

Chapter 3.

Equilibrium of a Particle

EQUILIBRIUM OF A PARTICLE, THE FREE-BODY DIAGRAM & COPLANAR FORCE SYSTEMS

Today's Objectives:

Students will be able to :

- a) Draw a free body diagram (FBD), and,
- b) Apply equations of equilibrium to solve a 2-D problem.



READING QUIZ

1) When a particle is in equilibrium, the sum of forces acting on it equals ____ . (Choose the most appropriate answer)

- A) a constant B) a positive number C) zero
D) a negative number E) an integer.

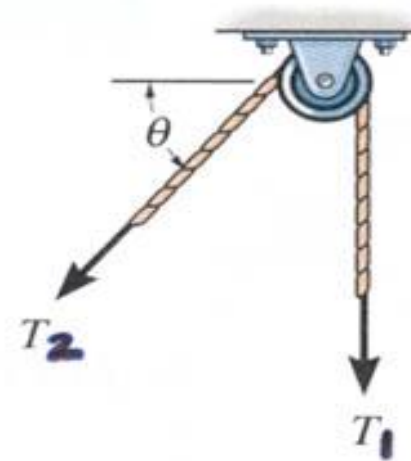
2) For a frictionless pulley and cable, tensions in the cable (T_1 and T_2) are related as _____ .

A) $T_1 > T_2$

B) $T_1 = T_2$

C) $T_1 < T_2$

D) $T_1 = T_2 \sin \theta$

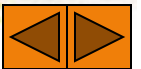


Cable is in tension



APPLICATIONS

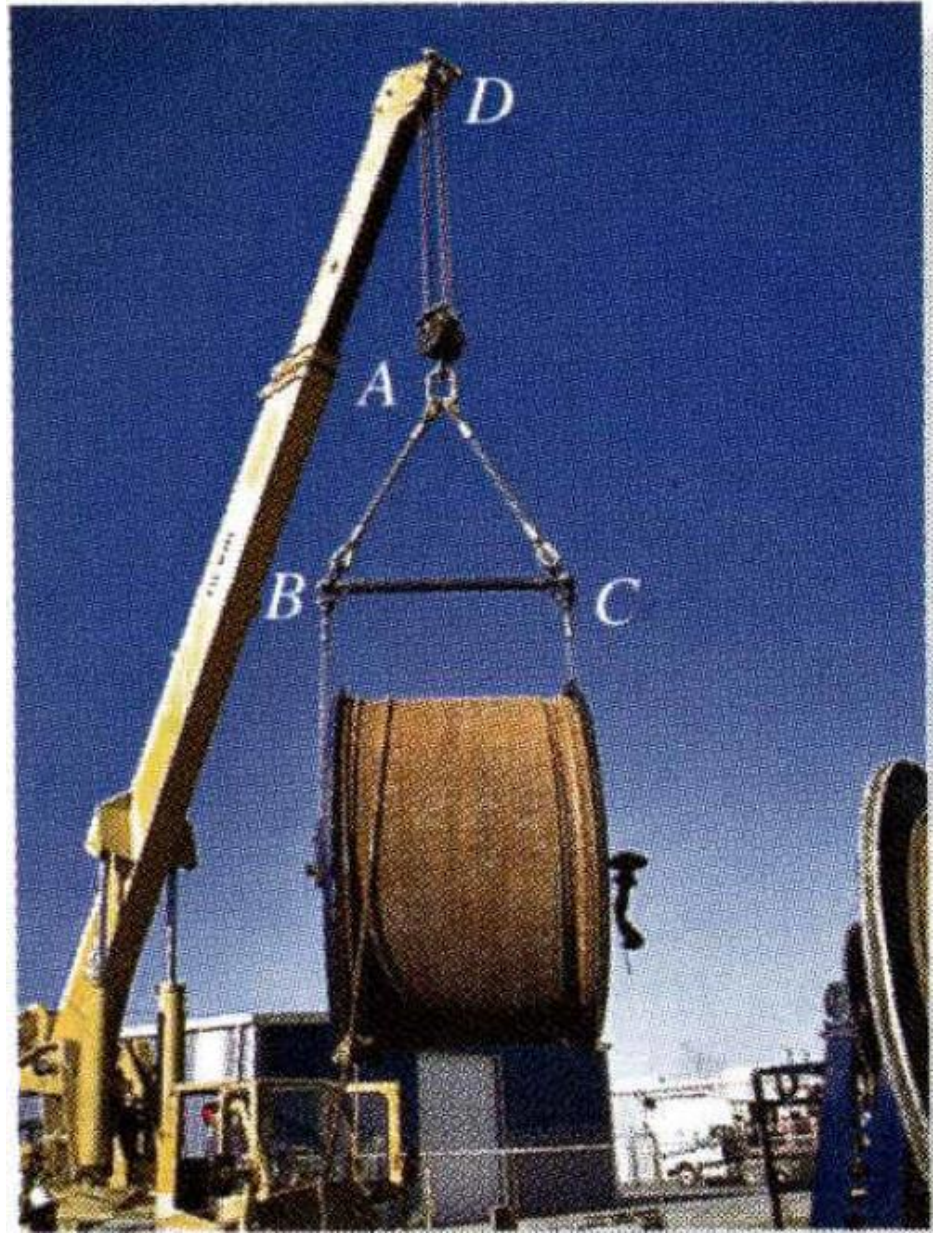
For a given cable strength, what is the maximum weight that can be lifted ?



