

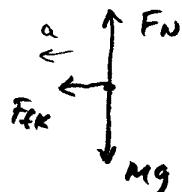
$$\Sigma F = ma \quad F_N = mg \cos \theta$$

$$F_g = mg \quad F_p = mg \sin \theta$$

$$F_{fs} \leq \mu_s F_N \quad F_{fk} = \mu_k F_N$$

Problems - Follow the 13 commandments. Draw and label FBD where indicated.

1. A 1000 kg pickup truck slams on its brakes and skids to a stop. (a) Draw and label a good FBD. (b) If the acceleration is -3.78 m/s^2 , what is the coefficient of friction between the tires and the road? (c) Is it μ_s or μ_k ? A 20 kg box in the bed of the truck has a static coefficient of 0.38. (d) Will it slide in the truck? Calculate or tell why.



$$m = 1000 \text{ kg}$$

$$a = -3.78 \frac{\text{m}}{\text{s}^2}$$

$$\mu_k = \underline{\hspace{2cm}}$$

$$m_2 = 20 \text{ kg}$$

$$\mu_s = 0.38$$

$$\begin{aligned}\Sigma F_y &= \mu_s F_N, 0 & \Sigma F_x &= m a_x \\ F_N - mg &= 0 & F_{fk} &= m a_x \\ F_N &= mg & \mu_k F_N &= m a_x \\ \mu_k \times g &= m a & \mu_k \times g &= m a \\ \mu_k &= \frac{a}{g} & & \\ &= \frac{-3.78 \frac{\text{m}}{\text{s}^2}}{9.8 \frac{\text{m}}{\text{s}^2}}\end{aligned}$$

$$\begin{aligned}b) \quad &\boxed{\mu_k = 0.386} \\ c) \quad &\boxed{\mu_k \text{ since it is sliding}}\end{aligned}$$

For box

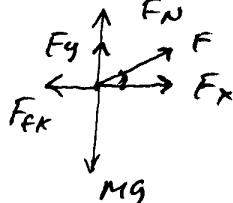
$$\begin{aligned}\alpha &= \mu_s g \\ &= 0.38(9.8 \frac{\text{m}}{\text{s}^2})\end{aligned}$$

$$\alpha = 3.72 \frac{\text{m}}{\text{s}^2}$$

Box will slide

Since F_{fs} can only prevent it from sliding if $a \leq 3.72 \frac{\text{m}}{\text{s}^2}$ but truck slows at $3.78 \frac{\text{m}}{\text{s}^2}$.

2. A guy drags a 15 kg box across a parking lot with a rope that makes a 32° angle with the horizontal. He exerts a force of 40 N on the rope. (a) Draw and label a good FBD. (b) If μ_k is 0.28, what is the acceleration of the box?



$$m = 15 \text{ kg}$$

$$\theta = 32^\circ$$

$$F = 40 \text{ N}$$

$$\alpha = \underline{\hspace{2cm}}$$

$$\begin{aligned}\Sigma F_y &= \mu_s F_N, 0 \\ F_N + F_y - mg &= 0 \\ F_N + F \sin \theta - mg &= 0 \\ F_N &= mg - F \sin \theta \\ &= 15 \text{ kg}(9.8 \frac{\text{m}}{\text{s}^2}) - 40 \text{ N}(\sin 32^\circ) \\ F_N &= 126 \text{ N}\end{aligned}$$

$$\begin{aligned}\Sigma F_x &= m a_x \\ F_x - F_{fk} &= m a_x \\ F \cos \theta - \mu_k F_N &= m a_x\end{aligned}$$

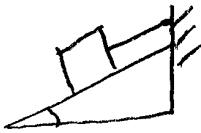
$$\begin{aligned}\alpha_x &= \frac{F \cos \theta - \mu_k F_N}{m} \\ &= \frac{40 \text{ N}(\cos 32^\circ) - 0.28(126 \text{ N})}{15 \text{ kg}}\end{aligned}$$

$$\alpha = -0.0905 \frac{\text{m}}{\text{s}^2}$$

This means box will either not start moving or will slow down.

or $\alpha = -0.0869 \frac{\text{m}}{\text{s}^2}$ if done in one step

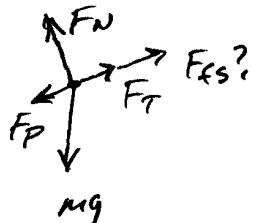
3. A 25 kg box is held on a 28° incline by a rope which runs parallel to the hill. The $\mu_s = 0.3$ and $\mu_k = 0.25$. (a) Draw and label a good FBD. (b) What is the tension in the rope? (It is not 115 N.)



will the box slide without the rope?
That is, which way does F_{fs} point?

