ME 270 – Fall 2024 Exam 2 **NAME (Last, First):** SOLUTION **(Please Print)**

PUID #: ____________________ **(Please Print)**

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
S. Dyke, Section 003, MWF 10:30AM-11:20AM
J. Jones, Section 002, MWF 11:30AM-12:20PM
F. Semperlotti, Section 005, MWF 12:30PM-1:20PM
F. Zhao, Section 008, MWF 1:30PM-2:20PM
F. Semperlotti, Section 009, MWF 2:30PM-3:20PM
A. Arrietta, Section 010, MWF 3:30PM-4:20PM
M. Murphy, Section 007, TR 9:00AM-10:15AM
J. Jones, Section Y01, 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.

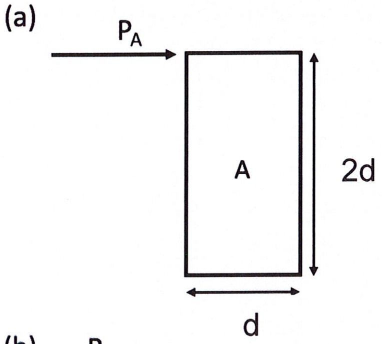
If the solution does not follow a logical thought process, it will be assumed in error.

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.

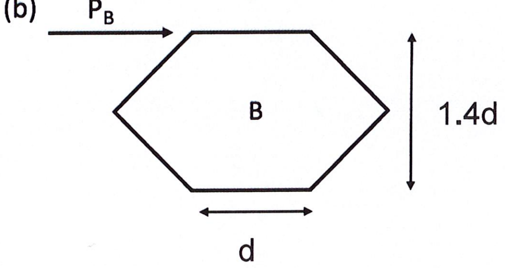
PROBLEM 1 (20 points)

1A. Block A with a uniformly distributed weight W and the dimensions shown in figure (a) is to be moved by force P_A. Draw the free body diagram for the case of tipping and determine the force P_A needed to tip block A in terms of W. A second block B with the dimensions shown in figure (b) has the same uniformly distributed weight W as block A. Draw a free body diagram for the case of tipping. Find the force P_B required to tip block B in terms of W. Which block would tip first? **(5 pts)**

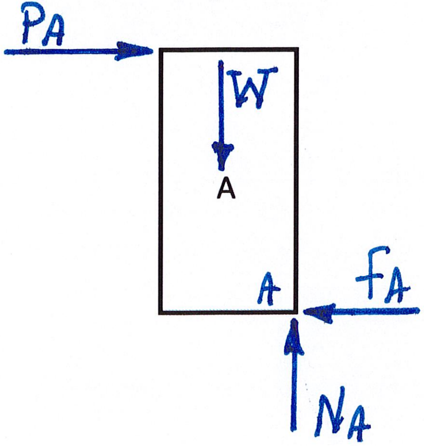
(a)

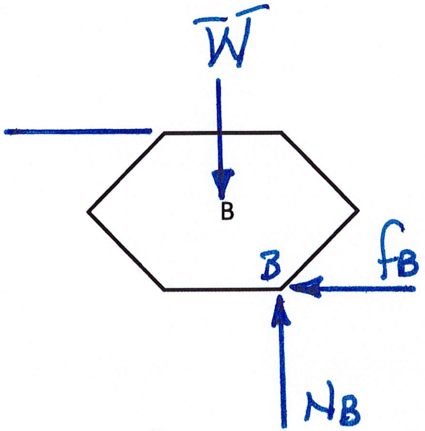


(b)



FBDs: (1 pt each)