APPLICATIONS

(continued)

For a spool of given weight, what are the forces in cables AB and AC ?



3.1 Condition for the Equilibrium of a Particle

A particle is in equilibrium provided it is at rest **if originally at rest** or has a constant velocity **if originally in motion**.

Most often "**static equilibrium**" is used to describe an object at rest.

To maintain equilibrium, it is necessary to satisfy Newton's first law of motion, which requires the resultant force acting on a particle to be equal to zero. This condition may be stated mathematically as

$$\Sigma \mathbf{F} = \mathbf{0} \quad (3-1)$$

where $\Sigma \mathbf{F}$ is the vector *sum of all the forces* acting on the particle.

3.2 The Free-Body Diagram

To apply equation of equilibrium, we must account for all the known and unknown forces ($\Sigma \mathbf{F}$) which act on the particle.

To do this we need to draw the Free Body Diagram (FBD) of the particle.

Before describing FBD we need to identify two types of connections:

- 1- Springs

- 2- Cables and pulleys.

3.2.1 Springs

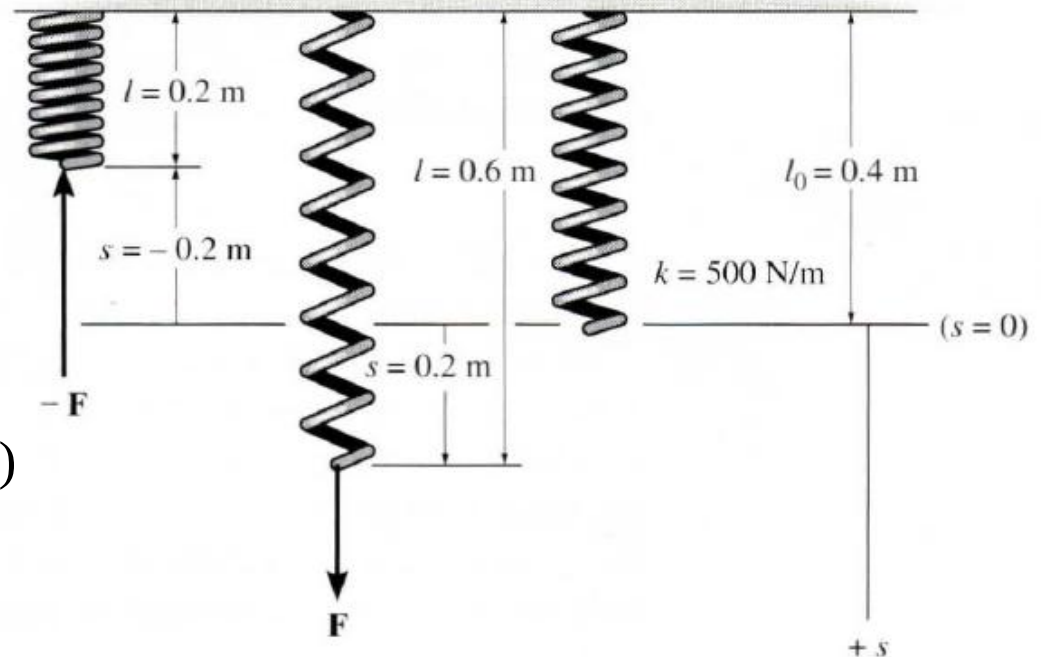
If a linear elastic spring is used for support, the length of the spring will change in direct proportion to the force acting on it.

