**ME 270 Exam 2 – Spring 2024** **NAME (Last, First):** Solution.

## Please review the following statement:

I certify that I have not given unauthorized aid nor have I received aid in the completion of this exam.

**Signature:** ______________________________________

**Instructor's Name and Section: (Circle Your Section)**

**Sections:** J. Jones, Section 001, MWF 9:30AM-10:20AM
T. Han, Section 002, MWF 1:30PM-2:20PM
J. Jones, Section 003, MWF 11:30AM-12:20AM
J. Jones, Section 005, Distance Learning

**Please review and sign the following statement:**

Purdue Honor Pledge – "As a Boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together – We are Purdue."

**Signature:** ______________________________________

**INSTRUCTIONS**

Begin each problem in the space provided on the examination sheets. If additional space is required, please request additional paper from your instructor.

Work on one side of each sheet only, with only one problem on a sheet.

Each problem is worth 20 points.

Please remember that for you to obtain maximum credit for a problem, it must be clearly presented. Also, please make note of the following instructions.

- The allowable exam time for Exam 1 is 90 minutes.
- The coordinate system must be clearly identified.
- Where appropriate, free body diagrams must be drawn. These should be drawn separately from the given figures.
- Units must be clearly stated as part of the answer.
- You must carefully delineate vector and scalar quantities.
- Please use a **black pen or dark lead pencil** for the exam.
- Do not write on the back side of your exam paper.

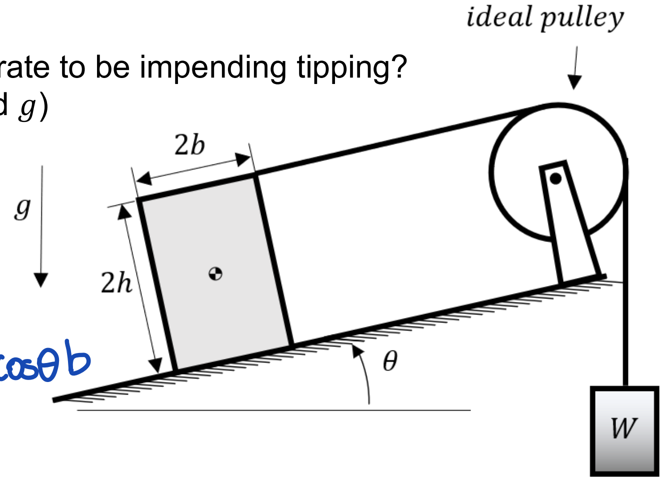
If the solution does not follow a logical thought process, it will be assumed in error.

**When submitting your exam on Gradescope, please make sure that all sheets are in the correct sequential order and make sure that your name is at the top of the cover page. Also, be sure to identify the page numbers for each problem before final submission on Gradescope. Do not include the cover page or the equation sheet with any of the problems.**

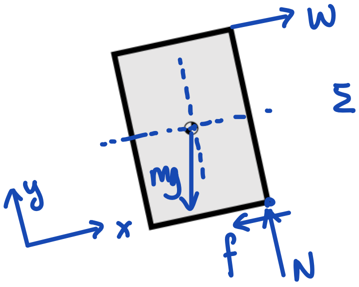
## PROBLEM 1 (20 points)

**1A. Given:** A crate of mass $m$ is placed on a rough incline with a cable attached to the top. The other end of the cable is attached to a free-hanging weight. The crate has a height of $2h$ and a width of $2b$. Consider the incline forms an angle $\theta$ with respect to the horizontal surface and has a coefficient of static friction $\mu_s$, please answer the following questions.

**Find:** Draw the FBD and calculate the weight $W$ for the crate to be impending tipping? (Express your answer in terms of $m$, $b$, $h$, $\theta$, $\mu_s$ and $g$)



**FBD for impending tipping**



$$\Sigma M_{tip} = -2h \cdot W + mg\sin\theta\, h + mg\cos\theta\, b$$
$$= 0$$

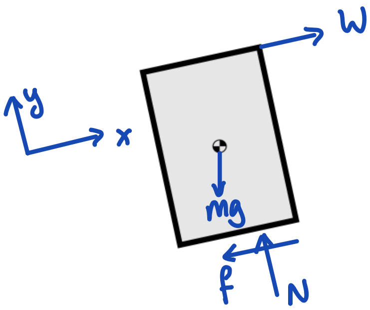
$$\Rightarrow 2h \cdot W = mg(\sin\theta\, h + \cos\theta\, b)$$

$$W = \frac{mg}{2h}(h\sin\theta + b\cos\theta)$$

W = $\frac{mg}{2h}(h\sin\theta + b\cos\theta)$ **(3 pts)**

**Find:** Draw the FBD and calculate the weight $W$ for the crate to be impending slipping upwards? (Express your answer in terms of $m$, $b$, $h$, $\theta$, $\mu_s$ and $g$)

