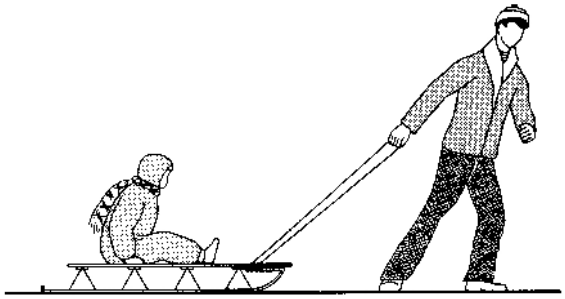
Correct response to preceding frame

The forces in question are exerted by the ***rock*** and the ***fulcrum***.

Frame 1-11

Force

A man is pulling his young son on a sled.



List all the forces acting on the sled.

1. _____

2. _____

3. _____

4. _____

5. _____

6._____

Correct response to preceding frame

1. The weight of the boy
2. The weight of the sled
3. The pull of the rope
4. The upward thrust of the snow against the runners
5. Some friction between the runners and snow, maybe
6. Friction between boy and sled

Frame 1-12

Force

(Review) Force is defined as _____

_____

Correct response to preceding frame

The action of one body on another which tends to cause motion, or retard, is defined as force.

Frame 1-13

Transition

We have seen that any force can be defined as the action of one body on another. To describe a particular force we must give three items of information about it. These are called the ***characteristics of the force*** and are:

- ***magnitude***
- ***direction***
- ***point of application***

The next several frames will deal with these characteristics.

When you are ready, go to the next frame.

Correct response to preceding frame

No response

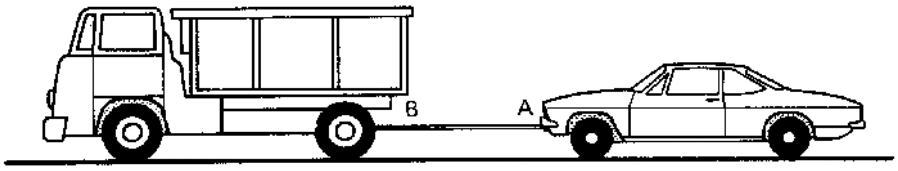
Frame 1-14

Characteristics of a Force

Every force has three characteristics:

1. magnitude
2. direction
3. point of application

The truck is exerting a 200 Newton force on the cable.



1. What is the magnitude of the force exerted on the car? _____

2. Draw an arrow in the direction of the force exerted on the car.

3. The point of application of the force on the car is ☐ A ☐ B

Correct response to preceding frame

1. 200 Newtons
2. 
3. applied at A

Frame 1-15

Characteristics of a Force

The magnitude of a force is given as a certain number of units. The units used are always of the kind you think of as measuring weight.

List several kinds of units you could use to describe force:

_____

_____

_____

Correct response to preceding frame

pounds, Newtons, ounces, dynes, tons, kilopounds as well as more exotic ones

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Frame 1-16

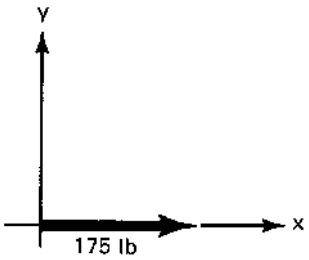
Characteristics of a Force

The direction of a force is defined by its ***line of action*** and its ***sense*** along that line.

For example, when we say that a force is vertical we have described its line of action, but until we say whether it acts up or down we have not completely defined its direction

because we have not specified the _____ .

In the figure below the x-axis represents the _____
of the force and its sense is in the (*positive, negative*) direction.



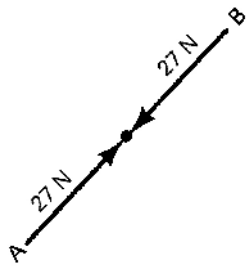
Correct response to preceding frame

sense
line of action
positive

Frame 1-17

Characteristics of a Force

Arrows A and B represent two forces acting on a particle.



They have the same _____ and _____

but different _____

1. Do forces A and B have the same direction? ☐ Yes ☐ No

2. Do forces A and B have the same point of application? ☐ Yes ☐ No

Correct response to preceding frame

same magnitude ***same*** line of action ***different*** senses
No, the directions are different.
Yes, both forces are applied at the same point.

Frame 1-18

Characteristics of a Force

In order to specify the direction of a force it is necessary to specify both

_____

and _____

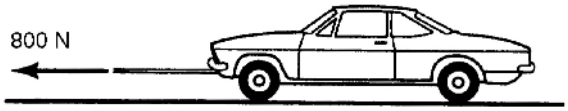
Correct response to preceding frame

line of action
sense

Frame 1-19

Characteristics of a Force

The late model car shown above is being towed to your friendly used car dealer. The arrow represents the force in the tow rope.



