ENGR-1100 Introduction to Engineering Analysis

Lecture 27

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:

- Reading Quiz
- Applications
- Analysis of a Wedge
- Analysis of a Belt
- Concept Quiz
- Group Problem Solving
- Attention Quiz

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?

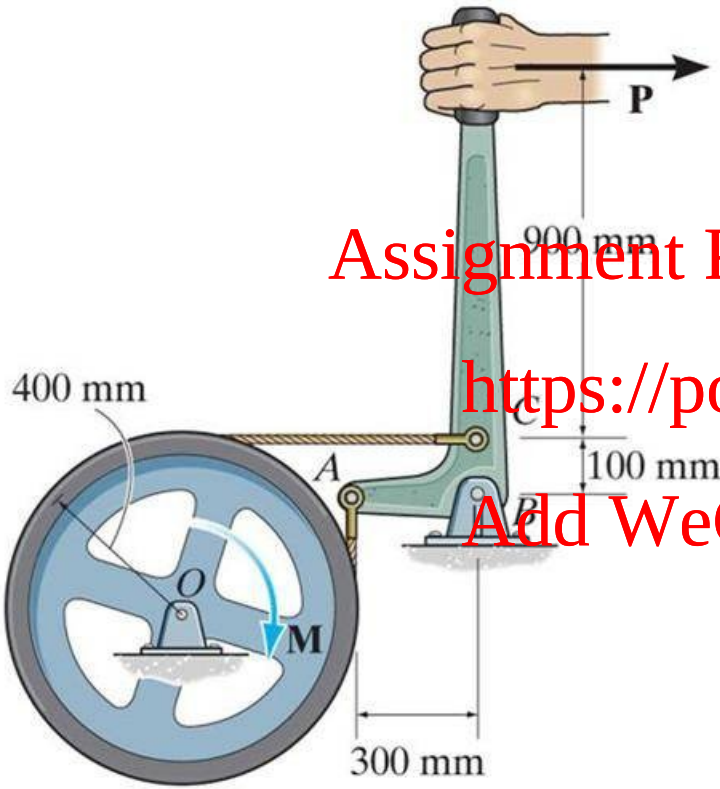
When there are no applied forces on the wedge, will it stay in place (*i.e.*, be self-locking) or will it come out on its own? Under what physical conditions will it come out?

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)

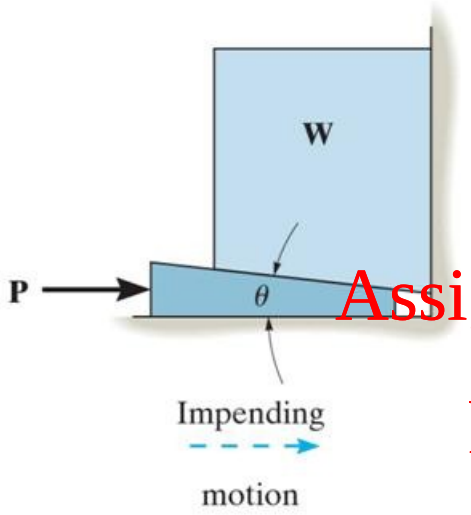


In the design of a band brake, it is essential to analyze the frictional forces acting on the band (which acts like a belt).

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.

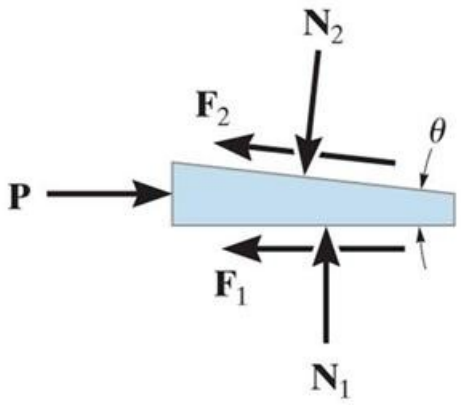
It is easier to start with a FBD of the wedge, since you know the direction of its motion.

Note that:

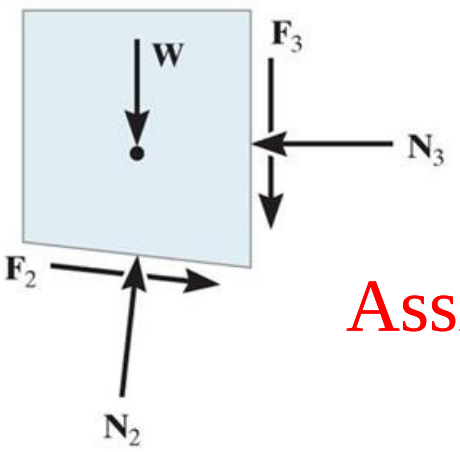
a) the friction forces are always in the direction opposite to the motion, or impending motion, of the wedge;

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)



