WEDGES AND FRICTIONAL FORCES ON FLAT BELTS

Today's Objectives:

Students will be able to:

a) Determine the forces on a wedge.

b) Determine tension in a belt.

In-Class Activities:

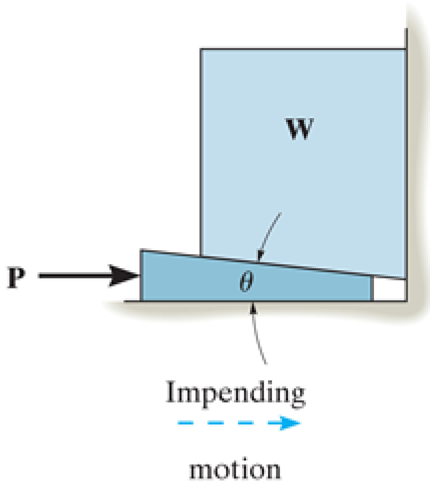
- Check Homework, if any
- Reading Quiz
- Applications
- Analysis of a Wedge
- Analysis of a Belt
- Concept Quiz
- Group Problem Solving
- Attention Quiz

READING QUIZ

1. A wedge allows a ______ force P to lift a _________ weight W.

   A) (large, large) B) (small, large)

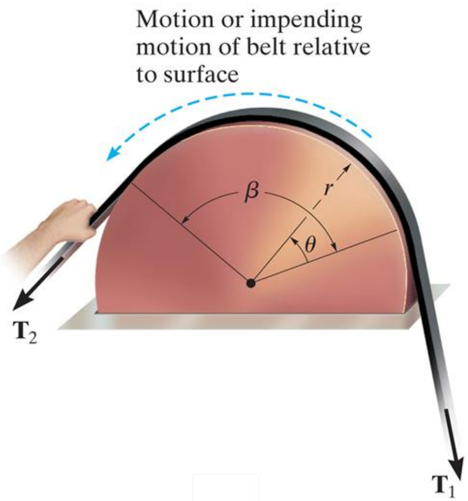
   C) (small, small) D) (large, small)



2. Considering friction forces and the indicated motion of the belt, how are belt tensions T_1 and T_2 related?

   A) $T_1 > T_2$ B) $T_1 = T_2$

   C) $T_1 < T_2$ D) $T_1 = T_2 e^{\mu}$



APPLICATIONS

Wedges are used to adjust the elevation or provide stability for heavy objects such as this large steel pipe.

How can we determine the force required to pull the wedge out?

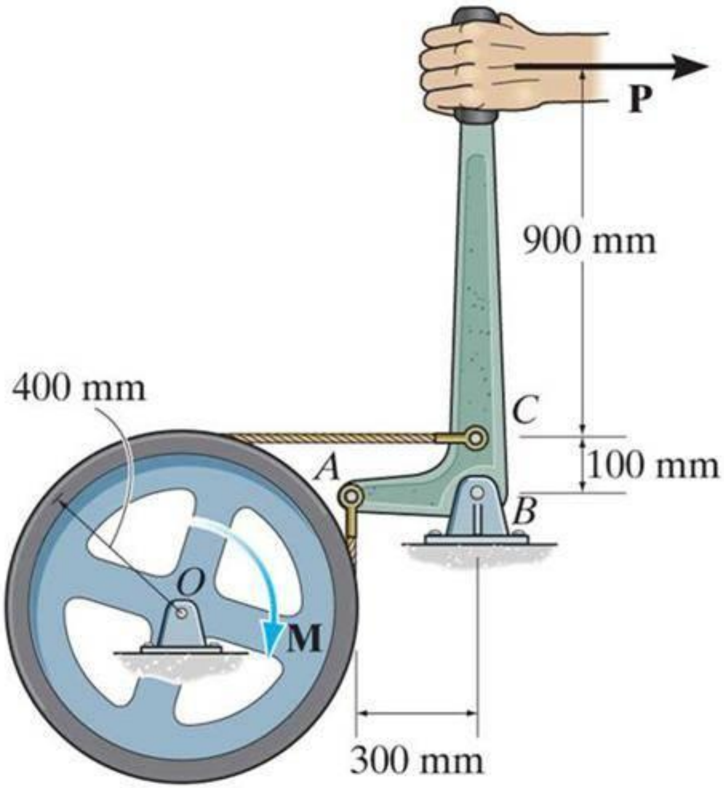
When there are no applied forces on the wedge, will it stay in place (i.e., be self-locking) or will it come out on its own? Under what physical conditions will it come out?