List its characteristics.

Magnitude: _____

Direction,

line of action: _____

sense: _____

Point of Application: _____

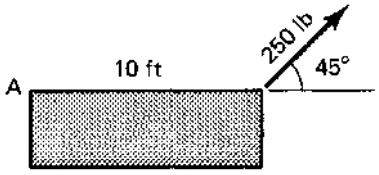
Correct response to preceding frame

Magnitude: 800 Newtons
Direction: horizontal
to the left
Point of Application: front bumper

Frame 1-20

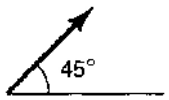
Characteristics of a Force

List the characteristics of the force shown.



Correct response to preceding frame

Magnitude: 250 lb
Direction: up and to the right at an angle of 45^0 with the horizontal
or

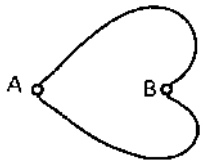


Point of Application: 10 ft to the right of A

Frame 1-21

Characteristics of a Force

A certain force acts on the body below.

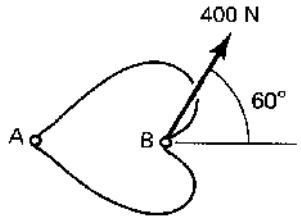


Its characteristics are as follows:

- It is applied at Point B
- It makes an angle of 60^0 with the horizontal
- Its magnitude is 400 Newtons
- It acts up and to the right

Draw the force.

Correct response to preceding frame



Frame 1-22

Characteristics of a Force

Complete the first section on page 1-2 of your Notebook.

Correct response to preceding frame

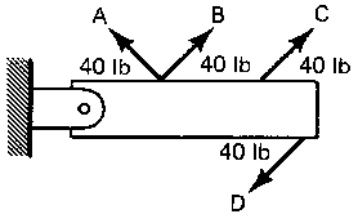
No response

Frame 1-23

Equal Forces

Forces are said to be equal when they have the same magnitude and parallel lines of action even though they do not have the same point of application.

Consider the forces on the body below:



Forces _____ , _____ , and _____ are equal.

Forces of equal magnitude which have opposite sense are said to be ***equal and opposite***. (or sometimes ***equal but opposite)***

In the above figure force B is equal and opposite to _____ .

Correct response to preceding frame

B, C, and D are equal.
Force B is equal and opposite to force D.

Frame 1-24

Transition

You have learned to define force as the action of one body on another and to characterize it by describing its magnitude, direction and point of application.

The last section of this unit will be devoted to showing you a bit about the peculiar way in which forces add.

A dozen more frames should see you through. Ready? Set? Go--to the next frame.

Correct response to preceding frame

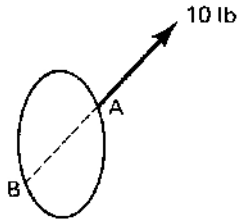
No response

Frame 1-25

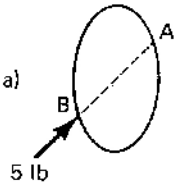
Equivalent Forces

Forces are said to be equivalent when they have the same external effect on a rigid body.

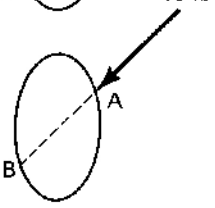
Which of the forces shown in the column on the right are equivalent to that shown on the left? (All forces are parallel.)



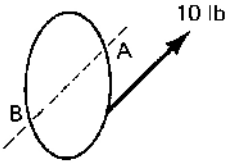
☐ (a)



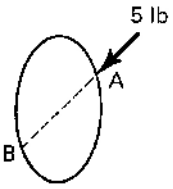
☐ (b)



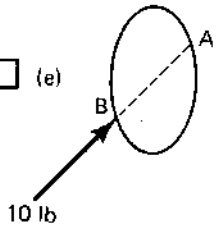
☐ (c)



☐ (d)



☐ (e)



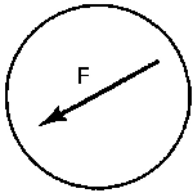
Correct response to preceding frame

Sketch (e) is the only one which shows an equivalent force.

Frame 1-26

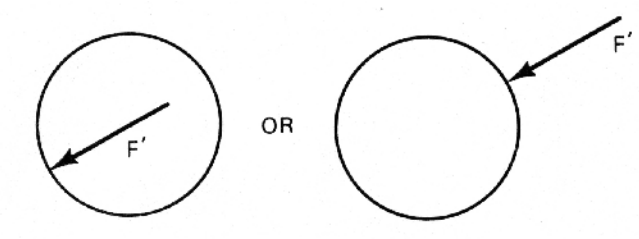
Principle of Transmissibility

Read the section on page 1-2 in your notebook on the principle of transmissibility.