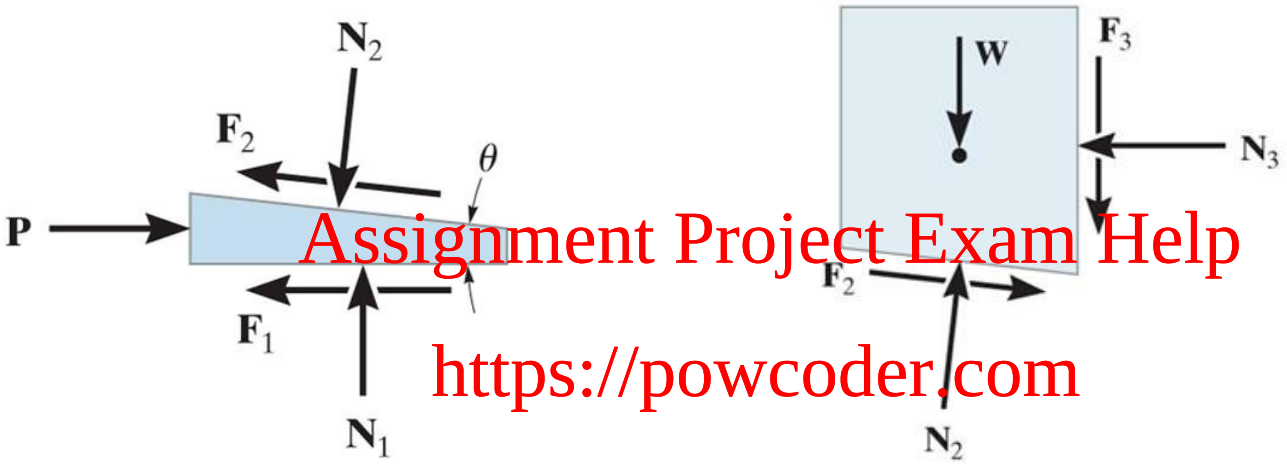
Next, a FBD of the object on top of the wedge is drawn. Please note that:

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.

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, $F = \mu_S N$.

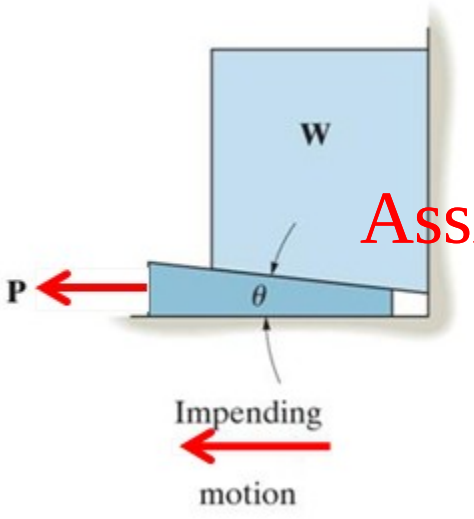
ANALYSIS OF A WEDGE (continued)



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

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

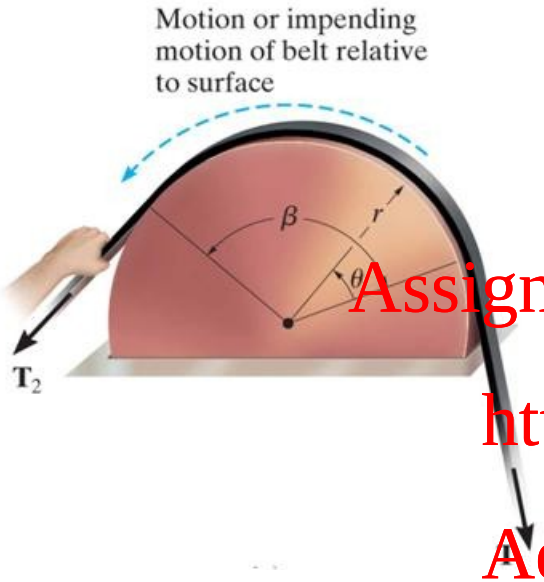
ANALYSIS OF A WEDGE (continued)



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.

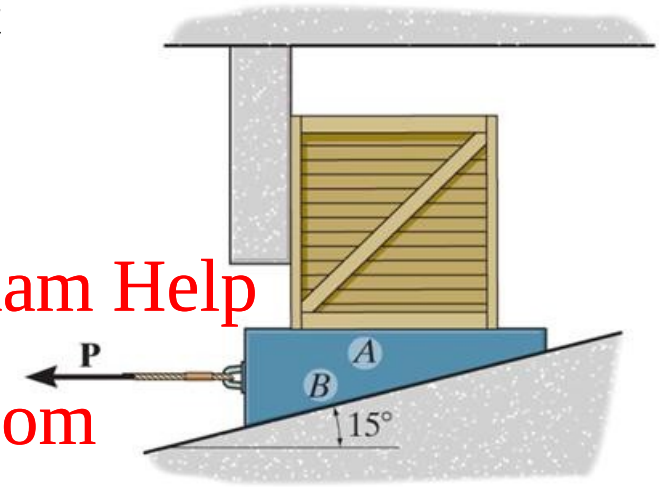
If the belt slips or is just about to slip, then T_2 must be larger than T_1 and the motion resisting friction forces. Hence, T_2 must be greater than T_1.

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!!

EXAMPLE

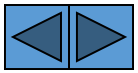
Given: The crate weighs 300 lb and μ_s at all contacting surfaces is 0.3. Assume the wedges have negligible weight.

Find: The smallest force P needed to pull out the wedge.