APPLICATIONS (continued)

Belt drives are commonly used for transmitting the torque developed by a motor to a wheel attached to a pump, fan or blower.

How can we decide if the belts will function properly, i.e., without slipping or breaking?

APPLICATIONS (continued)

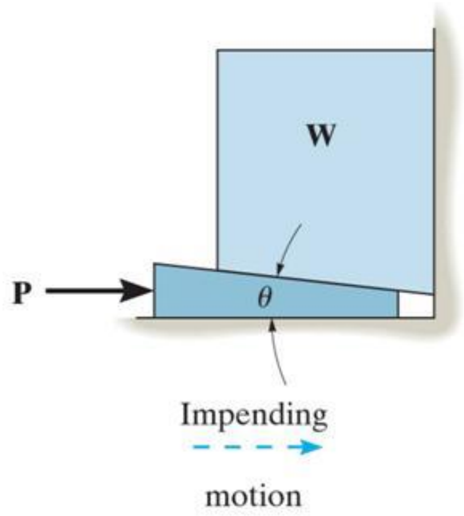


In the design of a band brake, it is essential to analyze the frictional forces acting on the band (which acts like a belt).

How can you determine the tension in the cable pulling on the band?

Also from a design perspective, how are the belt tension, the applied force P and the torque M, related?

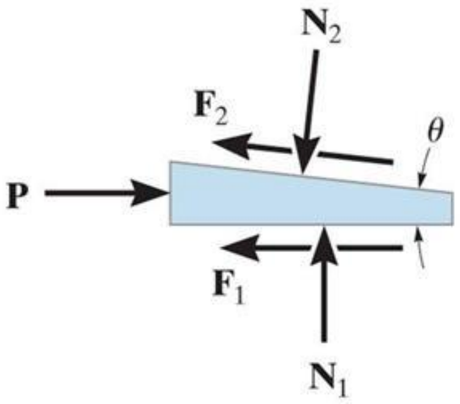
ANALYSIS OF A WEDGE



A wedge is a simple machine in which a small force P is used to lift a large weight W.

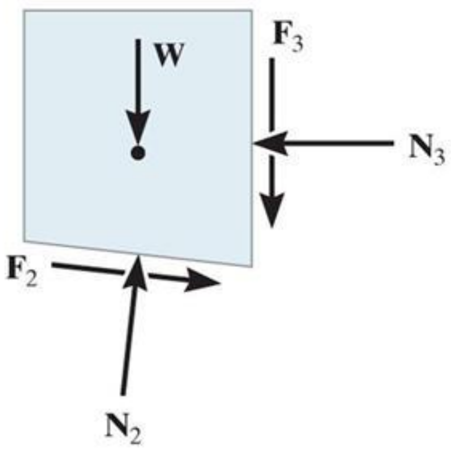
To determine the force required to push the wedge in or out, it is necessary to draw FBDs of the wedge and the object on top of it.

It is easier to start with a FBD of the wedge since you know the direction of its motion.



Note that:
a) the friction forces are always in the direction opposite to the motion, or impending motion, of the wedge;
b) the friction forces are along the contacting surfaces; and,
c) the normal forces are perpendicular to the contacting surfaces.