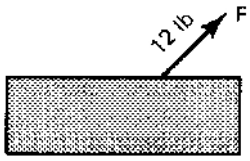
Draw a force F′ equivalent to F such that its point of application is on the circumference of the circle.

Correct response to preceding frame



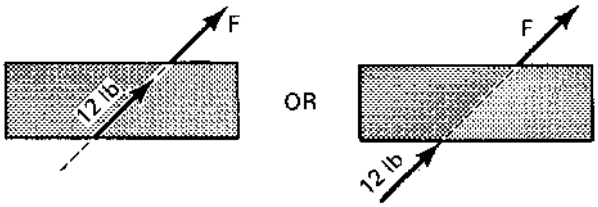
Frame 1-27

Principle of Transmissibility



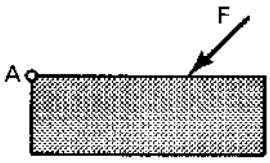
Show an equivalent force acting on the bottom of the block.

Correct response to preceding frame



Frame 1-28

Principle of Transmissibility



Can a force equivalent to F act through A? ☐ Yes ☐ No

If your answer is "Yes", draw the equivalent force.

If your answer is "No", tell why not.

_____

Correct response to preceding frame

No. A is not on the line of action of force F.

Frame 1-29

Principle of Transmissibility

The principle of transmissibility states that the external effect of a force on a rigid body is independent of its point of application so long as the point of application lies on

_____ .

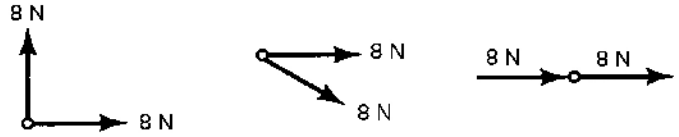
Correct response to preceding frame

the point of application lies on ***the line of action of the force.*** (Or equivalent response)

Frame 1-30

Combining Two Forces

In the figure below you see three particles, each of which is acted upon by two 8 Newton forces as shown.



1.Would all three particles tend to have the same motion as a result of the forces shown?

☐ Yes ☐ No

2.The result of combining forces appears to depend on (check one)

☐ magnitude alone
☐ direction alone
☐ magnitude and direction

Correct response to preceding frame

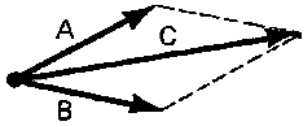
1. No. Each of the three particles would move in a different direction and at a different rate.
2. Magnitude and direction must both be involved in the combination of forces.

Frame 1-31

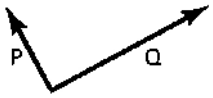
Resultant of Two Forces

Read the section on page 1-3 of your Notebook called "Resultant of Two Forces".

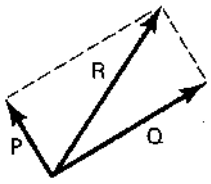
Force C is called the resultant of A and B.



Sketch the resultant of forces P and Q. Call it R.



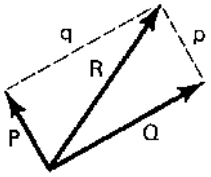
Correct response to preceding frame



Frame 1-32

Resultant of Two Forces

In sketching the resultant of P and Q the lines p and q were constructed parallel to the original forces.



We say that forces add according to the _____ law in order to remind ourselves of this construction.

Correct response to preceding frame

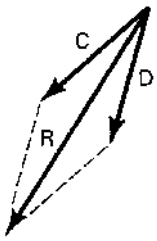
the ***parallelogram*** law

Frame 1-33

Resultant of Two Forces

Sketch the resultant of forces C and D. Call it R.

Correct response to preceding frame



Notice that C and D are placed with their tails together before the parallelogram is sketched.

Frame 1-34

Vectors

There are many physical quantities which have magnitude and direction and must be added by the parallelogram law. They are represented mathematically by "vectors" and are called "vector quantities."

1. Is force a vector quantity? ☐ Yes ☐ No

Physical quantities which have only magnitude and add by ordinary arithmetic are represented by "scalars" and are called "scalar" quantities. An example of such a quantity would be temperature, i.e. 90^0F.

2. Name some other scalar quantities if you can.

_____

_____

_____

_____

Correct response to preceding frame

1. Force is a vector.
2. Volume, mass, area and just plain numbers are all scalars. You may have thought of others.

Frame 1-35

Vectors

Force is a vector because it has _____ and _____

and is added according to the _____ .

Correct response to preceding frame

magnitude and direction
parallelogram law

Frame 1-36

Summary

You have completed this unit. You have learned or reviewed several things about force.

First you learned a definition of force, second you learned to describe the characteristics of force, and last you learned to identify force as a "vector".

The last accomplishment is more considerable than it first appears. In the following unit you will see that vector quantities have an algebra completely different from scalar algebra, which, when learned, will give you a very powerful tool.