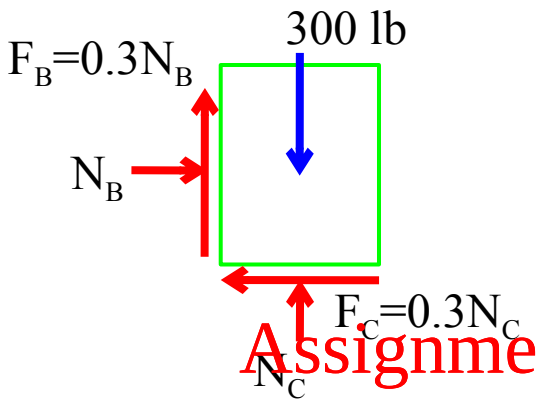


Plan:

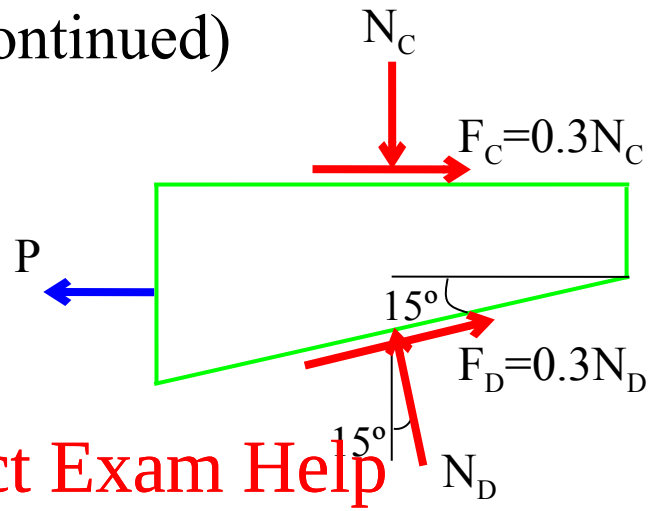
1. Draw a FBD of the crate. Why do the crate first?
2. Draw a FBD of the wedge.
3. Apply the E-of-E to the crate.
4. Apply the E-of-E to wedge.



EXAMPLE (continued)



FBD of Crate



FBD of Wedge

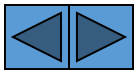
The FBDs of crate and wedge are shown in the figures. Applying the E-of-E to the crate, we get

$$\rightarrow + \sum F_X = N_B - 0.3N_C = 0$$

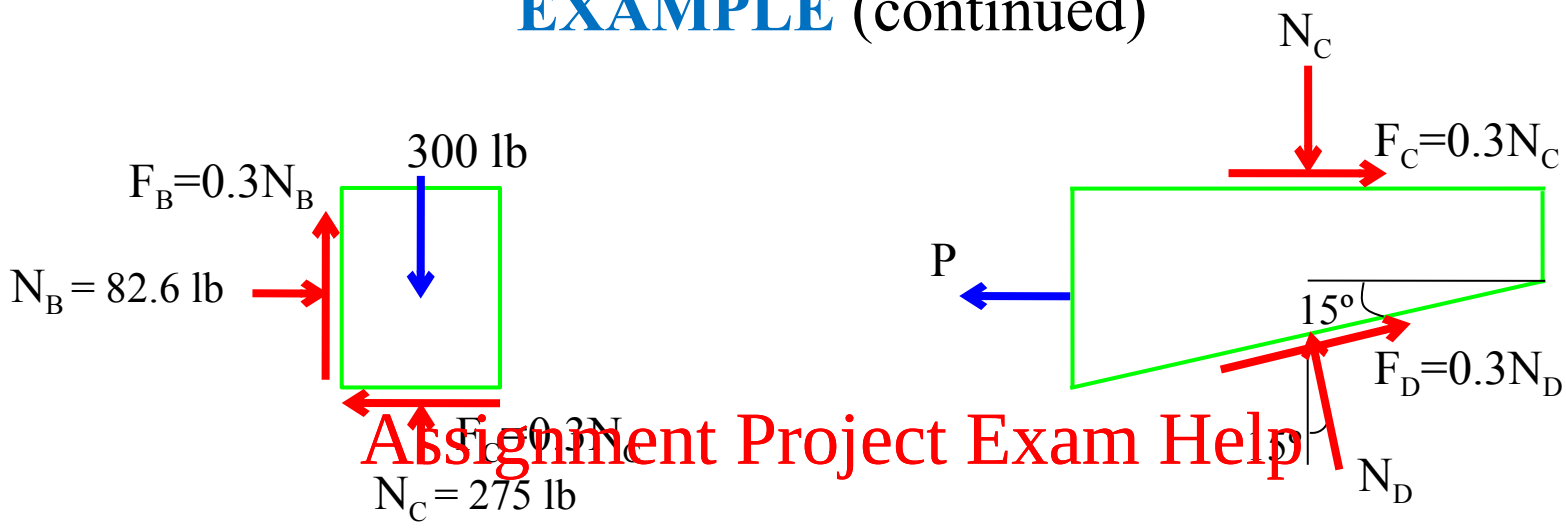
$$\uparrow + \sum F_Y = N_C - 300 + 0.3\,N_B = 0$$

Solving the above two equations, we get

$N_B = 82.57$ lb $= 82.6$ lb, $N_C = 275.3$ lb $= 275$ lb



EXAMPLE (continued)



Applying the E-of-E to the wedge, we get

$$\uparrow+ \sum F_Y = N_D \cos 15° + 0.3\, N_D \sin 15° - 275.2 = 0;$$

$$N_D = 263.7 \text{ lb} = 264 \text{ lb}$$

$$\rightarrow+ \sum F_X = 0.3(275.3) + 0.3(263.7)\cos 15° - (263.7)\sin 15° - P = 0;$$

