Chapter 4:Dynamics: Newton's Laws of Motion

Lecture 5

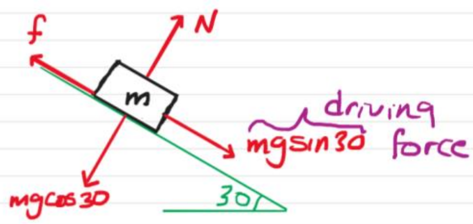
The University of Jordan/Physics Department

Prof. Mahmoud Jaghoub

أ.د. محمود الجاغوب

Example: In each of the following cases determine the type (kinetic or static) force of friction and its magnitude.

① $m = 4kg$, $\mu_s = 0.6$, $\mu_k = 0.2$



mgsin30 is the driving force (force that acts to move the object).

NOTE: $\nearrow^{+}$ $N - mg\cos 30 = 0$

$\therefore N = mg\cos 30$

$$mg\sin 30 = 4 \times 10 \times \frac{1}{2} = 20 \text{ Newtons.}$$

To determine if mass moves or not must find

$$f_{s,max} = \mu_s N = \mu_s \, mg\cos 30$$
$$= 0.6 \times 4 \times 10 \times \frac{\sqrt{3}}{2} \simeq 20.8 \text{ Newtons.}$$

$mg\sin 30 < f_{s,max} \Rightarrow$ mass m remains stationary.

$\therefore$ The acting friction is static friction f_s .

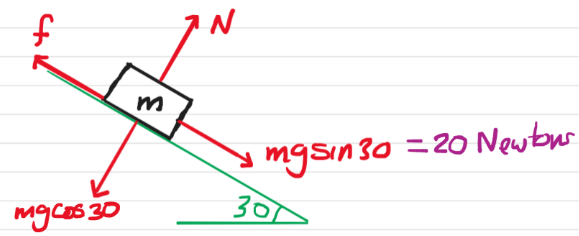
What is the value of f_s ?

$\searrow_+ \quad mg\sin 30° - f_s = 0$

$\therefore \; f_s = mg\sin 30° = 20$ Newtons.

↑ static friction.

(2) $m = 4kg$, $\mu_s = 0.4$, $\mu_k = 0.2$



$f_{s,max} = 0.4 \times 4 \times 10 \times \frac{\sqrt{3}}{2}$

$= 13.9$ Newtons.

$mg\sin 30 = 20 > f_{s,max}$

$\therefore$ mass moves down the inclined plane $\Rightarrow$
we have kinetic friction f_k .

$f_k = \mu_k N = 0.2\left(4 \times 10 \times \frac{\sqrt{3}}{2}\right) \simeq 6.9$ Newtons.

Find the acceleration of the mass.

$\searrow_+ \quad mg\sin 30 - f_k = ma$

$$a = \frac{mg\sin 30 - \mu_k mg\cos 30}{m} = (\sin 30 - \mu_k \cos 30)g$$

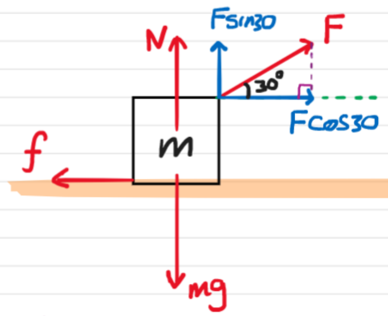
$\therefore \; a \simeq 3.3 \; m/s^2.$

Example

In the figure: $m = 10\,kg$, $\mu_s = 0.4$

$\mu_k = 0.3$, $F = 40$ Newtons

(i) is the object going to move ?



$f_{s,max} = \mu_s N$, Need to find N.

$\overset{+}{\uparrow}$ $N + F\sin30 - mg = 0$ (since $a_y = 0$)

$N = mg - F\sin30$

$N = 80$ Newtons.

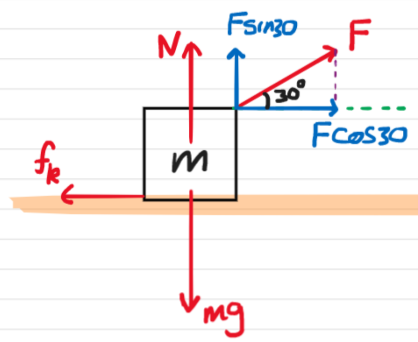
$\therefore$ $f_{s,max} = 0.4 \times 80 = \underline{32}$ Newtons.

The driving force is $F\cos30^\circ = 34.6$ N.

$\underbrace{F\cos30}_{\text{driving force}} > f_{s,max}$

$\Rightarrow$ object will move

and $f \equiv f_k$ i.e kinetic friction.



