PHYS 170 Section 101
Lecture 16
October 15, 2018

Oct 15—Announcements

- Will hand midterms back at end of class (average was 24.5/30 or 82%)
  - Check papers for tallying errors (grading was done subtractively), other issues
  - Direct questions/concerns to Matt
  - Exam/key available on Canvas in "Exams -> Previous exams" section

- Last week's homework (# 5) due today at 11:59 PM

- This week's homework (#6) due a week from today at 11:59 PM

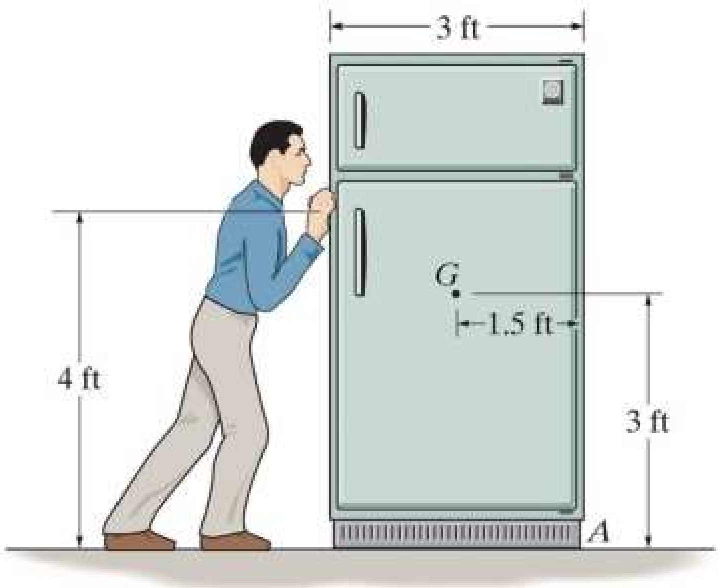
Lecture Outline/Learning Goals

- Finish first friction problem
- Second worked friction problem
- Wedges
- Worked wedge problem

Problem 8-27 (page 405, 12th edition)

The refrigerator weighs 180 lb and rests on a tile floor. The coefficient of static friction μ_R between the refrigerator and the floor is 0.25.
The man weighs 150 lb. The coefficient of static friction μ_M between his shoes and the floor is 0.6. The man pushes horizontally on the refrigerator.

(1) Determine whether the man can move the refrigerator. If so, does the refrigerator slip or tip?



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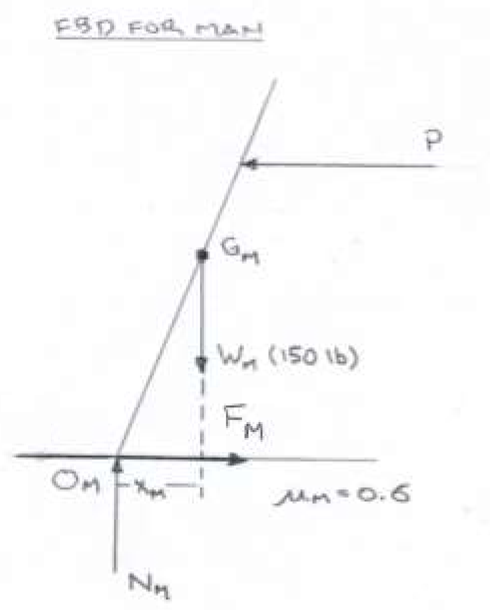
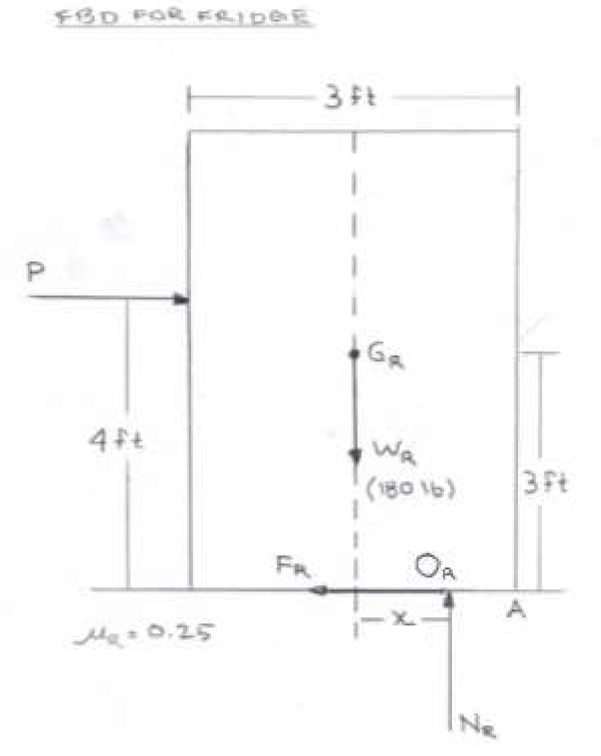