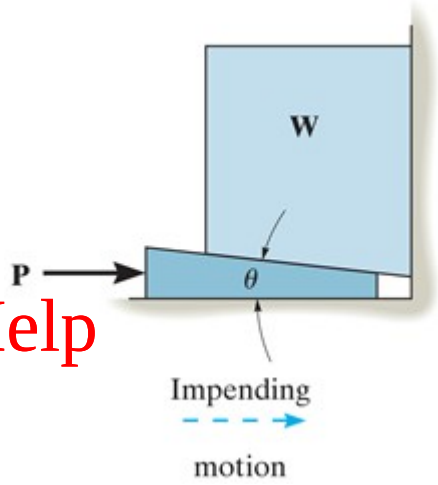
$$P = 90.7 \text{ lb}$$

READING QUIZ

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

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

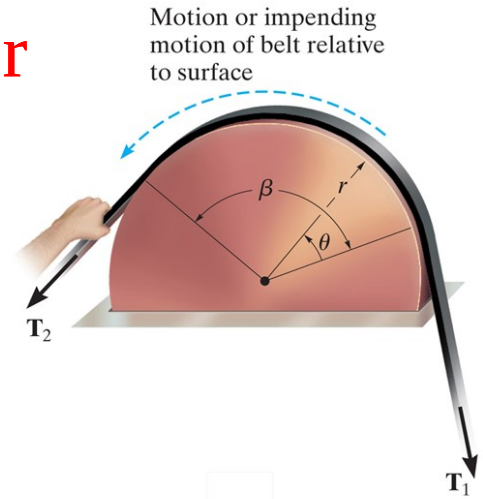
   C) (small, small) D) (large, small)



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

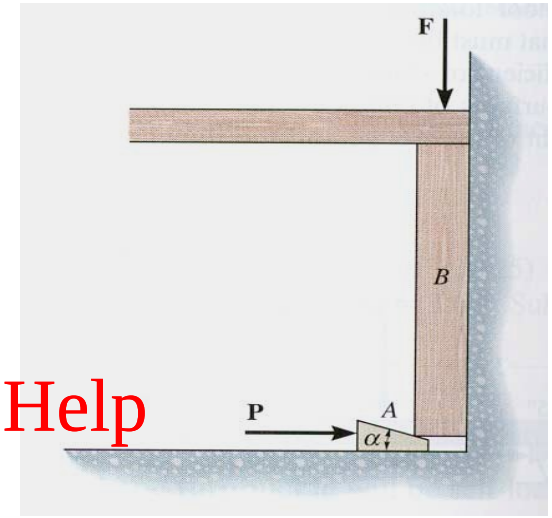
   A) $T_1 > T_2$ B) $T_1 = T_2$

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



CONCEPT QUIZ

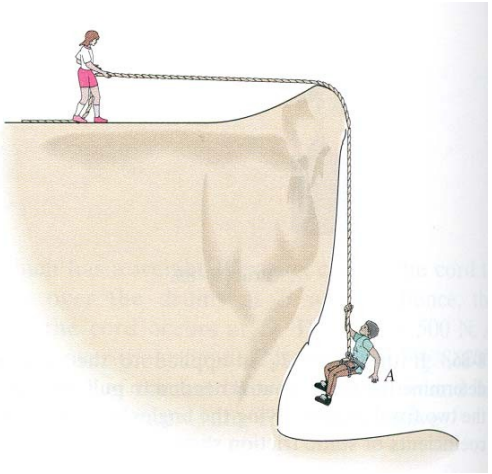
1. Determine the direction of the friction force on object B at the contact point between A and B.



A) ↘ B) ←

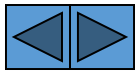
C) → D)

2. The climber hanging at A in the picture weighs 100 lb and the individual on top on the flat weighs 150 lb. The coefficient of static friction between this individual's shoes and the ground is 0.6. The climber will _____ ?



A) Be lifted up B) Slide down

C) Not be lifted up D) Not slide down



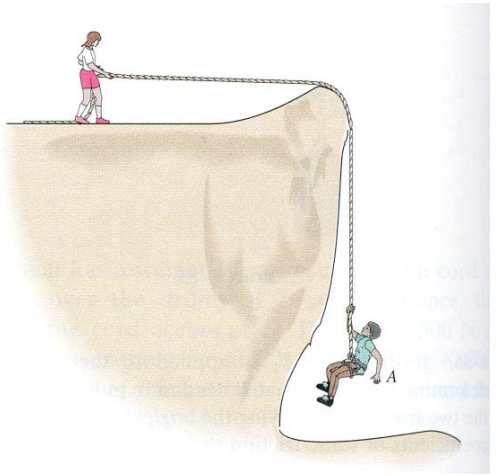
Wait! What? It is really more complicated.

In this problem, there are really 3 possibilities.

1. The climber is pulled up
2. The climber stays at A
3. The climber falls from A

Because we do not know the coefficient of friction at the 90° turn, **it is impossible to say** if there is enough friction combined with the weight of the holding individual to stop the climber from falling.

2. The climber hanging at A in the picture weighs 100 lb and the individual on top of the flat weighs 150 lb. The coefficient of static friction between this individuals shoes and the ground is 0.6. The climber will _____ ?