$\underline{\Sigma M_A = 0} = -P_A(2d) + W(\frac{d}{2})$

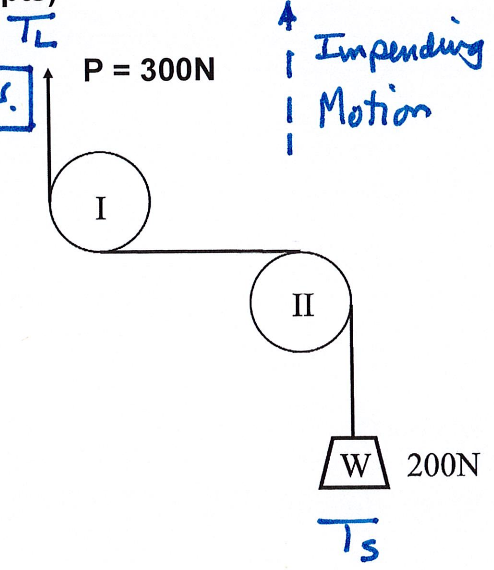
$\therefore P_A = W/4 = 0.25W$

$\underline{\Sigma M_B = 0} = -P_B(1.4d) + W(d/2)$

$\therefore P_B = W/2.8 = 0.357W$

P_A in terms of W =	W/4 or 0.25W	**(1 pt)**
P_B in terms of W =	W/2.8 or 0.357W	**(1 pt)**
Which Block would Tip First?	[✓ **Block A**] **Block B** **Both A and B** **(Circle One)**	**(1 pt)**

1B. A block with a weight of W=200N is suspended from a belt that passes over two fixed drums as shown. Determine the total angle of wrap in radians for both drums combined. Consider the case of **impending motion of the block upward**. Determine the coefficient of friction required to hold the block in static equilibrium with a force P=300N. Assume the coefficient of friction (μ) is the same for both drums (I and II). If the coefficient of friction increases, will the minimum force required to cause impending motion upward be larger, smaller or equal to 300N. **(5 pts)**



$$\beta_{TOT} = \beta_I + \beta_{II} = \frac{\pi}{2} + \frac{\pi}{2} = \boxed{\pi \text{ radians.}}$$

$$\frac{T_L}{T_s} = e^{\mu_s \beta_{TOT}}$$

$$\frac{300\ N}{200\ N} = e^{\mu_s(\pi)}$$

$$\ln(1.5) = \mu_s(\pi)$$

$$\frac{0.405465}{\pi} = \mu_s$$

$$\boxed{\therefore (\mu_s)_{min} = 0.129}$$

$$\boxed{\text{When } \mu_s \text{ increases} \Rightarrow P \text{ increases.}}$$

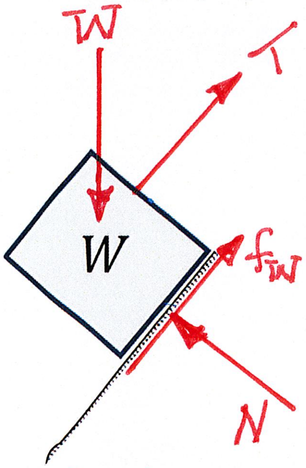
β = π or 3.14 rad **(1 pt)**

μ = 0.129 **(3 pt)**

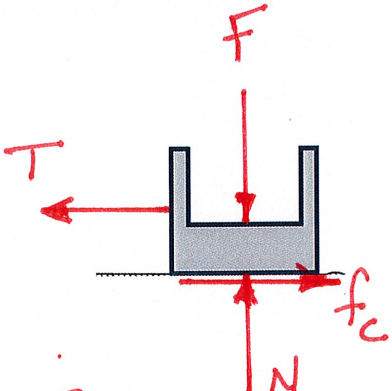
P = [✓ **Larger**] **Smaller** **Remain the Same** **(Circle One)** **(1 pt)**

1C. A crate is connected via a taut cable and an ideal pulley to a counterweight, $W = 100$ N. The incline and the ground above the pulley both have a rough surface with coefficient of static friction $\mu_s = 0.3$. The incline angle is $\theta = 45°$. Determine the magnitude of the **minimum** force (F) for the system to remain in static equilibrium. Include FBDs for both the counterweight and the crate. **(5 pts)**