**FBD for impending tipping**



$\Sigma F_y = N - mg\cos\theta = 0$ ①

$\Sigma F_x = W - f - mg\sin\theta = 0$ ②

$f = \mu_s N = \mu_s mg\cos\theta$ ③

① → $N = mg\cos\theta$

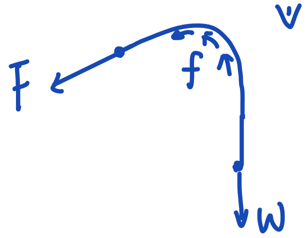
② → $W = f + mg\sin\theta = mg(\mu_s\cos\theta + \sin\theta)$

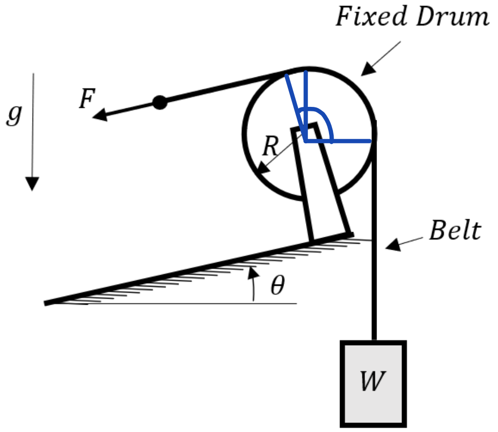
W = $mg(\mu_s\cos\theta + \sin\theta)$ **(3 pts)**

**1B. Given:** A drum with radius $R$ is fixed to an incline with an angle $\theta$ with respect to the horizontal surface. A belt is wrapped around a portion of the drum with a block weight $W$ attached at one end and a force $F$ applied at the other end. The drum is rough and have a coefficient of static friction $\mu_s$. Force $F$ is parallel to the incline. Consider $W$, $R$, $\theta$, and $\mu_s$ as known values.

**Find:** The minimum force $F$ needed to prevent the belt from slipping. Express your answer in terms of the given variables. **(5 pts)**

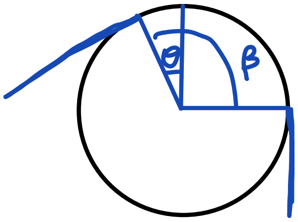
Belt impending slipping





$F < W$

$\hookrightarrow \frac{W}{F} = e^{\mu_s \beta}$



$\beta = \theta + \frac{\pi}{2}$

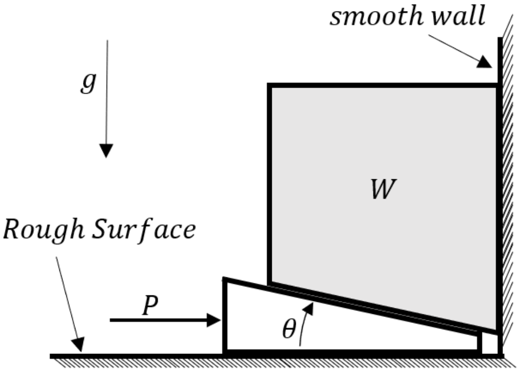
$\frac{W}{F} = e^{\mu_s(\theta + \frac{\pi}{2})}$

$F = \frac{W}{e^{\mu_s(\theta+\frac{\pi}{2})}}$

| | |
|---|---|
| $F = \frac{W}{e^{\mu_s(\theta+\pi/2)}}$ | **(5 pts)** |

**1C (5 pts).**

As shown on the right, a block with weight $W$ is held up by a wedge against a smooth surface. Please answer the following questions by circling the correct choice in each given scenario



If the given wedge is known to be self-locking, which of the following is true for the block to impending moving down?

A. $P > 0$
B. $P = 0$
[✓ C. $P < 0$]
D. Not enough information is given to determine.

If the given wedge is known to be self-locking, which of the following is true for the block to impending moving up?

[✓ A. $P > 0$]
B. $P = 0$
C. $P < 0$
D. Not enough information is given to determine.

If the given wedge is known to be self-locking with the current angle $\theta$, is the wedge still self-locking when $\theta$ is decreased?

[✓ A. Yes]
B. No
C. Not enough information is given to determine.

If the given wedge is known to be self-locking with the current angle $\theta$, is the wedge still self-locking when $\theta$ is increased?

