

## Friction:

- 1) caused by the interaction of 2 + objects
- 2) opposite (opposes) motion
- 3) Types- Kinetic, static, sliding, rolling
- 4) size determined by:
  - nature of surfaces
  - force pushing surfaces together

frictional characteristic of the surfaces  
"coefficient of friction"

$$F_f = \mu F_N$$

force of friction

Normal Force  
force pushing surfaces together  
⊥ to surface

" $\mu$ " is the "coefficient of friction" and is the frictional property of the two surfaces in contact. Each pair of surfaces has its own unique value of  $\mu$ . Note that  $\mu$  is a ratio of forces, and therefore a pure number.

$$\mu = F_f / F_N$$

$F_f$  is **parallel** to surface       $F_N$  is **perpendicular** to surface

plane of motion!

You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

1) data?

You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$f_h = 125 \text{ N}$$

$v_c$

$\mu$ ?

Plane of motion: Motion is along the horizontal

*With the question of **Type Motion** and **Type force** you have to consider planes **parallel** and **perpendicular to motion**.*

2) Type motion?

3) Type force?

You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$f_h = 125 \text{ N}$$

$$v_c$$

$$\mu?$$

horizontal (x)

*parallel*

$$v_c \therefore 1^{\text{st}} \text{ Law}$$

$$\Sigma F = 0$$

vertical (y)

*perpendicular*

$$\text{rest} \therefore 1^{\text{st}} \text{ Law}$$

$$\Sigma F = 0$$

as the box slides across the floor it is not moving up or down, therefore it is at rest in the "y" (perpendicular) axis

4) picture? (diagram)

You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$f_h = 125 \text{ N}$$

$$v_c$$

$$\mu?$$

horizontal (x)

*parallel*

$$v_c \therefore 1^{\text{st}} \text{ Law}$$

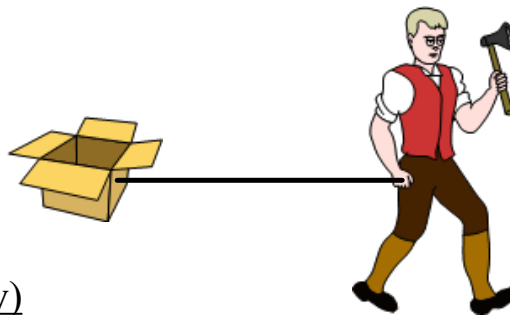
$$\Sigma F = 0$$

vertical (y)

*perpendicular*

$$\text{rest} \therefore 1^{\text{st}} \text{ Law}$$

$$\Sigma F = 0$$



5) force diagram

You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$f_h = 125 \text{ N}$$

$$v_c$$

$$\mu?$$

horizontal (x)

*parallel*

$$v_c \therefore 1^{\text{st}} \text{ Law}$$

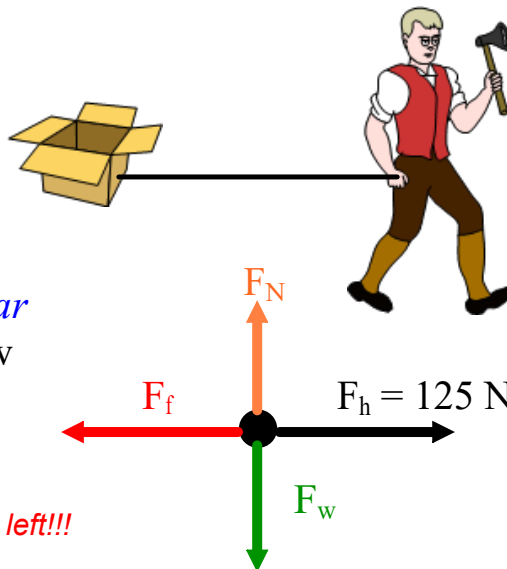
$$\Sigma F = 0$$

vertical (y)

