Phy 2A Extra Problems

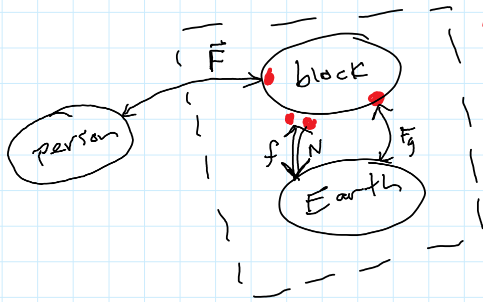
Wednesday, February 1, 2017 3:15 PM

Newton's Laws Problems:

1) This is from OpenStax: Ch 5-18

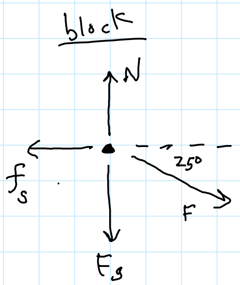
A contestant in a winter sporting event pushes a 45 kg block of ice across a frozen lake, as shown.
(For ice on ice $\mu_k = 0.03$ and $\mu_s = 0.1$)
(a) Calculate the minimum force, F, that must be exerted to get the block moving.
(b) What is the magnitude of the acceleration once it starts to move, if F remains constant?

1) Let's start with a system schema

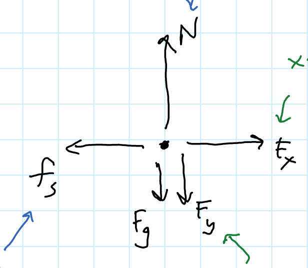


4 forces act on block

2) Now, a free body diagram for the block:



break up F into F_x and F_y components



Normal force

x-component of pushing force, F

friction starts out as static friction

Force of gravity ($F_g = mg$)

y-component of pushing force, F

3) Use $\Sigma \vec{F} = m\vec{a}$

vector equation → so, split into components

$\Sigma F_x = ma_x$ $\underbrace{\longrightarrow +}_{\text{define + direction}}$

$\Sigma F_y = ma_y$ $\underbrace{\uparrow +}_{\text{define + direction}}$

There are only 2 forces in the x-direction: F_x and f_s

There are 3 forces in the y-direction: N, F_g, F_y

$F_x - f_s = ma_x$

points in the negative direction

$N - F_g - F_y = ma_y$

Both point in the negative direction

Anytime you have friction in your system you will Need to find the normal force, N. Use y-direction to get N.

using y equation

$$N - F_g - F_y = m \cancel{a_y}^{\,0}$$

The block Never moves in the y direction, so $a_y = 0$

$$N - F_g - F_y = 0$$

$$N = F_g + F_y$$

because the person is pushing down on the block, the normal force increases

$F_g = mg$

$F_y = F \sin\theta$

$$N = mg + F \sin\theta$$

using x equation

$$F_x - f_s = ma_x$$

If we keep increasing F_x, f_s will keep increasing (up to some maximum value) and the block will Not move. Let's find the max F_x such that the block does Not move:

$$F_x - (f_s)_{max} = 0$$

block is Not moving, so $a_x = 0$

$$F_x = (f_s)_{max}$$

$$= \mu_s N$$

$$F_x = \mu_s \underbrace{(mg + F \sin\theta)}_{\text{from above}}$$

$F_x = F\cos\theta$

$$F \cos\theta = \mu_s (mg + F \sin\theta)$$

the only unknown is F

$$F \cos 25^\circ = (0.1)\left[(45)(9.8) + F \sin 25^\circ\right]$$

$$(0.906)F = 44.1 + (0.0423)F$$

$$(0.864)F = 44.1$$

$$F = 51.1\ N$$

← This is the maximum Force before the block starts sliding, so it is also the minimum force to get it sliding (any force larger than this will make the block slide)

b) Now the block is sliding. The f_s can be changed to f_k (kinetic friction), but everything else is the same:

x equation

$$F_x - f_k = m a_x$$

$$F\cos\theta - \mu_k N = m a_x$$

y equation

$$N - F_g - F_y = 0$$

$$N - mg - F\sin\theta = 0$$

$$N = mg + F\sin\theta$$

$$F\cos\theta - \mu_k \overbrace{(mg + F\sin\theta)}^{N} = m a_x$$

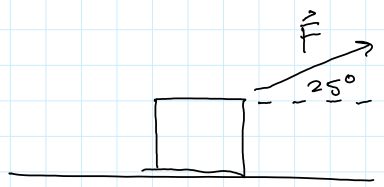
$$(51.1)\cos 25^\circ - (0.03)\left[(45)(9.8) + (51.1)\sin 25^\circ\right] = (45)\, a_x$$

$$46.3 - 13.9 = 45\, a_x$$

$$a_x = 0.721\ \frac{m}{s^2}$$

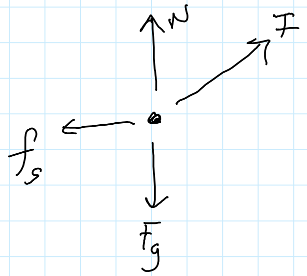
Newton's Laws Problems:

1. This is from OpenStax: Ch 5-19
   Repeat the previous question with the contestant pulling the block of ice with a rope over his shoulder at the same angle above the horizontal, as shown. (see above for friction coefficients)
   (a) Calculate the minimum force, F, that must be exerted to get the block moving.
   (b) What is the magnitude of the acceleration once it starts to move, if F remains constant?

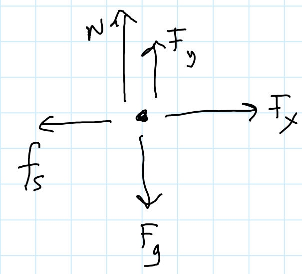


FBD for block

FBD for block



$\Rightarrow$



$$\sum \vec{F} = m\vec{a}$$

$$\sum F_x = m a_x \quad \rightarrow +$$

$$F_x - f_s = m a_x$$

$$F_x - (f_s)_{max} = 0$$

$$F_x = (f_s)_{max}$$

$$F_x = \mu_s N$$

$$F\cos\theta = \mu_s N$$

$$\sum F_y = m a_y \quad \uparrow +$$

$$N + F_y - F_g = m a_y$$

$$N + F_y - F_g = 0$$

$$N = F_g - F_y$$

Normal Force is less than F_g now

$$= mg - F\sin\theta$$

$$F\cos\theta = \mu_s\left[mg - F\sin\theta\right]$$

$$(0.906)\,F = (0.1)\left[(45)(9.8) - F\,(0.423)\right]$$

$$(0.949)\,F = 44.1$$

$$F = 46.5 \text{ N}$$

Less force because there is less friction

b) Change f_s to f_k

$$F_x - f_k = m a_x \qquad\qquad N + F_y - F_g = 0$$

$F_x - f_k = m a_x$ $\qquad\qquad$ $N + F_y - F_g = 0$

$F\cos\theta - \mu_k N = m a_x$ $\qquad\qquad$ $N = F_g - F_y$

$\qquad\qquad\qquad\qquad\qquad\qquad\quad = mg - F\sin\theta$

$$F\cos\theta - \mu_k\left[mg - F\sin\theta\right] = m a_x$$

$$(46.5)\cos 25^\circ - (0.03)\left[(45)(9.8) - (46.5)\sin 25^\circ\right] = 45\, a_x$$

$$42.1 - 12.6 = 45\, a_x$$

$$a_x = 0.655 \ \frac{m}{s^2}$$