Data

$W_R = 180 \text{ lb} \qquad \mu_R = 0.25 \qquad W_M = 150 \text{ lb} \qquad \mu_M = 0.6$

Cartesian component equations of equilibrium

Refrigerator (take moments about O_R):

$$\sum F_x = 0: \qquad F_R = P \qquad (1)$$

$$\sum F_y = 0: \qquad N_R = 180$$

$$\sum (M_z)_R = 0: \qquad 180 x_R = 4P \qquad (2)$$

Man (take moments about O_M):

$$\sum F_x = 0: \qquad F_M = P \qquad (3)$$

$$\sum F_y = 0: \qquad N_M = 150$$

$$\sum (M_z)_M = 0: \qquad 150 x_M = 4P \qquad (4)$$

Eqns. (1) to (4) contain 5 unknowns:

$F_R, \; P, \; F_M, \; x_R, \; x_M$

Need another equation to solve the problem.

ASSUME impending sliding for the refrigerator

$$F_R = \mu_R N_R = 45 \text{ lb} \qquad (5)$$

Solution to eqns. (1) to (5)

$P = F_R = F_M = 45 \text{ lb} \qquad x_R = 1.00 \text{ ft} \qquad x_M = 1.20 \text{ ft}$

Check restrictions:

$F_M < \mu_M N_M = (0.6)(150)\,\text{lb} = 90\ \text{lb} \quad \Rightarrow$ the man does not slide

$x_R < 1.50\ \text{ft} \quad \Rightarrow$ the refrigerator does not tip

The man can move the refrigerator. The refrigerator slides.

For completeness, check assumptions for other scenarios

(A) Assume impending tipping: $x_R = 1.50\ \text{ft}$ (5)

$F_R = 67.5\ \text{lb} > \mu_R N_R = 45\,\text{lb} \quad \Rightarrow$ assumption incorrect

(B) Assume impending sliding for the man

$$F_M = \mu_M N_M = 90 \text{ lb} \qquad (5)$$

$F_R = 90 \text{ lb} > \mu_R N_R = 45 \text{ lb} \quad \Rightarrow$ assumption incorrect

$x_R = 2.00 \text{ ft} > 1.50 \text{ ft} \quad \Rightarrow$ assumption incorrect

Problem 8-56 (page 414, 13th edition)

The uniform 6 kg slender rod rests on the top center of the 3 kg block. The coefficients of static friction at *A*, *B* and *C* are $\mu_A = 0.4$, $\mu_B = 0.6$, $\mu_C = 0.3$.

(1) Determine the largest couple moment M which can be applied to the rod without causing motion of the rod.