*perpendicular*

$$\text{rest} \therefore 1^{\text{st}} \text{ Law}$$

$$\Sigma F = 0$$



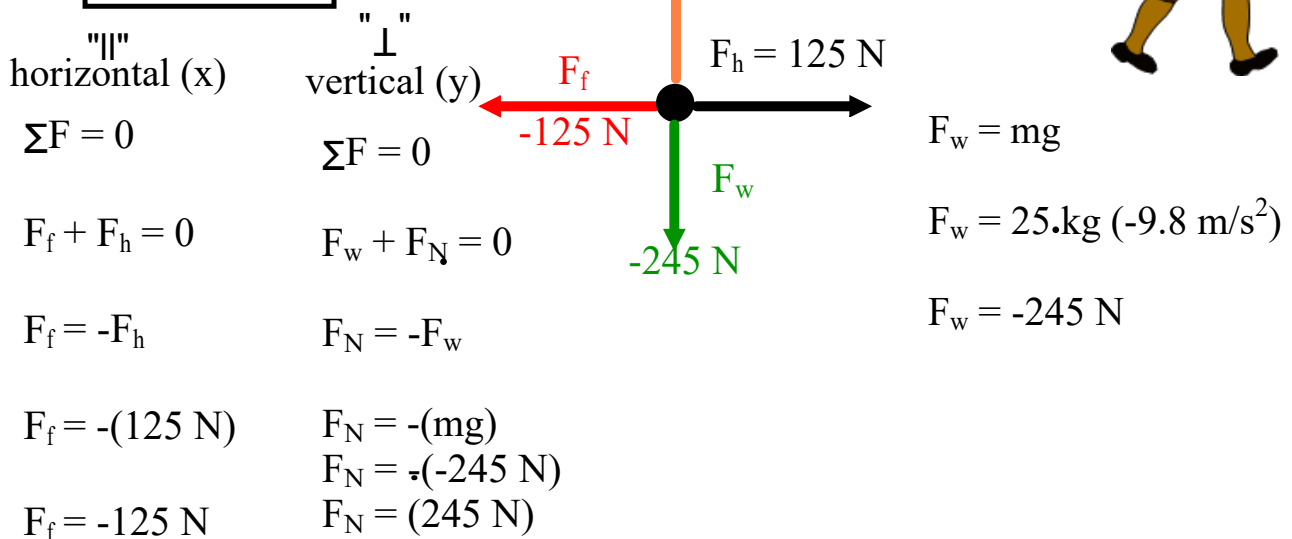
*the box is sliding right, there  $F_f$  is left!!!*

6) Determine any forces you don't know



You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

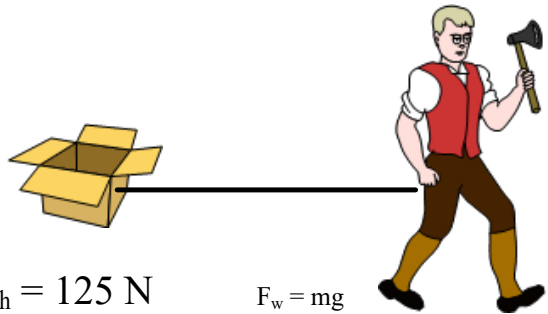
$m_{\text{box}} = 25 \text{ kg}$
$F_h = 125 \text{ N}$
$v_c$
$\mu?$
horizontal (x)    vertical (y)
parallel    perpendicular
$v_c$ : 1 <sup>st</sup> Law    rest
$\Sigma F = 0$ $\Sigma F = 0$



7) Find unknown

You pull a 25.0 kg box across a floor at a constant velocity with a horizontal force of 125 N. What is  $\mu$ ?