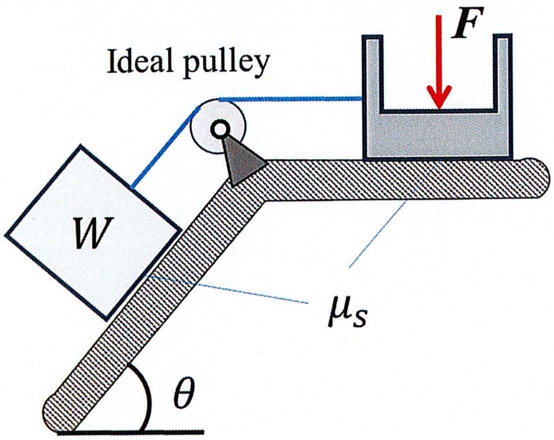
FBDs (2 pts)



FBD 1



FBD2



FBD 1

$$\sum F_x = 0 = T + f_w - W\sin\theta$$
$$\sum F_y = 0 = N - W\cos\theta$$
$$f_w = \mu_s N$$

$$\rightarrow T = -\mu_s W\cos\theta + W\sin\theta$$

FBD 2

$$\sum F_x = 0 = -T + f_c$$
$$\sum F_y = 0 = N - F$$
$$f_c = \mu_s N$$

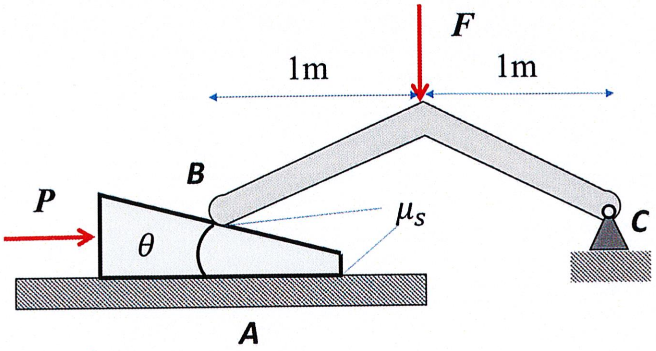
$$\rightarrow T = \mu_s F$$

Yielding:

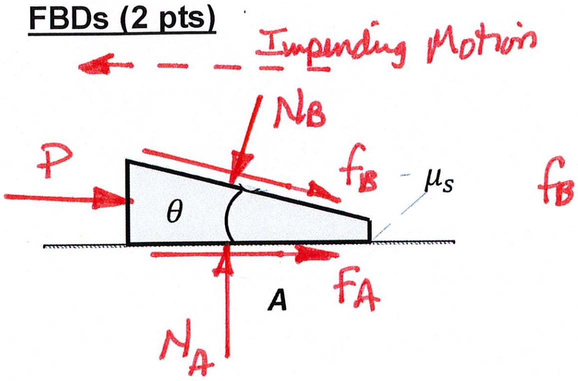
$$-\mu_s W\cos\theta + W\sin\theta = \mu_s F$$
$$\therefore F = W\left(\frac{-\mu_s\cos\theta + \sin\theta}{\mu_s}\right) = 100\,(1.65) = 165N$$

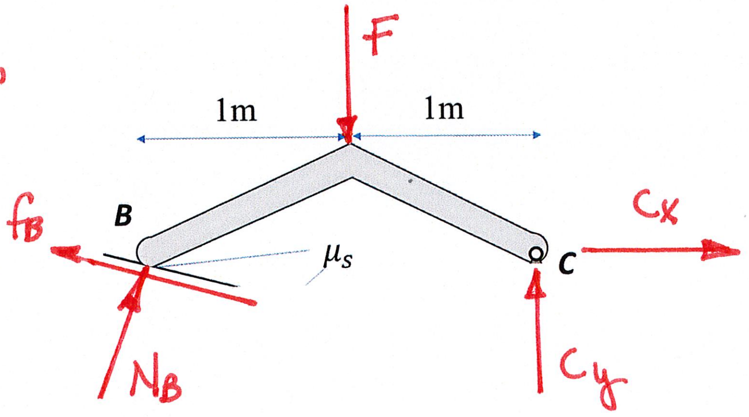
F = 165 N **(3 pts)**

1D. Force $F = 100$ N acts on an angled bar that rests on a wedge. The coefficient of static friction on both sides of the wedge is $\mu = 0.2$. The mass of the bar and wedge are negligible. The wedge's angle is $\theta = 18°$. On the artwork provided, complete the FBDs of the Wedge and Bar BC assuming the wedge is **impending motion to the left**. If the resultant value of P < 0, would the wedge be self-locking, not self-locking or cannot be determined? **(5 pts)**