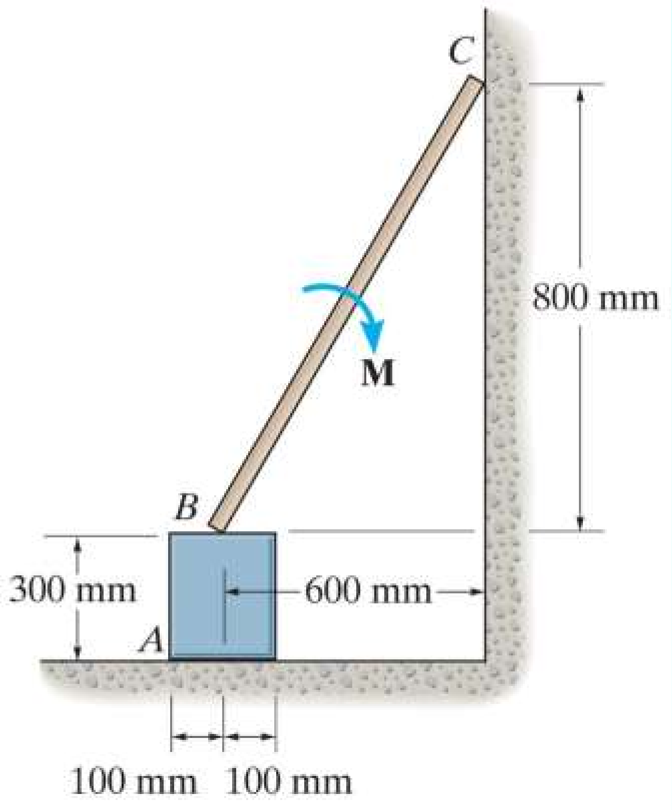


Figure: 08_P056

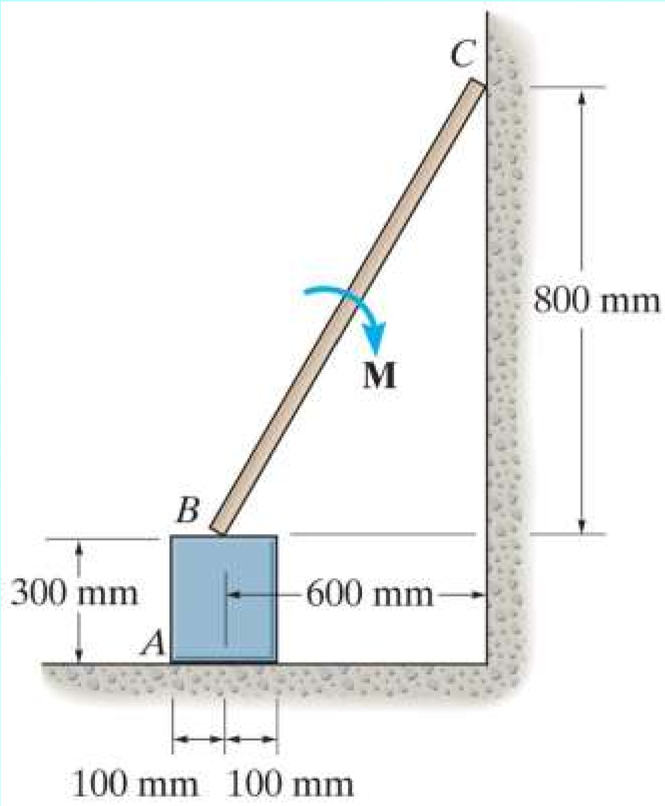