ANALYSIS OF A WEDGE (continued)



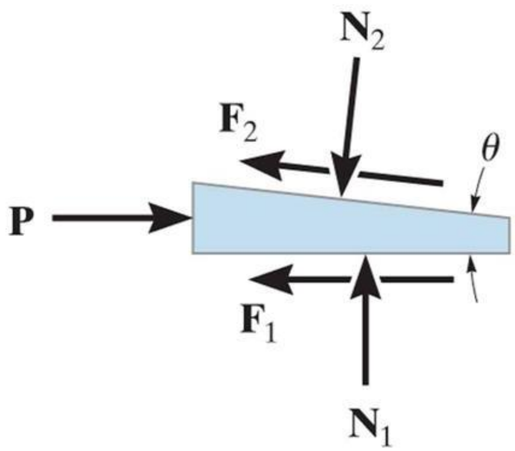
Next, a FBD of the object on top of the wedge is drawn. Please note that:

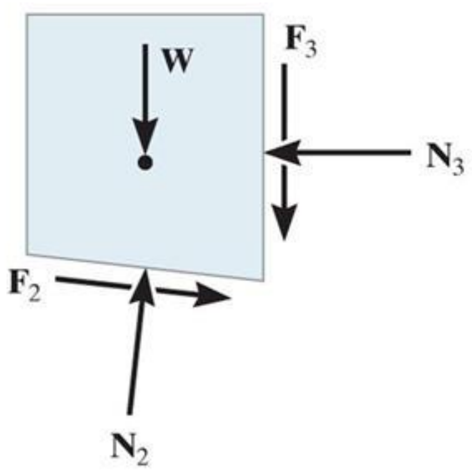
a) at the contacting surfaces between the wedge and the object, the forces are equal in magnitude and opposite in direction to those on the wedge; and,

b) all other forces acting on the object should be shown.

To determine the unknowns, we must apply E-of-E, $\sum F_x = 0$ and $\sum F_y = 0$, to the wedge and the object as well as the impending motion frictional equation, $F = \mu_S N$.

ANALYSIS OF A WEDGE (continued)

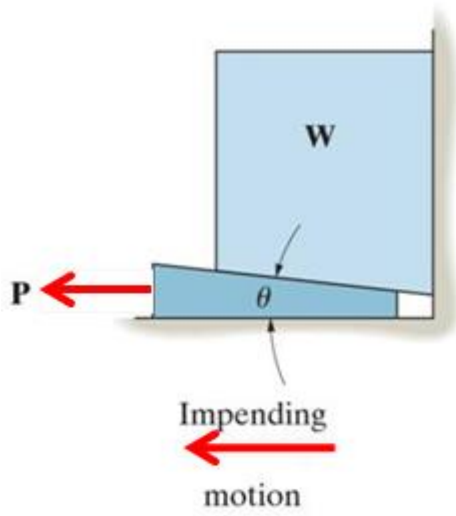




Now of the two FBDs, which one should we start analyzing first?

We should start analyzing the FBD in which the number of unknowns are less than or equal to the number of E-of-E and frictional equations.

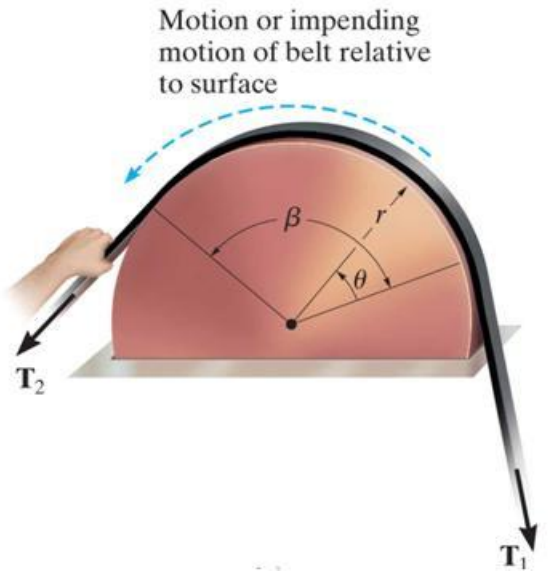
ANALYSIS OF A WEDGE (continued)



NOTE:

If the object is to be lowered, then the wedge needs to be pulled out. If the value of the force P needed to remove the wedge is positive, then the wedge is self-locking, i.e., it will not come out on its own.

BELT ANALYSIS



Consider a flat belt passing over a fixed curved surface with the total angle of contact equal to β radians.

If the belt slips or is just about to slip, then T_2 must be larger than T_1 and the motion resisting friction forces. Hence, T_2 must be greater than T_1.