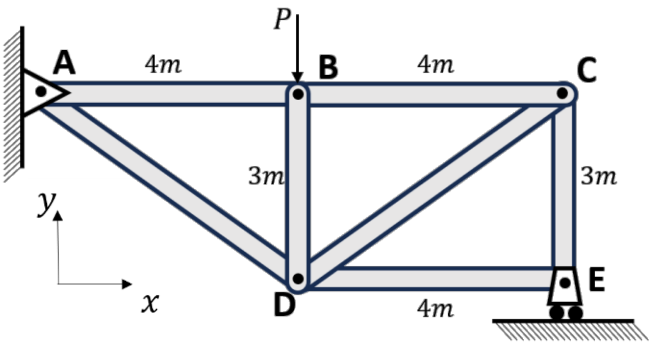
A. Yes
B. No
[✓ C. Not enough information is given to determine.]

If the given wedge is known to be self-locking with vertical smooth wall, is the wedge still self-locking when the vertical wall is no longer smooth?

[✓ A. Yes]
B. No
C. Not enough information is given to determine.

**PROBLEM 2. (20 points)**

**Given:** A truss structure is made of 7 members with point A on pinned support and E on roller support. Truss AB, BC, and DE are 4 meters long and are in horizontal position. Truss BD and CE are 3 meters long and are in vertical position. A vertical load $P$ is applied at B.



**Find**:

**a)** Complete the free body diagram on the artwork provided below and find the reactions at points A and E. Express the reactions in vector form in terms of $P$.**(6 pts)**

$\Sigma M_A = -4m \cdot P + 8m \cdot E_y = 0$

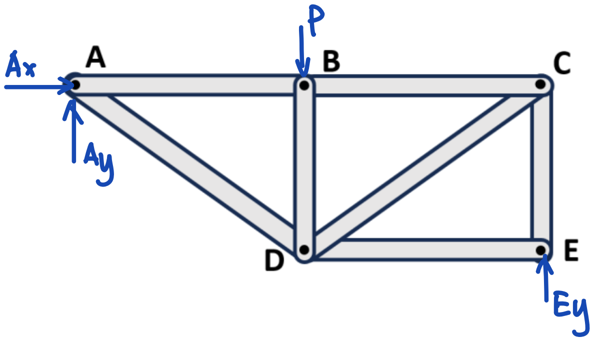
$\hookrightarrow E_y = \frac{1}{2}P$

$\Sigma F_x = A_x = 0$

$\Sigma F_y = A_y - P + E_y = 0$

$\hookrightarrow A_y = P - E_y = \frac{1}{2}P$

**FBD (2 pt)**



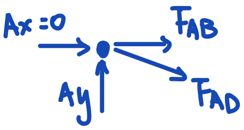
| | | |
|---|---|---|
| $\boldsymbol{A} = ( \quad 0 \quad )\hat{\boldsymbol{\imath}} + ( \quad \frac{1}{2}P \quad )\hat{\boldsymbol{\jmath}}$ | **(2 pts)** |
| $\boldsymbol{E} = ( \quad 0 \quad )\hat{\boldsymbol{\imath}} + ( \quad \frac{1}{2}P \quad )\hat{\boldsymbol{\jmath}}$ | |

**b)** Identify the number of zero-force members. No work needs to be shown, just select your answer in the box below. (2 points) only DE

| | |
|---|---|
| **0 [✓ 1] 2 3 4 5 6 7 (circle one)** | **(2pts)** |

**c)** Use the method of joints to find the magnitudes of the loads in the truss AB and AD in terms of $P$. Clearly state (by circling one option) if the links are in tension, compression, or zero force. Include a free body diagram of the joint used. **(5 pts)**

Joint A:



$\Sigma F_x = F_{AB} + \frac{4}{5}F_{AD} = 0$ ①

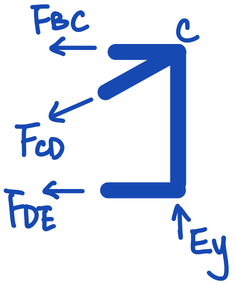
$\Sigma F_y = A_y - \frac{3}{5}F_{AD} = 0$ ②

② $\rightarrow F_{AD} = \frac{5}{3}A_y = \frac{5}{6}P$

① $\rightarrow F_{AB} = -\frac{4}{5}F_{AD} = -\frac{4}{5}\cdot\frac{5}{6}P = -\frac{2}{3}P$

| | | | | | |
|---|---|---|---|---|---|
| $F_{AB} = \frac{2}{3}P \approx 0.67P$ | **Tension** | [✓ **Compression**] | **Zero** | **(circle one)** | **(2 pts)** |
| $F_{AD} = \frac{5}{6}P \approx 0.83P$ | [✓ **Tension**] | **Compression** | **Zero** | **(circle one)** | |