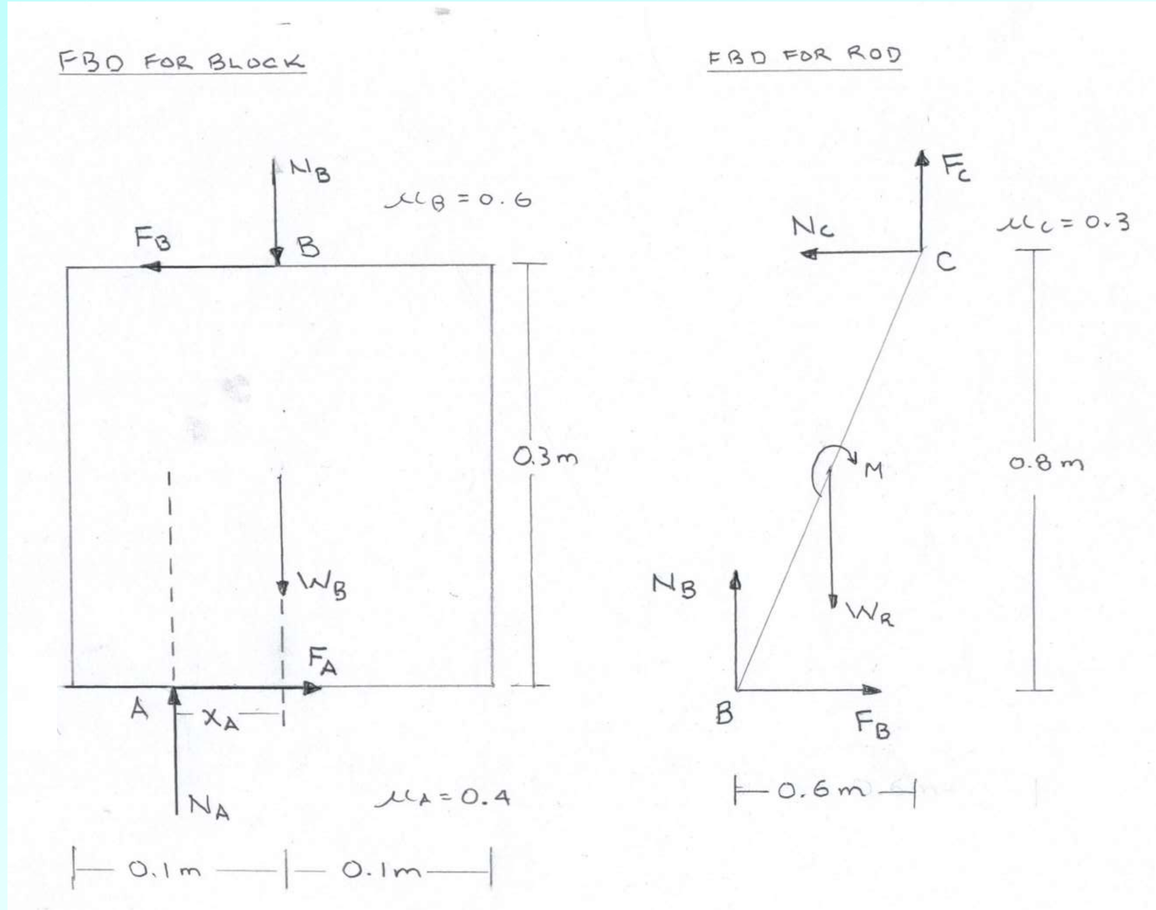
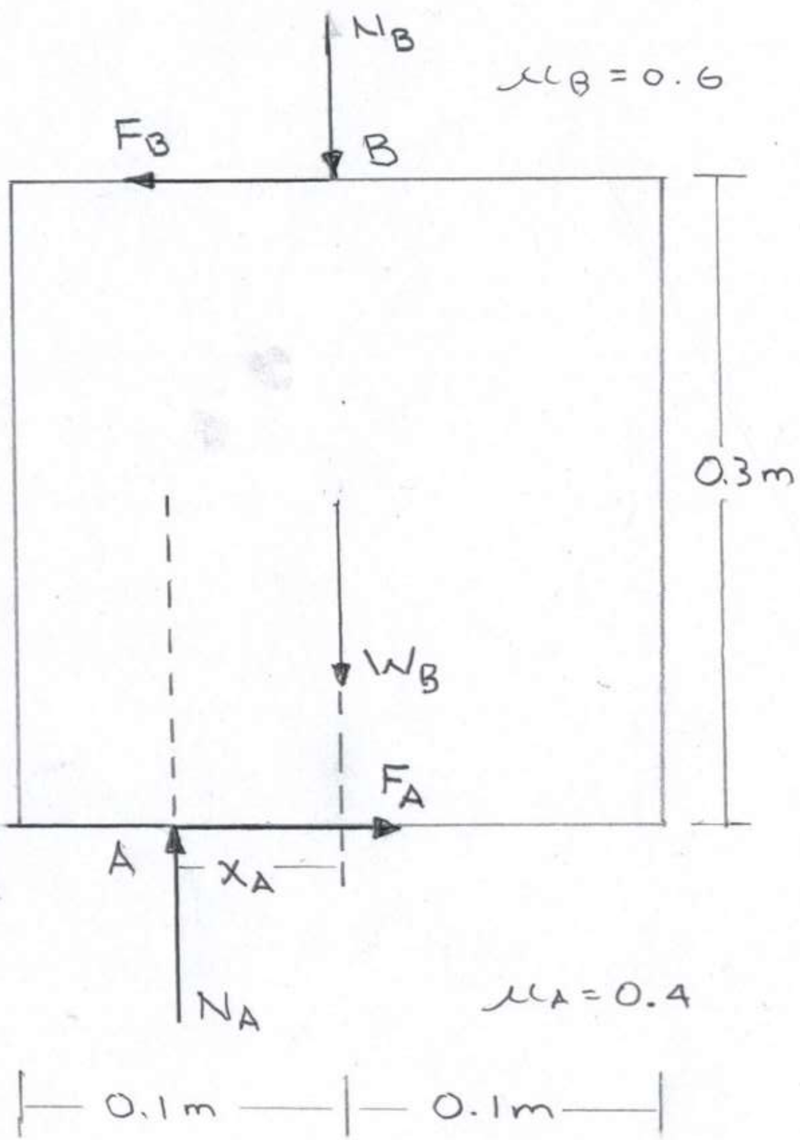