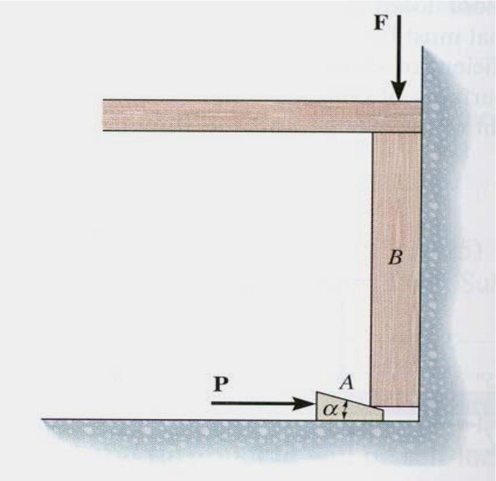
Detailed analysis (please refer to your textbook) shows that $T_2 = T_1 \, e^{\mu \beta}$ where μ is the coefficient of static friction between the belt and the surface. Be sure to use radians when using this formula!!

CONCEPT QUIZ

1. Determine the direction of the friction force on object B at the contact point between A and B.

   A) ↘ B) ←

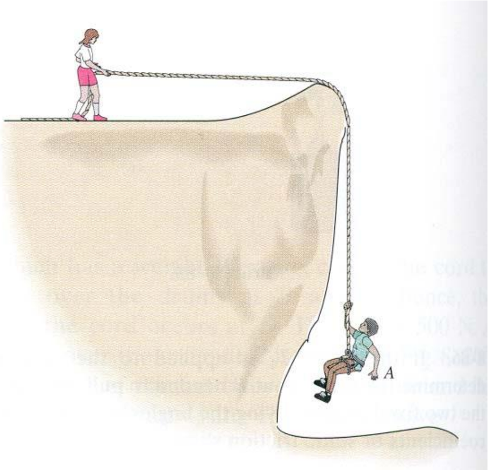
   C) → D) ↖



2. The boy (hanging) in the picture weighs 100 N and the woman weighs 150 N. The coefficient of static friction between her shoes and the ground is 0.6. The boy will ______ ?

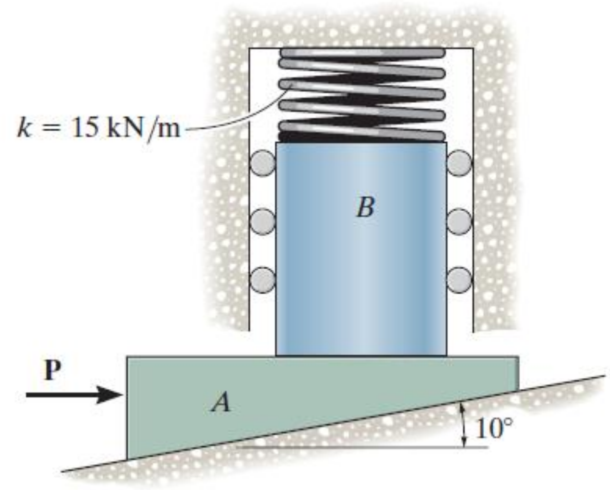
   A) Be lifted up B) Slide down

   C) Not be lifted up D) Not slide down



GROUP PROBLEM SOLVING

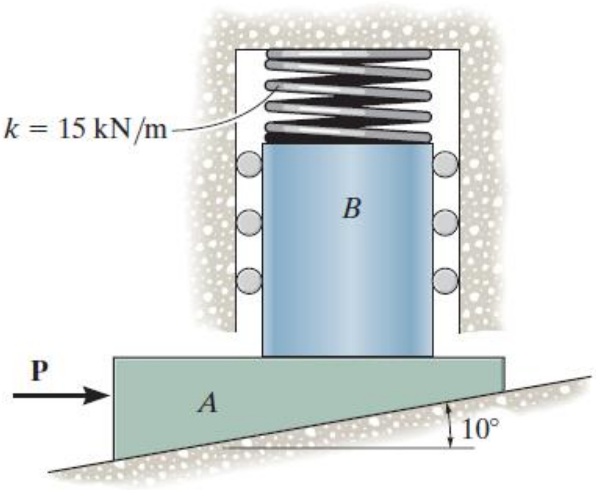
Given: A force **P** is applied to move wedge A to the right. The spring is compressed a distance of 175 mm.
The static friction coefficient is $\mu_S = 0.35$ for all contacting surfaces. Neglect the weight of A and B.