FBDs (2 pts)





Circle the correct equilibrium equation below for the wedge shown below. **(2 pts)**

[✓ a) $\sum F_x = 0 = P + F_A + F_B\cos\theta - N_B\sin\theta$]

b) $\sum F_x = 0 = P + F_A - F_B\sin\theta - N_B\cos\theta$

c) $\sum F_x = 0 = P + F_A + F_B\cos\theta + N_B\sin\theta$

d) $\sum F_x = 0 = P + F_A + F_B\sin\theta - N_B\cos\theta$

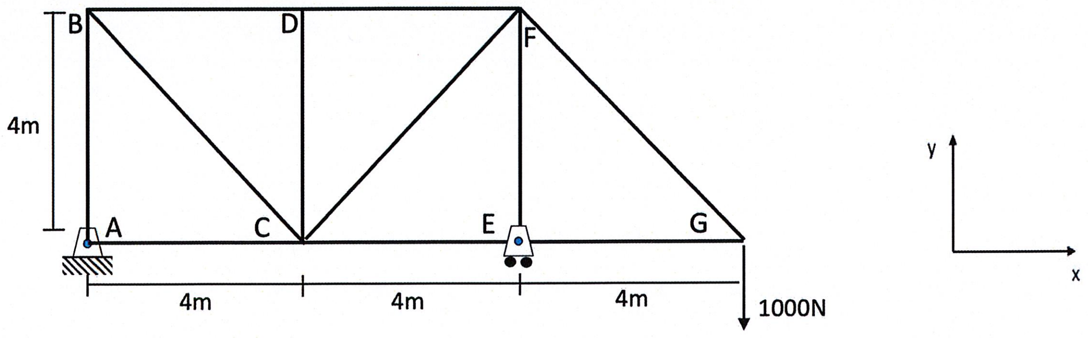
e) None of the above

<u>Is the wedge?</u>: [✓ Self-Locking] Not Self-Locking Cannot be Determined (Circle One) **(1 pt)**

PROBLEM 2. (20 points)

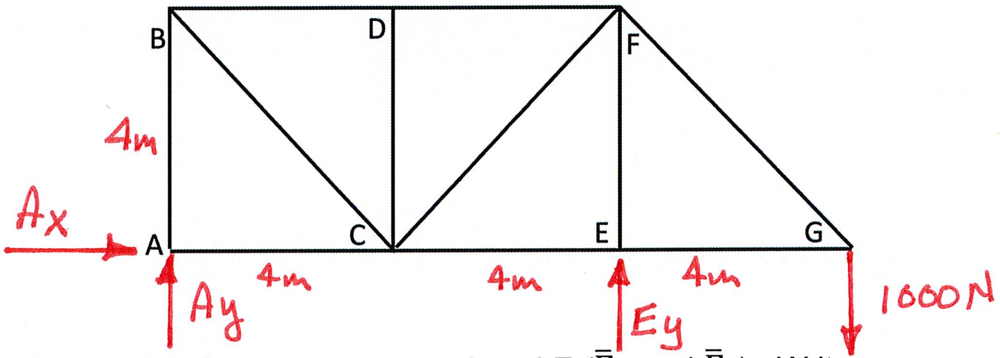
Problem 2 (20 points)

Given: A truss has the dimensions shown in the figure. It has a pin-joint support at A, a roller support at E, and a load of 1000 N applied at G as shown. The truss is in static equilibrium.