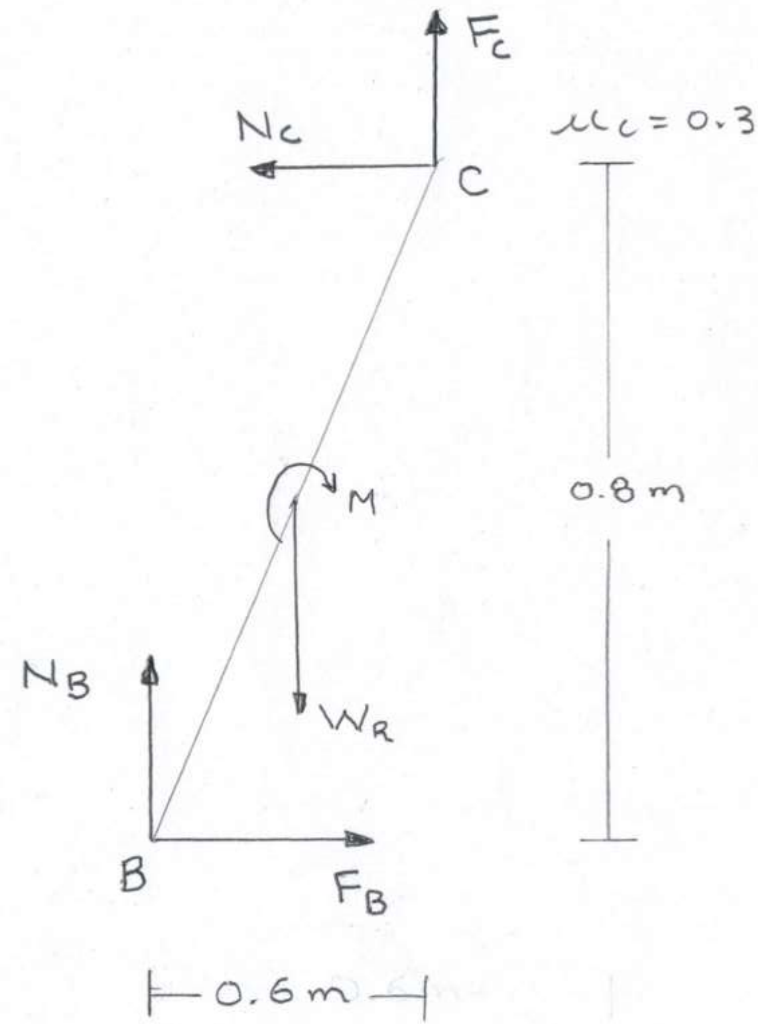
Figure: 08_P056



FBD FOR BLOCK



FBD FOR ROD



Data

$m_R = 6\ \text{kg}$ $\quad g = 9.81\ \text{m/s}^2$ $\quad W_R = m_R g$

$m_B = 3\,\text{kg}$ $\quad W_B = m_B g$ $\quad h_B = 0.3\,\text{m}$ $\quad w_B = 0.2\ \text{m}$

$\mu_A = 0.4$ $\quad \mu_B = 0.6$ $\quad \mu_C = 0.3$

Cartesian component equations of equilibrium

Rod: (take moments about *B*)

$$\sum F_x = 0: \qquad F_B - N_C = 0 \qquad (1)$$

$$\sum F_y = 0: \qquad N_B + F_C - W_R = 0 \qquad (2)$$

$$\sum (M_Z)_B = 0: \qquad -M + 0.6F_C + 0.8N_C - 0.3W_R = 0 \qquad (3)$$

Block (take moments about A)

$$\sum F_x = 0: \qquad F_A - F_B = 0 \qquad (4)$$
$$\sum F_y = 0: \qquad N_A - N_B - W_B = 0 \qquad (5)$$
$$\sum (M_z)_A = 0: \qquad 0.3F_B - x_A(N_B + W_B) = 0 \qquad (6)$$

Restrictions:

$F_A \le \mu_A N_A \qquad F_B \le \mu_B N_B \qquad F_C \le \mu_C N_C \qquad x_A \le 0.100$ m

Eqns. (1) to (6) contain 8 unknowns:

$M,\ x_A,\ F_A,\ N_A,\ F_B,\ N_B,\ F_C,\ N_C$

Need two more equations to solve problem

ASSUME impending sliding at C and impending tipping of block

$$F_C = \mu_C N_C \qquad (7)$$

$$x_A = 0.100 \text{ m} \qquad (8)$$

Solution to eqns. (1) to (8) (EXERCISE! But note that by substituting (7) and (8) into (1)-(6) we get 6 equations in 6 unknowns.)