$$F = k * S$$

F = Spring Force

k = Spring constant (stiffness)

S = Spring deformation



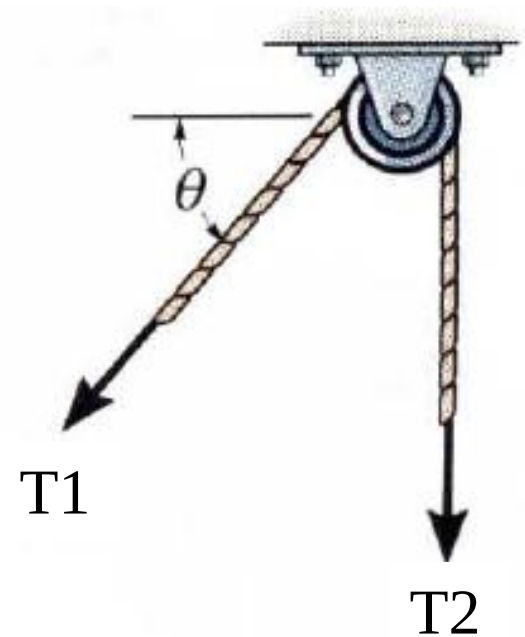
Cables and Pulleys

In this course, Cables;

- Are assumed to have negligible weight;
- Can not be stretched.
- Can only support tension or “pulling” forces.

With a frictionless pulley;

$$T_1 = T_2.$$



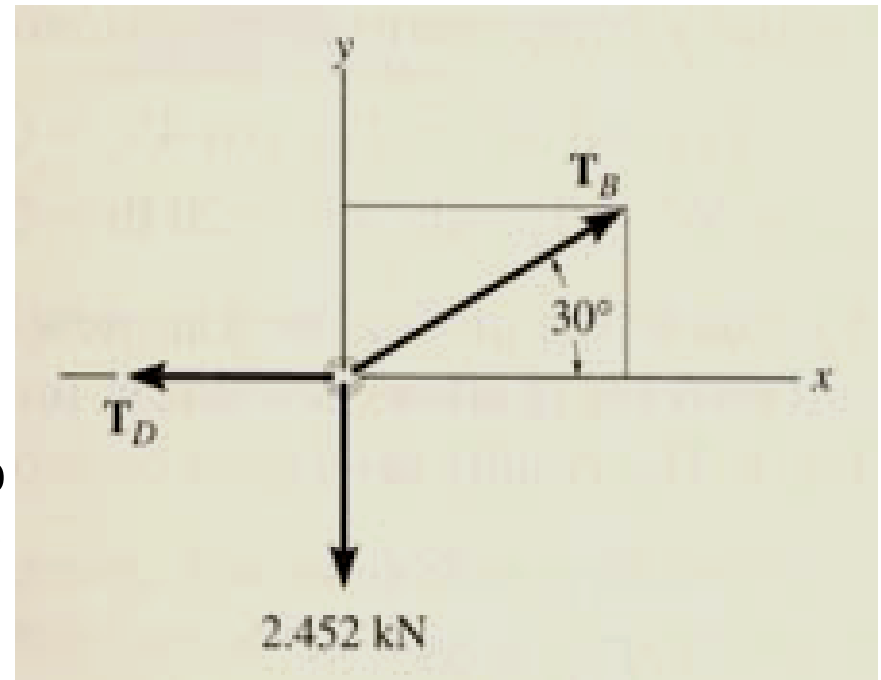
Cable is in tension

The WHAT, WHY AND HOW of A Free Body Diagram (FBD)

Free Body Diagrams are one of the most important things for you to know how to draw and use.

What ? - It is a drawing that shows all external forces acting on the particle.

Why ? - It helps you write the equations of equilibrium used to solve for the unknowns (usually forces or angles).



How ?

1. Imagine the particle to be isolated or cut free from its surroundings.
2. Show all the forces that act on the particle.