Find: The smallest force P needed to move wedge A.

Plan:

GROUP PROBLEM SOLVING (continued)



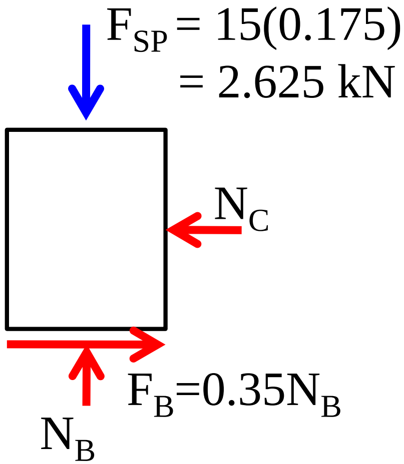
Plan:

1. Draw FBDs of block B and wedge A.

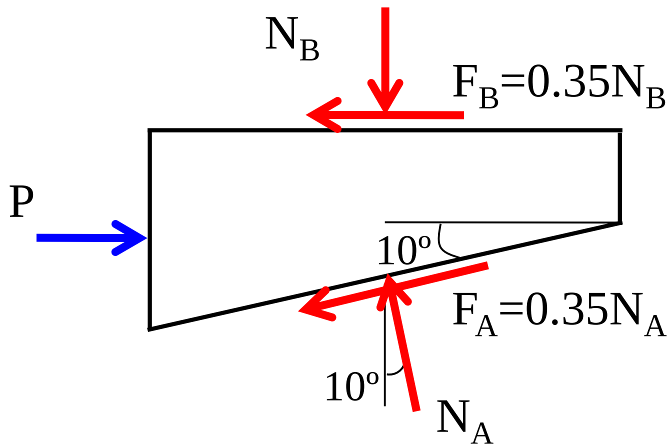
2. Apply the E-of-E to block B to find the friction force when the wedge is on the verge of moving.

3. Apply the E-of-E to wedge A to find the smallest force needed to cause sliding.

GROUP PROBLEM SOLVING (continued)



FBD of Block B



FBD of Wedge A

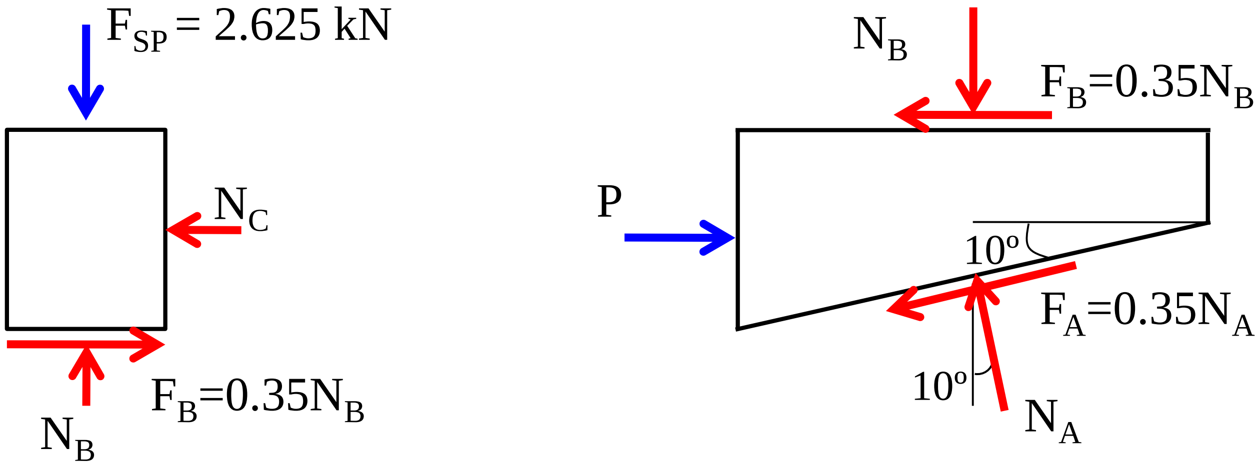
Using the spring formula:

$$F_{sp} = K\,x = (15\text{ kN/m})\,(0.175\text{m}) = 2.625\text{ kN}$$

If the wedge is on the verge of moving to the right, then slipping will have to occur at both contact surfaces.