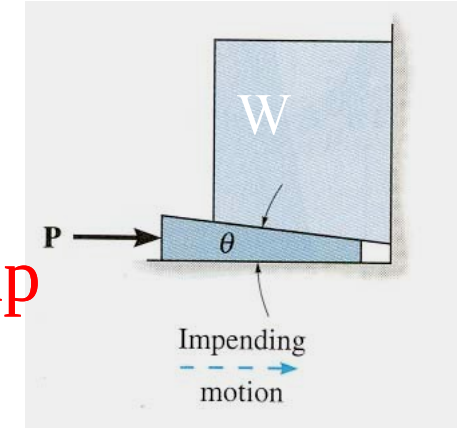


A) Be lifted up B) Slide down

C) Not be lifted up D) Not slide down

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.



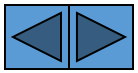
A) The wedge B) The block

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



Final Exam Information

- Tuesday 12/15/2020; **8:00** – 11:00 am:

  Students starting late will not get extra time.

- The test ends at **10:55** am.
- The deadline to upload your exam to **LMS** is **10:55** am.
- You have a 5-minute grace period to **upload** your exam **to LMS** without a penalty.
- You can upload your exam to LMS after **11:00** am with a penalty of 1 point/minute (*e.g.*, if you submit your exam on 11:15 am your exam grade will be reduced by 15 points!).

Final Grade Components

Highest grade of Exams 1, 2 and 3	20%
Other two Exams (15% each)	30%
HomeWorks	20%
In-Class assignments	5%
Final examination	25%

The 2 HW assignments and 4 CA with the lowest grades will be dropped.

Final Exam

4 Problems equally weighted (25 points each):

- Problems 1 and 2 (mandatory):
  1. Frames/Machines
  2. Friction (Dry/Belt)
- Problems 3 and 4, select 2 problems out of 3:
  1. Test 1 topics
  2. Test 2 topics
  3. Test 3 topics

Final Exam

- You will be graded **on 4 problems**, 25 points per problem. Problems 1 and 2 **are mandatory** and will be systematically graded.
- Select two problems out of problems 3, 4 and 5 and submit only the 2 selected problems. If you submit the three problems (3, 4 and 5), only 2 will be graded at random.
- Clearly **show all steps** and state all assumptions made in order for full credit to be given.
- Express your final answers clearly and highlight them in **boxes**.
- **Careless and untidy work** will be penalized. An **illegible** answer is a **wrong** answer.

Makeup Exam

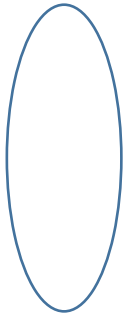
- Tuesday 12/15/2020, 11:30 am – 2:30 pm
- **Only** for students that have a conflict with the regular final exam

NOTE: Let your instructor know no later than Tuesday 12/08/2020 and specify the course that is conflicting with IEA

Final EXAM logistics

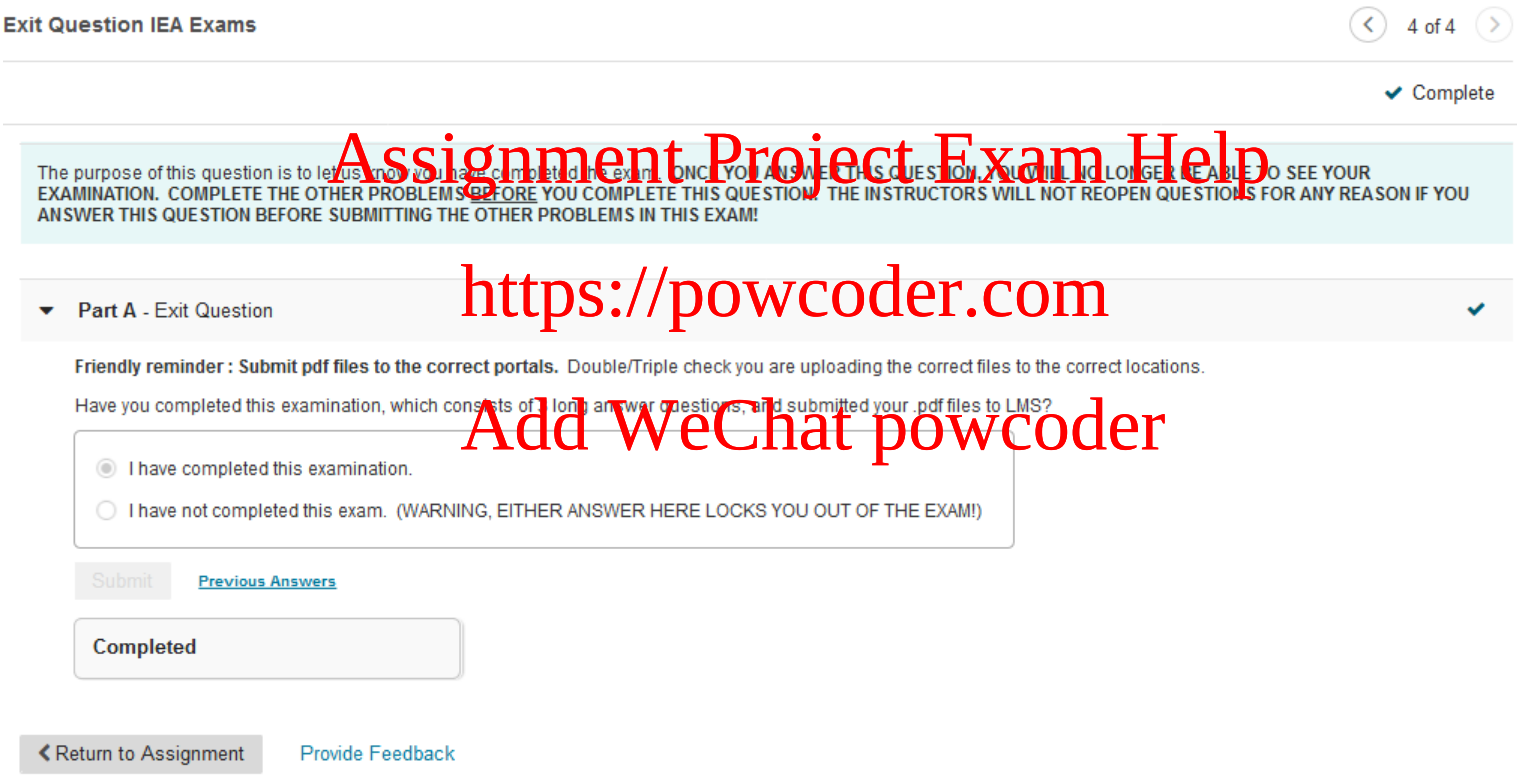
- The Final Exam is to be accessed using MasteringEngineering, in the same fashion as for Exam 1, 2 and 3.
- MasteringEngineering is used to deliver the problems with randomized ***numerical values that are different for each student***. You get a **zero grade** if you **do not** use the numerical values that were **assigned to you**.