First do it without the rope.

$$\begin{aligned} M &= 25 \text{ kg} \\ \theta &= 28^\circ \\ \mu_s &= 0.3 \\ \mu_k &= 0.25 \\ F_T &= \underline{\quad} \end{aligned}$$



$$\begin{aligned} \sum F &= 115 \text{ N} \\ F_p - F_{fs} &= 0 \\ mg \sin \theta - \mu_s mg \cos \theta &= 0 \end{aligned}$$

$$\mu_s = \frac{\tan \theta}{\cos \theta}$$

$$\mu_s = \tan \theta$$

$$\tan \theta = 0.3$$

$$\theta = 16.7^\circ$$

Box would slide without rope
since $\theta = 28^\circ$ which exceeds 16.7°
Therefore, F_{fs} points uphill.

$$\sum F = 115 \text{ N}$$

$$F_p - F_T - F_{fs} = 0$$

$$F_T = F_p - F_{fs}$$

$$\begin{aligned} &= mg \sin \theta - \mu_s mg \cos \theta \\ &= mg (\sin \theta - \mu_s \cos \theta) \end{aligned}$$

$$F_T = 25 \text{ kg} (9.8 \frac{\text{m}}{\text{s}^2}) (\sin 28^\circ - 0.3 \cos 28^\circ)$$

$$\boxed{F_T = 50.1 \text{ N}}$$

OR Find F_p and F_N and compare.

$$\begin{aligned} F_p &= mg \sin \theta \\ &= 25 \text{ kg} (9.8 \frac{\text{m}}{\text{s}^2}) \sin 28^\circ \end{aligned}$$

$$\boxed{F_p = 115 \text{ N}}$$

$$\begin{aligned} F_{fs} &= \mu_s mg \cos \theta \\ &= 0.3 (25 \text{ kg}) (9.8 \frac{\text{m}}{\text{s}^2}) \cos 28^\circ \end{aligned}$$

$$\boxed{F_{fs} = 64.9 \text{ N} \therefore F_T \text{ must be uphill.}}$$

Therefore, since

$$\sum F = 0$$

$$F_p - F_{fs} - F_T = 0$$

$$F_T = F_p - F_{fs}$$

$$= 115 \text{ N} - 64.9 \text{ N}$$

$$\boxed{F_T = 50.1 \text{ N}}$$

4. A 700 kg car is set down on a 20° hill which is covered with ice. The $\mu_k = 0.10$. (a) Draw and label a good FBD. (b) What will be the car's acceleration?

$$\theta = 20^\circ \quad m = 700\text{kg} \quad \mu_k = 0.1$$

$$\sum F = ma \quad F_p - F_{fK} = ma$$

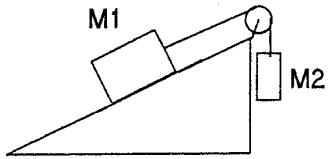
$$mg \sin \theta - \mu_k mg \cos \theta = ma$$

$$a = (g \sin \theta - \mu_k \cos \theta) g$$

$$= (9.8 \sin 20^\circ - 0.1 \cos 20^\circ) 9.8 \frac{\text{m}}{\text{s}^2}$$

b) $a = 2.43 \frac{\text{m}}{\text{s}^2}$

EC)



μ_k
Mass 1 is 25 kg and mass 2 is 20 kg. The μ_k between m_1 and the hill is 0.35. (a) Draw and label a good FBD. (b) What is the acceleration of the masses?

MUST first find if M_1 goes up or down hill!
Find answer without friction first,

$$\begin{array}{ll} \sum F_1 = M_1 a & \sum F_2 = M_2 a \\ -F_p + F_T = M_1 a & M_2 g - F_T = M_2 a \\ -M_1 g \sin \theta - F_T = M_1 a & \end{array}$$

ADD

$$(M_2 - M_1 \sin \theta) g = (M_1 + M_2) a$$

\uparrow If this is positive, it wants to go uphill

$$F = 20\text{kg} - 25\text{kg} \sin 25^\circ$$

$$F = 9.43\text{N} ; \text{ goes up hill. Now less } M \text{ friction}$$

$$\begin{array}{l} \sum F = M_1 a \\ -F_p - F_{fK} + F_T = M_1 a \\ -M_1 g \sin \theta - \mu_k M_1 g \cos \theta + F_T = M_1 a \\ M_2 g - F_T = M_2 a \end{array}$$

$$\begin{array}{l} a = \frac{(M_2 - M_1 (\sin \theta - \mu_k \cos \theta)) g}{M_1 + M_2} \\ = \frac{(20\text{kg} - 25\text{kg} (\sin 25^\circ - 0.35 \cos 25^\circ)) 9.8}{25\text{kg} + 20\text{kg}} \\ a = 3.78 \frac{\text{m}}{\text{s}^2} \end{array}$$