(ii) Find the acceleration of mass m (object).

$\Sigma F_x = m a_x$

$\xrightarrow{+}$ $F\cos30 - f_k = ma$

$F\cos30 - \mu_k N = ma$

$$F\cos30 - \mu_k(mg - F\sin30) = ma$$

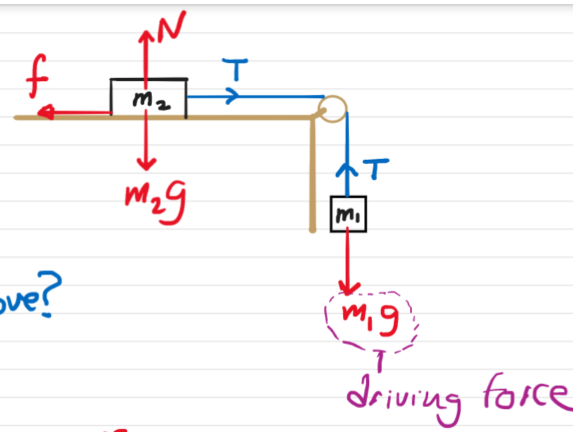
$$\therefore a = \frac{F(\cos30 + \mu_k \sin30) - \mu_k mg}{m}$$

$\therefore a \sim 1.1 \ m/s^2$. (along positive x-direction : a_x) .

Example :

$m_1 = 4kg$, $m_2 = 2kg$

$\mu_s = 0.3$, $\mu_k = 0.1$



Is this system going to move?

Driving force m_1g .

If $m_1g > f_{s,max}$ $\Rightarrow$ system moves.

$f_{s,max} = \mu_s N = \mu_s m_2 g = 0.3 \times 2 \times 10 = 6$ Newtons.

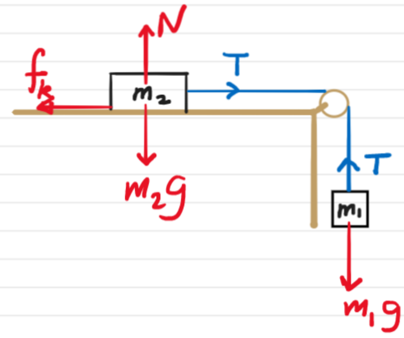
driving force

$m_1g = 40 > f_{s,max} \Rightarrow$

m_1 moves down

m_2 moves to the right and $f \equiv f_k$

(ii) Find a and T.



for m_1: $\downarrow +$

$$m_1 g - T = m_1 a \quad - (1)$$

for m_2: $\rightarrow +$

$$T - f_k = m_2 a \quad - (2)$$

$(1) + (2) \Rightarrow \quad m_1 g - f_k = (m_1 + m_2) a$

$$\therefore a = \frac{m_1 g - \mu_k m_2 g}{(m_1 + m_2)} = \left(\frac{m_1 - \mu_k m_2}{m_1 + m_2}\right) g$$

$\therefore a \simeq 0.63 \ m/s^2$.

form (1) $\quad T = m_1 (g - a) \simeq 37.5$ Newtons.

Example

33. (III) Three blocks on a frictionless horizontal surface are in contact with each other as shown in Fig. 4–54. A force $\vec{F}$ is applied to block A (mass m_A). (*a*) Draw a free-body diagram for each block. Determine (*b*) the acceleration of the system (in terms of m_A, m_B, and m_C), (*c*) the net force on each block, and (*d*) the force of contact that each block exerts on its neighbor. (*e*) If $m_A = m_B = m_C = 10.0$ kg and $F = 96.0$ N, give numerical answers to (*b*), (*c*), and (*d*). Explain how your answers make sense intuitively.

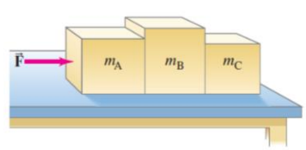
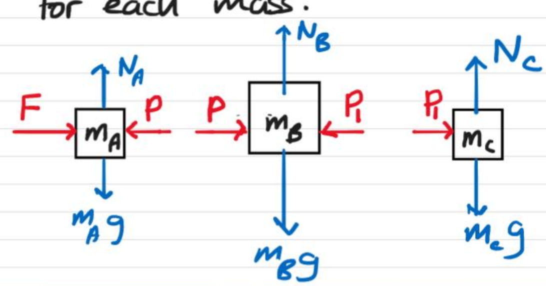


FIGURE 4–54
Problem 33.

(a) Draw a free-body diagram for each mass.