- Under “Final Exam-Fall 2020 IEA,” you will see 6 items.
- Item 6 is an **exit question** that **does not** affect your grade. It is intended to ensure that you do not get locked out of the exam before you are done working on items/problems 1 to 5. **Do not touch it until you are done**. **You can also skip it totally.**



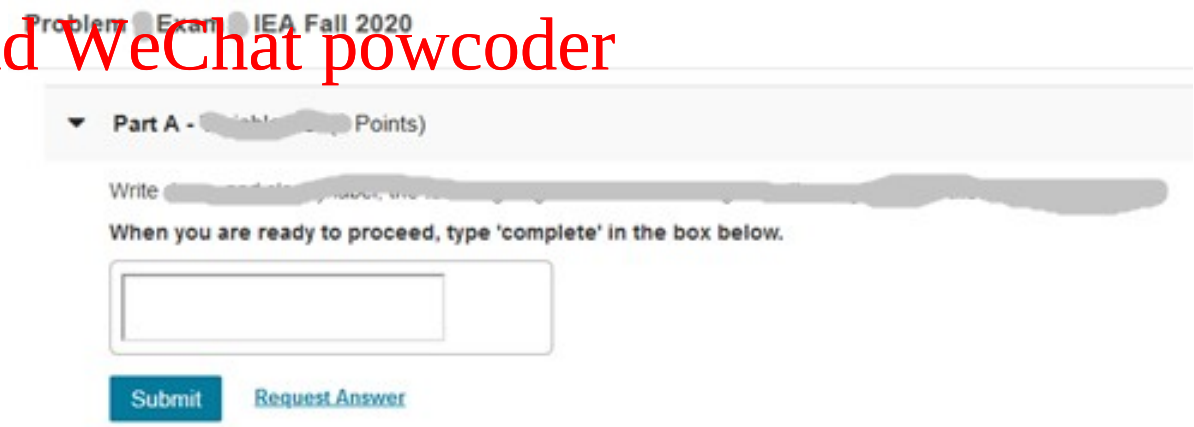
The Possible Points that you see are place holders and are not relevant.
The exam grade will be on LMS (The LMS grade is the only grade that matters).