Find:

a) Complete the free body diagram of the truss on the artwork provided below. **(2 points)**



b) Calculate the reaction forces at supports A and E ($\bar{F}_A$ and $\bar{F}_E$). Write your answers in vector form. **(6 points)**

$$\Sigma M_A = 0 = E_y(8) - 1000(12) \Rightarrow E_y = 1500N$$

$$\Sigma F_x = 0 = A_x \Rightarrow A_x = 0N$$

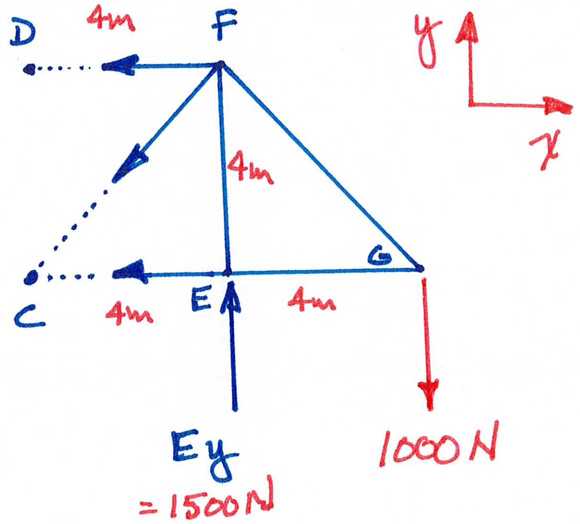
$$\Sigma F_y = 0 = A_y + \overset{1500N}{E_y} - 1000 \Rightarrow A_y = -500N$$

$\bar{F}_A$ = 0 $\hat{\imath}$ + -500 $\hat{\jmath}$ N (3 pts) $\bar{F}_E$ = +1500 $\hat{\jmath}$ N (3 pts)

c) Identify all zero-force members in the truss. No work needs to be shown. **No partial credit**. **(2 points)**

Zero-Force Members = AC CD (2 pts)

d) Use the **method of sections** to determine the magnitude of the load in the member DF. Indicate whether the load is in tension, zero or compression. Include a free-body diagram and specify the units. No credit will be awarded if the requested methodology is not used. **(4 points)**



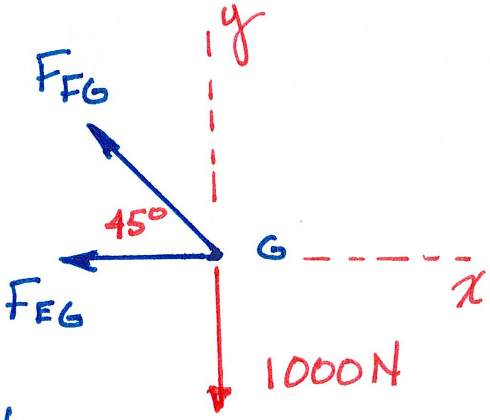
$$\underline{\Sigma M_c = 0} = \overset{1500N}{E_y}(4) - 1000(8) + F_{DF}(4)$$

$$\therefore \quad F_{DF} = +\frac{2000}{4} = +500\,N$$

$$\boxed{F_{DF} = 500\,N \quad \textcircled{T}}$$

F_{DF}= 500 N [✓ Tension] Zero Compression (circle one) (4 pts)

e) Use the **method of joints** to determine the magnitude of the loads in the members FG and EG. Indicate whether the load is in tension, zero or compression. Include a free-body diagram and specify the units. No credit will be awarded if the requested methodology is not used. **(6 points)**



$$\underline{\Sigma F_y = 0} = F_{FG} \sin 45^\circ - 1000\,N$$

$$\therefore F_{FG} = +1414N$$

$$= 1414N \text{ Ⓣ}$$

$$\underline{\Sigma F_x = 0} = -F_{EG} - F_{FG} \cos 45^\circ$$

$$\therefore F_{EG} = -F_{FG} \cos 45^\circ$$

$$F_{EG} = -1000N$$

$$F_{EG} = 1000N \text{ Ⓒ}$$

F_{EG} = 1000 N Tension Zero [✓ Compression] (circle one) (3 pts)