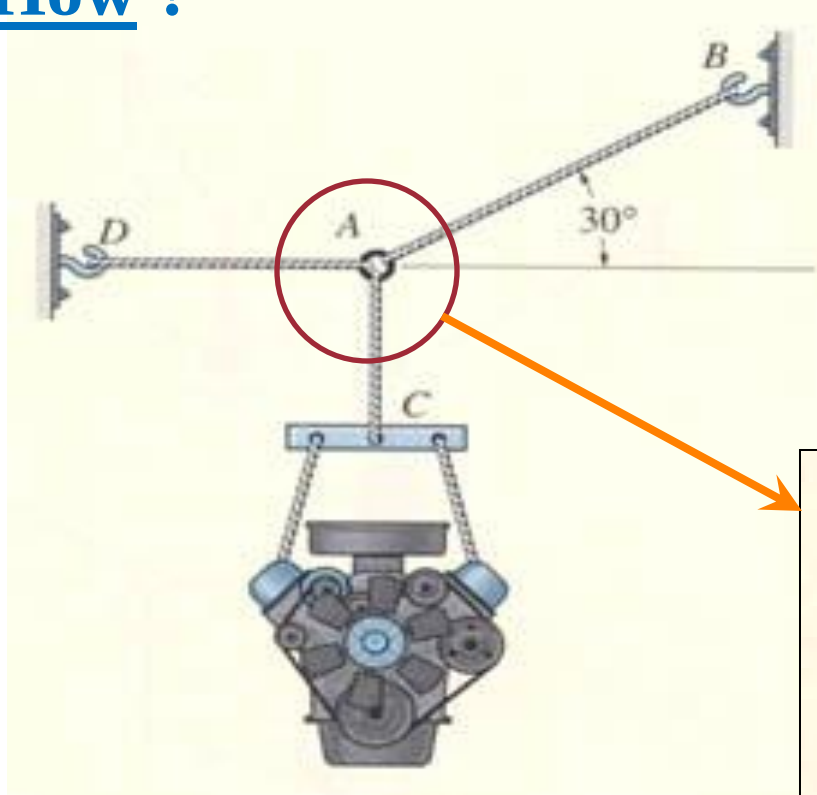
Active forces: They want to move the particle.

Reactive forces: They tend to resist the motion.

3. Identify each force and show all known magnitudes and directions.

Show all unknown magnitudes and / or directions as variables .

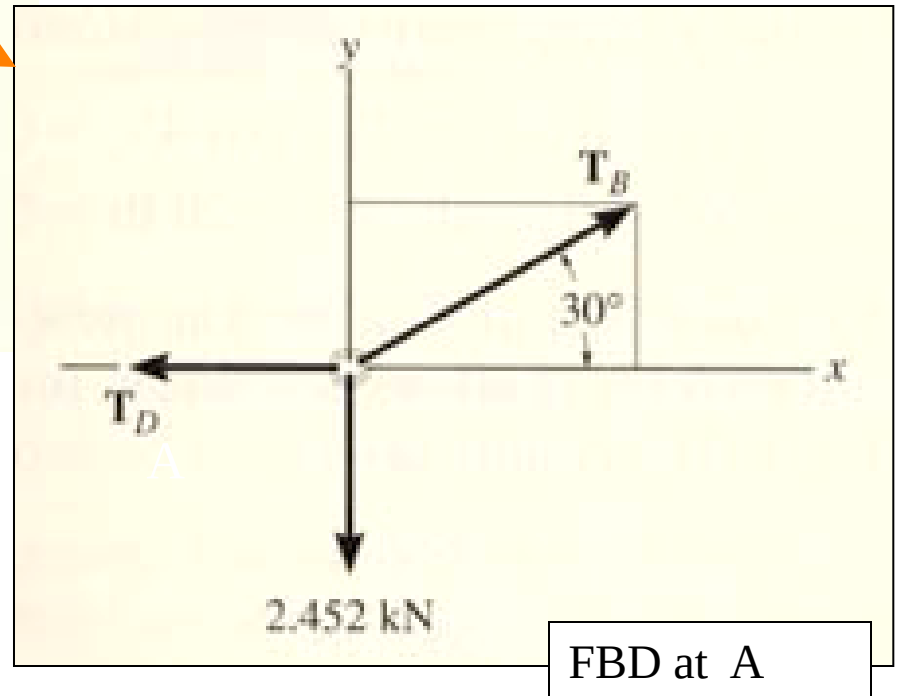
How ?



Note :

Engine mass = 250 Kg

Engine weight (Force) =
 $250 \times 9.81 / 1000 = 2.452 \text{ kN}$



Free Body Diagram

Consider the spool having a weight W which is suspended from the crane boom. If we wish to obtain the forces in cables AB and AC then we can consider the free-body diagram of the ring at A since these forces act on the ring. Here the cables AD exert a resultant force of W on the ring and the condition of equilibrium is used to obtain T_B and T_C .