This is view of item 6



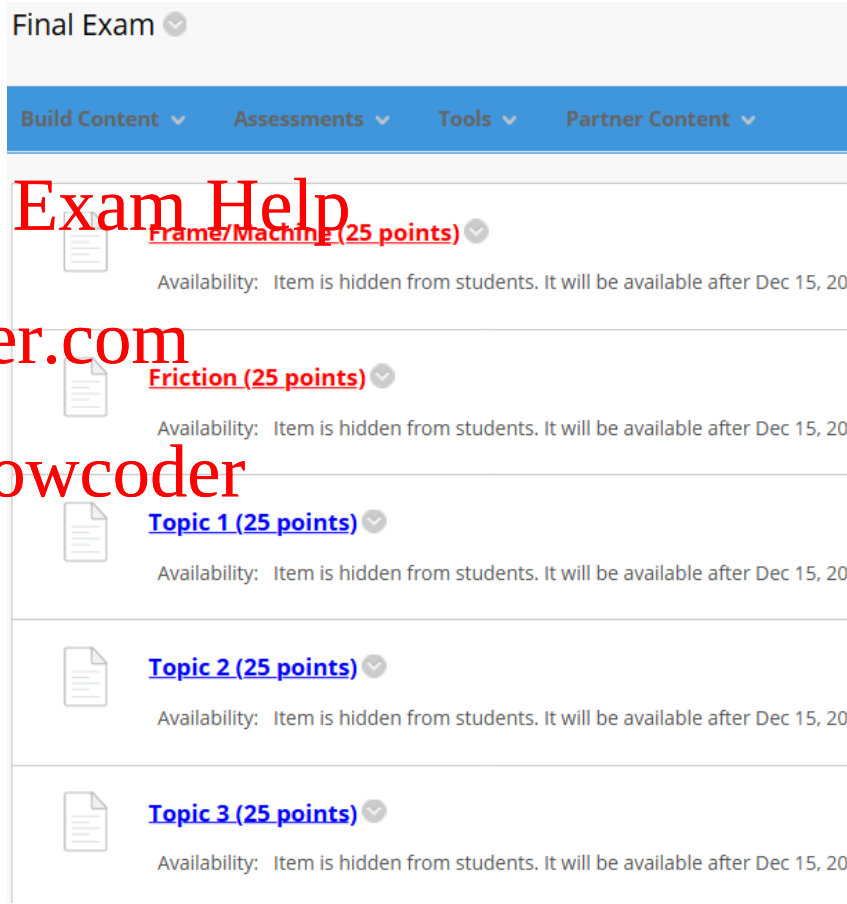
Final Exam logistics

- You solve the 4 problems on paper (or tablet if you prefer).
- MasteringEngineering is used only to deliver the exam.
- To help you track your progression in answering all the questions, you can type (at any time) "complete," for each question. **You can also skip this step.**



Final Exam Logistics

- Your test solution and answers (on paper or tablet) are to be scanned and submitted in **pdf** format using **LMS**:
  - You will have to submit the **problems separately**—so use a different sheet (paper or electronic) for each problem:
    - Under "content," select "Final Exam 3," then select "**Frame/Machine (20 Points)**" to submit your solution to the " **Frame/Machine**" problem only, etc.
    - You are entitled to **one single submission** per problem
  - The **deadline** for all submissions on LMS is **11:55 am**
  - You have a 5-minute grace period to **upload** your exam **to LMS** without a penalty. You can upload your exam to LMS after **11:00** am with a penalty of 1 point per minute.
  - You **cannot email** your test to the instructor or the TA and emailed tests **will be ignored.**



Regular and Extra-Time Submission Deadlines

	End of the test	Deadline for submission	Late submission
Regular	10:35 am	**10:55 am**	5-minute grace period, 1-point penalty/minute thereafter.
50 % Extra time	11:53 am	**12:13 pm**	5-minute grace period, 1-point penalty/minute thereafter.
100 % Extra time	1:10 pm	**1:30 pm**	5-minute grace period, 1-point penalty/minute thereafter.

Late submissions will be handled using the time recorded by LMS

Final Exam Rules

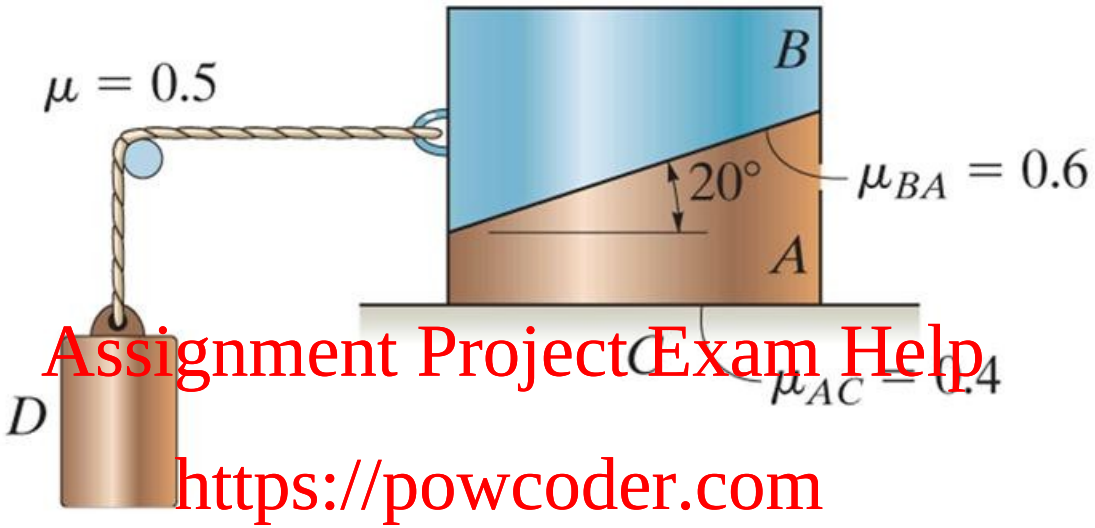
- The exam is open book and notes.

- The exam will be monitored electronically

- You connect from LMS to Webex at least 5 minutes before 8:00 am on 12/15/2020

- You must turn on your video camera
- You must remain connected until you submit your test.
- You can **only use the chat function** to communicate with the instructor, *i.e.*, You are not allowed to unmute yourself and ask a question

GROUP PROBLEM SOLVING

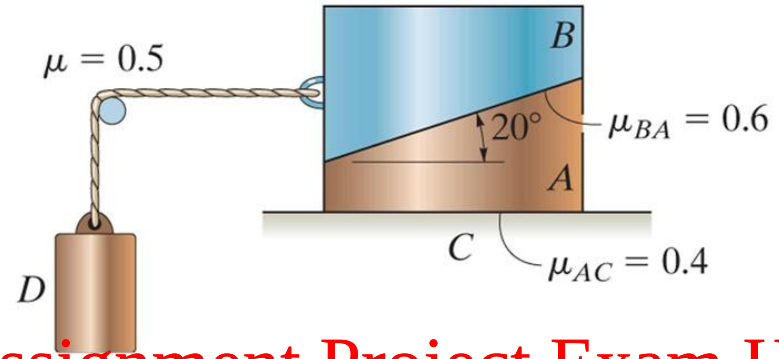


Given: Blocks A and B weigh 50 lb and 30 lb, respectively.