**d)** Use the method of sections to find the magnitudes of the loads in the links BC, CD and DE in terms of $P$. Clearly state (by circling one option) if the links are in tension, compression, or zero force. Include a free body diagram of the section used. **(7 pts)**



$\Sigma M_C = F_{DE}\cdot 3m = 0$ ①

$\Sigma F_x = -F_{BC} - \frac{4}{5}F_{CD} - F_{DE} = 0$ ②

$\Sigma F_y = E_y - \frac{3}{5}F_{CD} = 0$ ③

① $\rightarrow F_{DE} = 0$

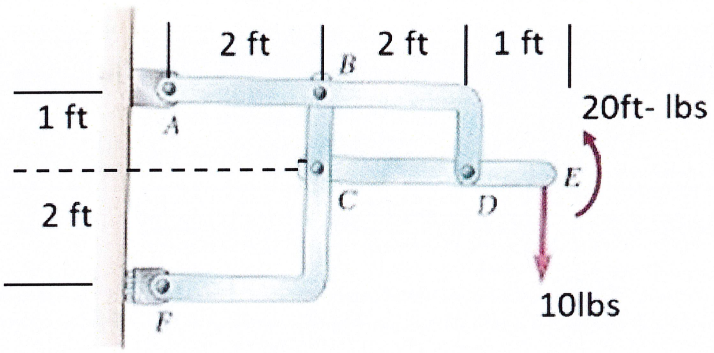
③ $\rightarrow F_{CD} = \frac{5}{3}E_y = \frac{5}{3}\cdot\frac{1}{2}P = \frac{5}{6}P$

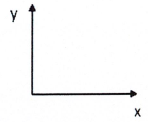
② $\rightarrow F_{BC} = -\frac{4}{5}F_{CD} = -\frac{4}{5}\cdot\frac{5}{6}P = -\frac{2}{3}P$

| | | | | | |
|---|---|---|---|---|---|
| $F_{BC} = 2/3P \approx 0.67P$ | **Tension** | [✓ **Compression**] | **Zero** | **(circle one)** | **(3 pts)** |
| $F_{CD} = 5/6P = 0.83P$ | [✓ **Tension**] | **Compression** | **Zero** | **(circle one)** | |
| $F_{DE} = 0$ | **Tension** | **Compression** | [✓ **Zero**] | **(circle one)** | |

**PROBLEM 3. (20 points)**

**Given:** The frame ABCDEF is supported by a pin joint at A and a roller support at F. One external force and a couple act on the frame as shown.





**Find:**

**a)** On the artwork provided, complete the overall free body diagram (1 point) and solve for the reactions at supports A and F. Express the reactions at A and F in vector form.

$$\underline{\underline{\Sigma M_A = 0}} = 20 - 10(5) + F_x(3)$$

$$\boxed{\therefore F_x = +10\text{ lbs.}}$$

(+10 lbs.)

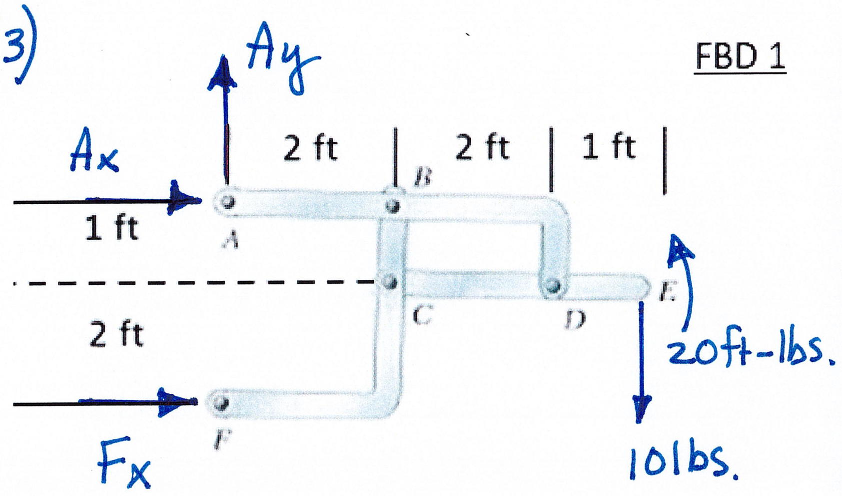
$$\underline{\underline{\Sigma F_x = 0}} = A_x + F_x$$