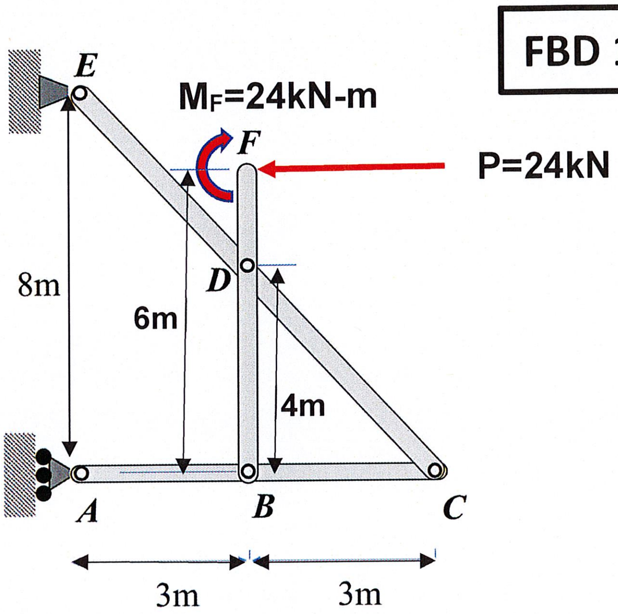
F_{FG} = 1414 N [✓ Tension] Zero Compression (circle one) (3 pts)

PROBLEM 3. (20 points)

GIVEN:

Frame A-F is loaded with an applied force (P = 24kN) and a moment (M_F = 24kN-m) at F as shown below. The frame is held in static equilibrium by a roller support at A and a pin support at E. Neglect the weight of the frame members.

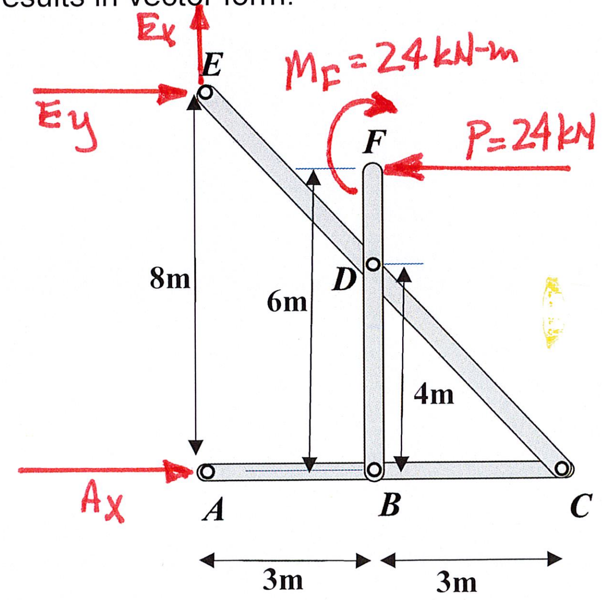
FBD 1



Find:

a) On the artwork shown below, complete the overall free body diagram. (3 pts)

b) Solve for the reactions at A and E and express the results in vector form.