(b) for m_A : $\xrightarrow{+}$ $\overbrace{F - P}^{\text{net force on } m_A} = m_A a$ — ①

for m_B : $\xrightarrow{+}$ $\underbrace{P - P_1}_{\text{net force on } m_B} = m_B a$ — ②

for m_C : $\xrightarrow{+}$ $P_1 = m_C a$ — ③

net force on m_C

NOTE : P and P_1 are contact forces.

① + ② + ③ ⇒ $F = (m_A + m_B + m_C) a$

$$\therefore a = \frac{F}{m_A + m_B + m_C}$$

From ① $P = F - m_A a = F\left(1 - \frac{m_A}{m_A + m_B + m_C}\right)$

$$\therefore P = \left(\frac{m_B + m_C}{m_A + m_B + m_C}\right) F$$

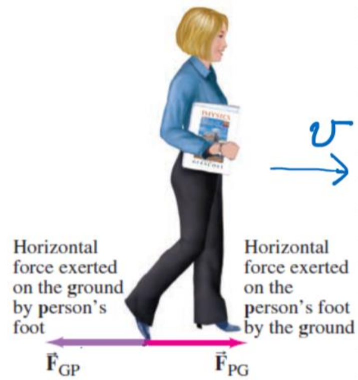
From ③ $P_1 = m_C a = \frac{m_C}{m_A + m_B + m_C} F$

Note $P > P_1$ as P moves m_B and m_C

But P_1 only moves m_C.

The lady in the figure walks forward to the right.

FIGURE 4–11 We can walk forward because, when one foot pushes backward against the ground, the ground pushes forward on that foot (Newton's third law). The two forces shown *act on different objects*.



NOTE:

i) While her foot is in contact with the ground it (her foot) is stationary with respect to the ground. This means it is static friction ($\vec{F}_{PG}$) that acts on her foot.

ii) The lady exerts a force $\vec{F}_{GP}$ to the left as shown. We may call this the action.

iii) The ground exerts a reaction force F_{PG} to the right on the lady $\Rightarrow$ $\vec{F}_{PG} = -\vec{F}_{GP}$ and they form a pair of action – reaction forces.

iv) So when we walk forward (as in the figure) without skidding the static force of friction acts in our direction of motion. Without friction it would not be possible for us to walk.

v) If there is NO friction (smooth surface) the foot of the lady would slide backwards. On a rough surface static friction stops the foot from sliding backwards (opposes the backward motion of the foot) and hence our bodies move forward.

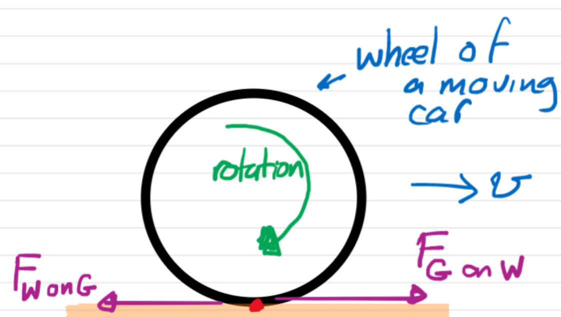
vi) When our foot slids (skids) forward it moves while it is in contact with the ground $\Rightarrow$ kinetic friction acts in opposite direction to th forward sliding foot $\Rightarrow$ f_k acts backwards.

vii) When a car moves forward without skiding static friction also acts forward.

When the wheels skid forward $\Rightarrow$ f_k acts backward

Wheel of a car moving to the right.

At the instant the red point of the wheel is in contact with the ground, this point is at rest (with respect to the ground) at that instant $\Rightarrow$ static friction acts forward.



F_{WonG} : force of wheel on ground (action)

$F_{G\,on\,W}$: force of ground on wheel (reaction), which is the static force of friction when the wheel does NOT skid on the ground.

How to determine the direction of the force of friction?

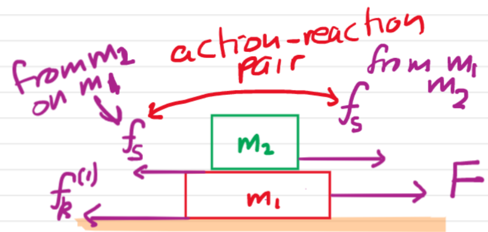
Look at the surface of contact. Determine the direction of motion of the surface and draw the friction in the opposite direction.

draw the friction in the opposite direction.

Example

All surfaces are rough.
Determine the direction of friction forces on m_1 and m_2.

Assume m_2 moves with m_1.



If no friction between m_1 and m_2 $\Rightarrow f_k = 0$ and m_2 remains stationary while m_1 moves to the right.