$M = 8.56$ Nm $x_A = 0.100$ m

$F_A = F_B = 26.8$ N $F_C = 8.03$ N

$N_A = 80.3$ N $N_B = 50.8$ N $N_C = 26.8$ N

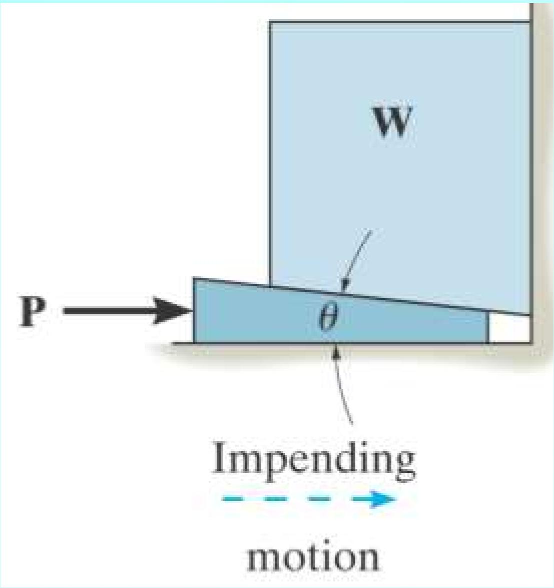
Check restrictions (no sliding at A or B)

$F_A < \mu_A N_A = 0.4(80.26) \text{ N} = 31.1 \text{ N} \Rightarrow$ assumption correct

$F_B < \mu_B N_B = 0.6(50.83) \text{ N} = 30.5 \text{ N} \Rightarrow$ assumption correct


Two kittens are on a roof. Which one falls off first?
The one with the lowest mew.

8.3 Wedges

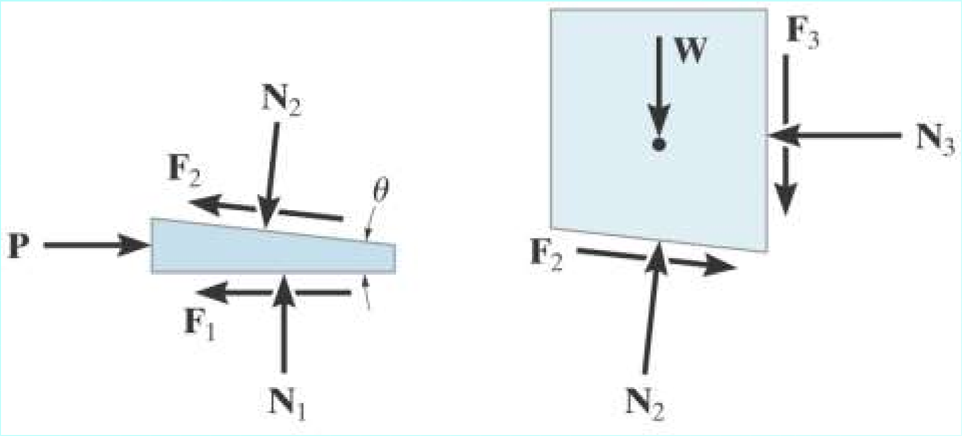


- **WEDGE:** Simple machine (inclined plane) that can convert applied force, *P*, to larger forces acting at approximately right angles to *P*

- Note that wedge is characterized by a **wedge angle**, θ

- Consider example as shown here, want to determine magnitude, *P*, of applied force necessary to lift block (assume weight *W* of block is given)

- Thus have impending motion at all three contact surfaces (block-wall, block-wedge, wedge-floor), so have 3 frictional equations



- From FBDs, have 7 unknowns (here we ignore the weight of the wedge, not always the case)

- There is no tendency for block or wedge to rotate so we do not consider moment equilibrium eqns

- Force equilibrium for each FB yields 4 equations, so with 3 frictional equations

  $F_1 = \mu_1 N_1 \qquad F_2 = \mu_2 N_2 \qquad F_3 = \mu_3 N_3$

  we have a total of 7 equations in 7 unknowns, which should yield a solution

- If block is to be lowered, frictional forces will act in opposite sense to what is shown in FBDs above

- If **P = 0** and block/wedge system is in equilibrium, then wedge is called **self-locking**