$$\underline{\Sigma M_E = 0} = A_x(8) - 24(2) - 24$$

$$\boxed{\therefore A_x = 9 \text{ kN}}$$

$$\underline{\Sigma F_x = 0} = \overset{9kN}{A_x} + E_x - 24$$

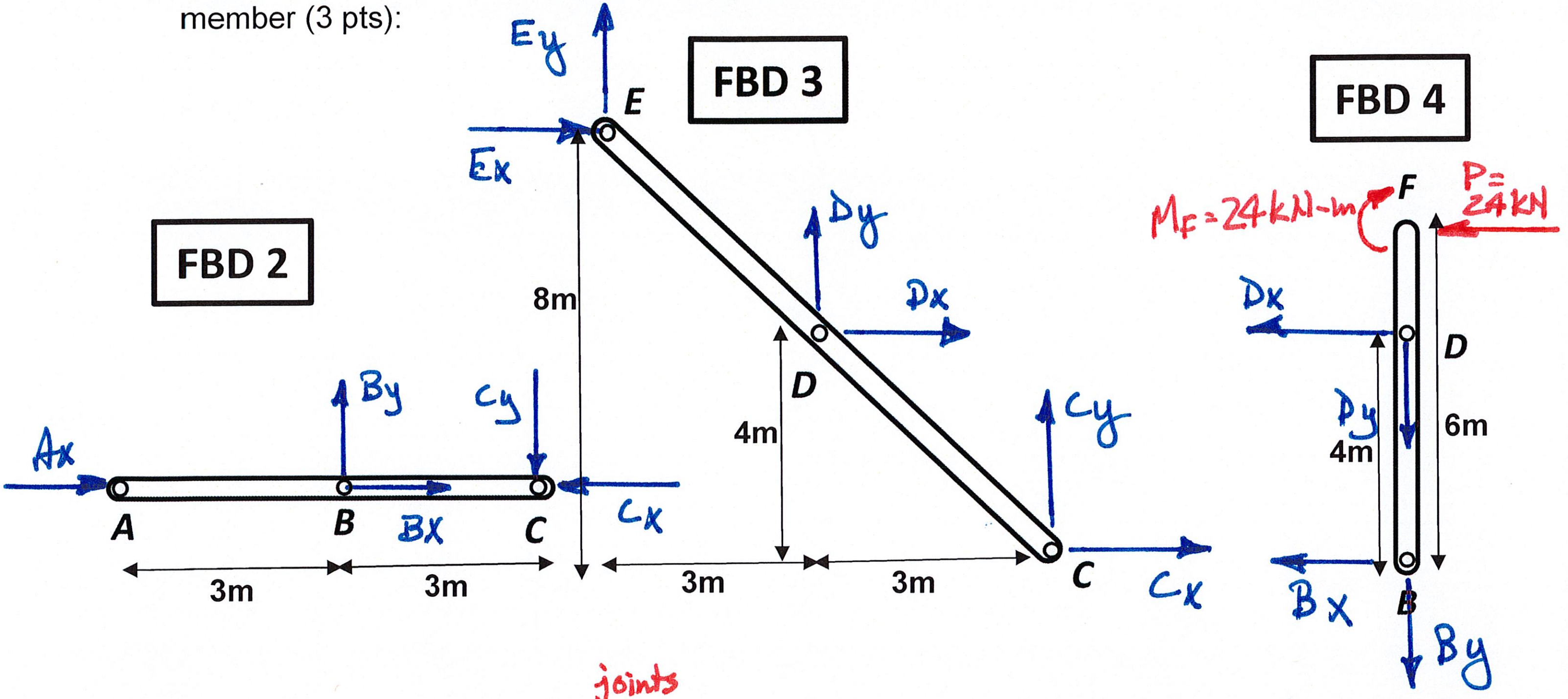
$$\boxed{\therefore E_x = 15 \text{kN}}$$

$$\underline{\Sigma F_y = 0} = E_y$$

$$\boxed{\therefore E_y = 0 \text{ kN}}$$

$\vec{A}$ = 9 $\hat{\imath}$ kN	(3 pts)
$\vec{E}$ = 15 $\hat{\imath}$ + 0 $\hat{\jmath}$ kN	(3 pts)

c) On the artwork provided below, complete the individual free body diagrams for each individual member (3 pts):



d) Solve for the internal forces at ~~pins~~ joints C and D on member EDC. Express the resultant forces in vector form.

FBD 4

$$\Sigma M_B = 0 = D_x(4) + \overset{24kN}{P}(6) - 24 \Rightarrow \boxed{D_x = \frac{-124}{4} = -30\,kN}$$

FBD 3

$$\Sigma M_C = 0 = -\overset{-30kN}{D_x}(4) - D_y(3) - \overset{15kN}{E_x}(8) - \overset{0}{\cancel{E}_y}(6) \qquad \therefore D_y = 0\,kN$$

$$\Sigma F_x = 0 = \overset{15kN}{E_x} + \overset{-30kN}{D_x} + C_x \Rightarrow \boxed{C_x = +15\,kN}$$

$$\Sigma F_y = 0 = \overset{0}{\cancel{E_y}} + \overset{0}{\cancel{D_y}} + C_y \Rightarrow \boxed{C_y = 0\,kN}$$

$(\overrightarrow{C})_{\text{on EDC}}$	= +15 $\hat{\imath}$ + 0 $\hat{\jmath}$ kN	(4 pts)
$(\overrightarrow{D})_{\text{on EDC}}$	= - 30 $\hat{\imath}$ + 0 $\hat{\jmath}$ kN	(4 pts)