$$\boxed{\therefore A_x = -10\text{ lbs.}}$$

$$\underline{\underline{\Sigma F_y = 0}} = A_y - 10$$

$$\boxed{\therefore A_y = +10\text{ lbs}}$$

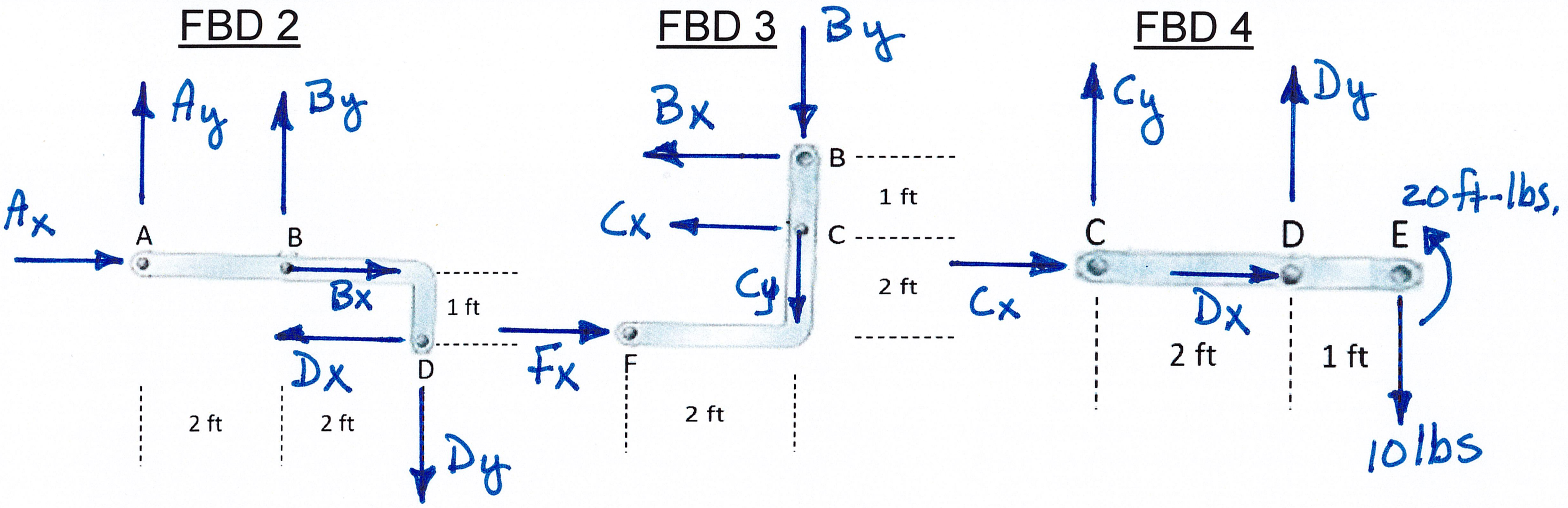
FBD 1



$\bar{A} = ($ −10 $)\hat{\imath} + ($ +10 $)\hat{\jmath}$ **lbs (2 pts)**

$\bar{F} = ($ +10 $)\hat{\imath}$ **lbs (2 pts)**

**b)** On the members provided below, complete the individual free body diagrams of the three members. **(3 points)**



**c)** Compute the forces at pins C and D as seen by the member CDE in vector form. (12 pts)

FBD 3

$$\Sigma M_B = 0 = -C_x(1) + \overset{(+10lbs)}{F_x}(3) \Rightarrow \boxed{\therefore C_x = +30 lbs.}$$

FBD 4

$$\Sigma M_D = 0 = -C_y(2) - 10(1) + 20 \Rightarrow \boxed{\therefore C_y = +5 lbs.}$$

$$\Sigma F_x = 0 = \overset{(+30lbs)}{C_x} + D_x \Rightarrow \boxed{\therefore D_x = -30 lbs.}$$

$$\Sigma F_y = 0 = \overset{(+5lbs)}{C_y} + D_y - 10 \Rightarrow \boxed{D_y = +5 lbs.}$$

| | |
|---|---|
| $\overline{(C)}_{\text{on CDE}} = (+30)\hat{\imath} + (+5)\hat{\jmath}$ lbs | **(6 pts)** |
| $\overline{(D)}_{\text{on CDE}} = (-30)\hat{\imath} + (+5)\hat{\jmath}$ *lbs* | **(6 pts)** |

## *Exam 2 – Equation Sheet*

**Belt Friction**

$$\frac{T_L}{T_s} = e^{\mu\beta}$$