Thus, $F_A = \mu_S N_A = 0.35\,N_A$ and $F_B = 0.35\,N_B$.

GROUP PROBLEM SOLVING (continued)



FBD of Block B

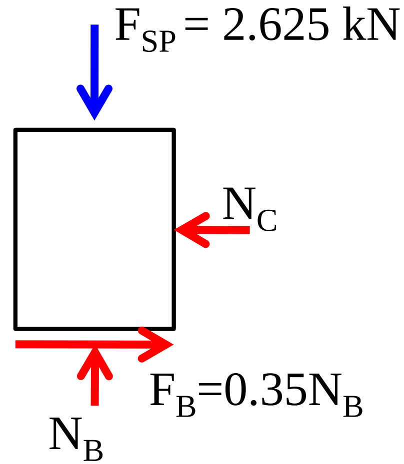
FBD of Wedge A

Applying the E-of-E to the Block B, we get:

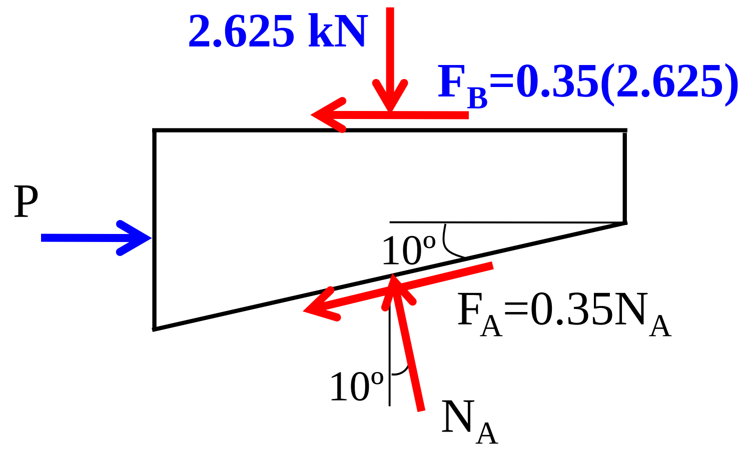
$$\uparrow + \sum F_Y = N_B - 2.625 = 0$$

$$N_B = 2.625 \text{ kN}$$

GROUP PROBLEM SOLVING (continued)



FBD of Block B



FBD of Wedge A

Applying the E-of-E to Wedge A:

$$\uparrow + \sum F_Y = N_A \cos 10° - 0.35N_A \sin 10° - 2.625 = 0$$

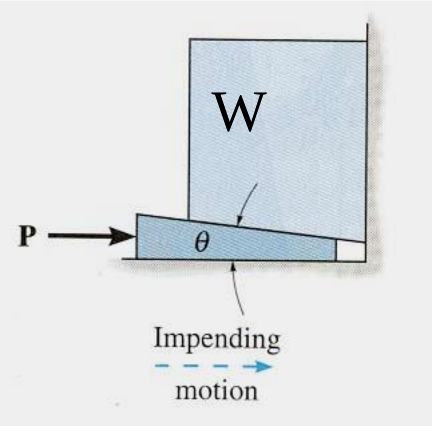
$$N_A = 2.841 \text{ kN}$$

$$\rightarrow + \sum F_X = P - 0.35(2.625) - 0.35(2.841) \cos 10° - 2.841 \sin 10° = 0$$

$$\underline{P = 2.39 \text{ kN}}$$

ATTENTION QUIZ

1. When determining the force P needed to lift the block of weight W, it is easier to draw a FBD of ______ first.



A) The wedge

B) The block

C) The horizontal ground

D) The vertical wall

2. In the analysis of frictional forces on a flat belt, $T_2 = T_1 e^{\mu \beta}$. In this equation, β equals ______ .

A) Angle of contact in degrees

B) Angle of contact in radians

C) Coefficient of static friction

D) Coefficient of kinetic friction

End of the Lecture

Let Learning Continue