1) Mechanics lab on 21st & 23rd September

2) Make groups of 5 and email me your group, along with your day of preference. It will be 2 groups on one day. First come first served.

3) Exam on Wednesday Sept 30th 2015 [Chapter 1-3]

4) Lab report due on Wednesday 1st Oct 2015 before 11 am

5) Homework (1) is posted. It is due on Wednesday 23rd Sept 2015 (11 am)

Chapter 3 - Forces

A force is a push or pull upon an object resulting from the object's interaction with another object.

Terminology

1) Line of Action: When a force is represented by a vector, the straight line colinear with the vector is called the line of action of the force.
2. System of Forces: A system of forces is simply a particular set of forces.

A system of forces is coplanar, or two dimensional, if the lines of action of the forces lie in a plane. Else it's a three dimensional.

A system of forces is concurrent if lines of action of forces intersect at a point. & parallel if the lines of action are parallel.

\[ \begin{align*}
\vec{F}_a \quad & \quad \vec{F}_b \quad \vec{F}_c \\
\end{align*} \]

(a) Concurrent

3) External Forces: A force is exerted by different objects, e.g., friction, air resistance.

4) Internal Forces: When one part of a given object is subjected to a force by another part of the same object, e.g., spring force.

4) Body & Surface Forces: A force acting on an object is called a body force if it acts on the volume of the object. A surface force if it acts on the surface.
Gravitational force on an object is a body force.

Gravitational Force or weight of an object can be represented by a vector, \( \vec{w} \).

The magnitude is \( |w| = mg \).

Contact Forces: are the forces that result from contact between objects. Example: when you push a wall, if \( \vec{F} \) is the force your hand exerts on the wall then \( -\vec{F} \) is the force that wall exerts on your hand. (Newton's 3rd Law)

Ropes & Cables: A contact force is exerted on an object by attaching a rope or cable to the object & pulling it. This force is called Tension.
Springs: Springs are used to exert contact forces in mechanical devices, e.g., in suspensions of cars.

The magnitude of force exerted by a spring depends on the material it is made up of, its design, and how much it is stretched or compressed relative to its unstretched length.

\[ F = k |L - L_0| \]

where \( L_0 \) is the unstretched length of the spring.

\( L \) is the stretched or compressed length.

\( k \) is the spring constant.

**EQUILIBRIUM & FREE BODY DIAGRAM**

Equilibrium means the state of balance. This means the vector sum of external forces on an object is zero.

\[ \sum F = 0 \]
FREE BODY DIAGRAM

1. Identify the object you want to isolate.

2. Draw a sketch of the object isolated from its surrounding & show all relevant dimensions & angles.

3. Draw vectors representing all external forces acting on the isolated object & label them.

4. Draw a coordinate system specifying all directions.

Some forces might be oriented diagonally with respect to your coordinate system. Start again at Step 2. Do not erase previous version. For the forces that are "diagonal" to your coordinate system—resolve it into component form.

Now all the forces should be same as before except some of them that are resolved in component form.

5. Write the Newton's Law and any other geometric constraints.

6. Solve for unknown.
Newton's Law: $\sum F = ma \implies \sum F = 0 \implies T_{AB} \uparrow - W \downarrow = 0 \implies T_{AB} = \frac{W}{x}$ (Tension on cable AA)
Newton's Law:

\[ \Sigma F = ma \implies \Sigma F = 0. \]

\[ T_{CD} - W = T_{AB} = 0 \]

\[ T_{CD} - W - W = 0 \quad (From \ 1) \]

\[ T_{CD} - 2W = 0 \]

\[ (T_{CD} - 2W)^t = 0 \]

\[ T_{CD} = 2W \]

Two-Dimensional Force System

\[ \Sigma F = (\Sigma F_x)^t + (\Sigma F_y)^t = 0 \]

\[ \Sigma F_x = 0 \quad \land \quad \Sigma F_y = 0 \]
The automobile engine block is suspended by a system of cables. The mass of block is 200 kg.

What are the tensions in cable AB and AC?

Solution

Step 1:

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Newtons Laws

\[ \sum F_x = T_{AC} \cos 45^\circ - T_{AB} \cos 60^\circ = 0 \]  \hspace{1cm} -(1)

\[ \sum F_y = T_{AC} \sin 45^\circ + T_{AB} \sin 60^\circ - W = 0 \]  \hspace{1cm} -(2)

\[ W = mg = (200 \text{ kg}) \times (9.81 \text{ m/s}^2) = 1962 \text{ N} \]  \hspace{1cm} -(3)

Plug (3) in (2):

\[ T_{AC} \sin 45^\circ + T_{AB} \sin 60^\circ - 1962 = 0 \]  \hspace{1cm} -(4)

From (1) & (4)

\[ T_{AB} = 1436 \text{ N} \]

\[ T_{AC} = 1016 \text{ N} \]
2. Mass of each pulley is \( m \), and mass of the suspended object \( A \) is \( ma \). Determine force \( T \) necessary for the system to be in equilibrium.

\[
T + T + T_D - mg - ma g = 0
\]

\[
T_D + 2T - mg - ma g = 0 \quad \text{(2)}
\]

Plug in (1) in (2):

\[
T = ma g / 4
\]
(3) Determine the required length of chord AC so that the 8 kg weight can be suspended in the position shown. The undeformed length of spring AB is $l_{AB} = 0.4m$ and spring has a stiffness of $k_{AB} = 300 \text{ N/m}$.

\[ l_{AC} = ? \]

Solution

Note: Total horizontal length is given

\[ 2m = l_{AC} \cos 30 + l_{AB} \]

\[ l_{AB} = l_{AC} + l_{AB} \]

\[ T_{AB} = F = k_{AB} \cdot l_{AB} \]

Newtons Law:

\[ \sum F = ma = 0 \]

\[ \sum F_x = 0 \quad \sum F_y = 0 \]

\[ T_{AB} - T_{AC} \cos 30 = 0 \]
\[ \sum F_y = 0 \]
\[ T_{ac} \sin 30^\circ - W = 0. \]
\[ W = mg = (88g)(9.8 \text{ m/s}^2) = 78.5 \text{ N}. \]

\[ T_{ac} \sin 30^\circ - 78.5W = 0. \]
\[ T_{ac} = 157.0 \text{ N}. \]

From (i)
\[ T_{AB} = 135.9 \text{ N}. \]

Let stretch be \( S_{AB} \).
\[ T_{AB} = k_{AB} S_{AB} \]
\[ 135.9 = (3000 \text{ N/m}) (S_{AB}) \]
\[ S_{AB} = 0.453 \text{ m}. \]

\[ L_{AB} = L_{AB} + S_{AB} \]
\[ = 0.4 \text{ m} + 0.453 \text{ m} = 0.853 \text{ m}. \]

Now total distance from \( C \) to \( B = 2 \text{ m}. \)
\[ 2 = L_{AC} \cos 30^\circ + 0.853 \text{ m}. \]
\[ L_{AC} = 1.32 \text{ m}. \]