Find: The smallest weight of cylinder D which will cause the loss of static equilibrium.

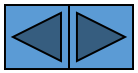
Plan:

GROUP PROBLEM SOLVING (continued)



Plan:

1. Consider two cases: a) both blocks slide together, and, b) block B slides over the block A.
2. For each case, draw a FBD of the block(s).
3. For each case, apply the E-of-E to find the force needed to cause sliding.
4. Choose the smaller P value from the two cases.
5. Use belt friction theory to find the weight of block D.



GROUP PROBLEM SOLVING (continued)

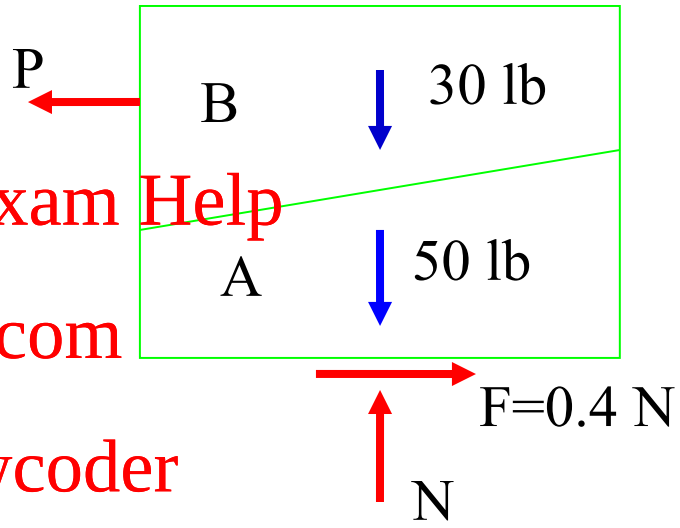
Case a (both blocks sliding together):

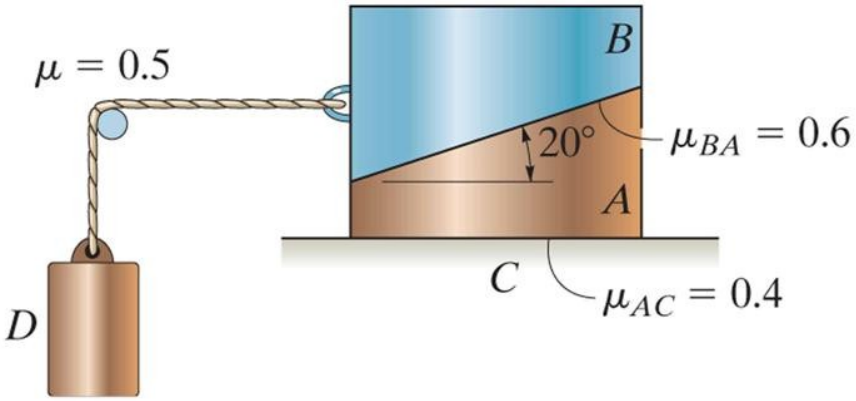
$\uparrow + \sum F_Y = N - 80 = 0$

$N = 80$ lb

$\rightarrow + \sum F_X = 0.4\,(80) - P = 0$

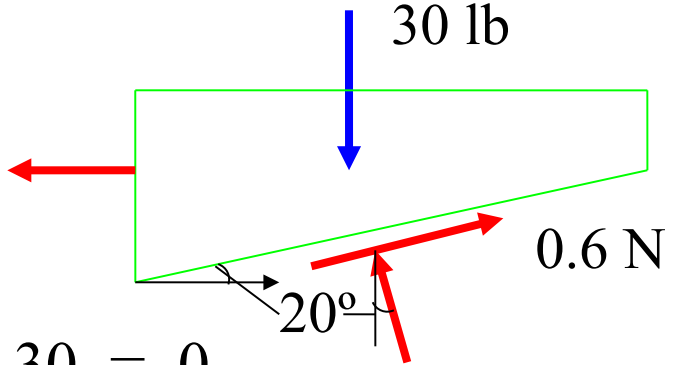
$P = 32$ lb





GROUP PROBLEM SOLVING (continued)

Case b (block B slides over A):



$$\uparrow + \sum F_y = N\cos 20° + 0.6\,N \sin 20° - 30 = 0$$

$$N = 26.20 \text{ lb}$$

$$\rightarrow + \sum F_x = -P + 0.6\,(26.2)\cos 20° - 26.2 \sin 20° = 0$$

$$P = 5.812 \text{ lb}$$

Case b has the lowest P (case a was 32 lb) and thus will occur first. Next, using a frictional force analysis of belt, we get

$$W_D = P\,e^{\mu\beta} = 5.812\;e^{0.5\,(0.5\,\pi)} = 12.7 \text{ lb}$$

A Block D weighing 12.7 lb will cause the block B to slide over the block A.