$m_{\text{box}} = 25 \text{ kg}$	
$F_h = 125 \text{ N}$	
$v_c$	
$\mu?$	
horizontal (x)	vertical (y)
parallel	perpendicular
$v_c$ : 1 <sup>st</sup> Law	rest
$\Sigma F = 0$	$\Sigma F = 0$



horizontal (x)

vertical (y)

$$\Sigma F = 0$$

$$\Sigma F = 0$$

$$F_f + F_h = 0$$

$$F_w + F_N = 0$$

$$F_f = -F_h$$

$$F_N = -F_w$$

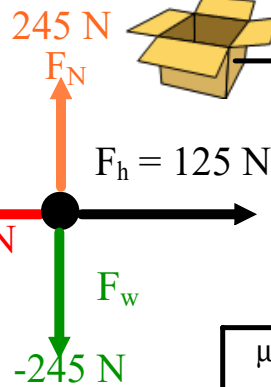
$$F_f = -(125 \text{ N})$$

$$F_N = -(mg)$$

$$F_N = -(-245 \text{ N})$$

$$F_f = -125 \text{ N}$$

$$F_N = (245 \text{ N})$$



$$F_w = mg$$

$$F_w = 25 \text{ kg} (-9.8 \text{ m/s}^2)$$

$$F_w = -245 \text{ N}$$

$$\mu = F_f/F_N$$

$$\mu = -125 \text{ N}/245 \text{ N}$$

$$\mu = 0.510$$

The "-" in  $\mu$  is meaningless because it is a vector direction and  $\mu$  is not a vector- it is a pure number (ratio of forces), therefore it is dropped

7) Find unknown

You pull a 25.0 kg box across a *waxed* floor with an acceleration of  $2.50 \text{ m/s}^2$  with a horizontal force of 125 N. What is  $\mu$ ?

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$$m_{\text{box}} = 25 \text{ kg}$$

$$f_h = 125 \text{ N}$$

$$a = 2.50 \text{ m/s}^2$$

$\mu$ ?

horizontal  
 $a \therefore 2^{\text{nd}} \text{ Law}$   
 $\Sigma F = ma$

vertical  
 rest  
 $\Sigma F = 0$

$$F_f + F_h = ma$$

$$F_f = ma - F_h$$

$$F_f = 25.0 \text{ kg}(2.50 \text{ m/s}^2) - (125 \text{ N})$$

$$F_f = 62.5 \text{ N} - (125 \text{ N})$$

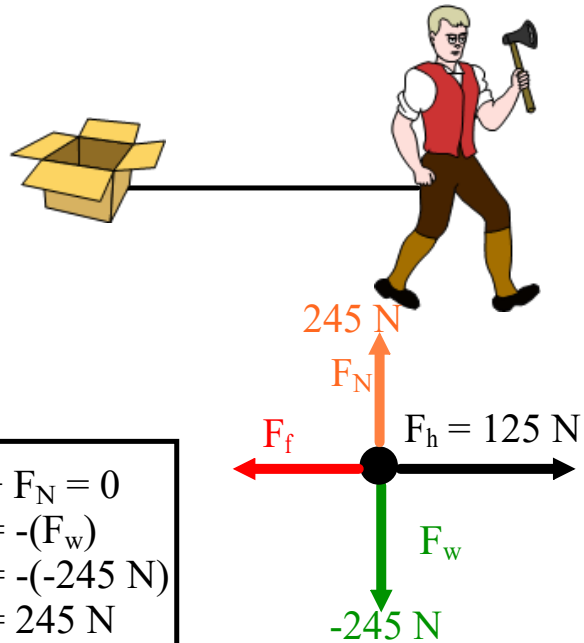
$$F_f = -62.5 \text{ N}$$

$$F_w + F_N = 0$$

$$F_N = -(F_w)$$

$$F_N = -(-245 \text{ N})$$

$$F_N = 245 \text{ N}$$



You pull a 25.0 kg box across a *waxed* floor with an acceleration of  $2.50 \text{ m/s}^2$  with a horizontal force of 125 N. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$f_h = 125 \text{ N}$$

$$a = 2.50 \text{ m/s}^2$$

$\mu$ ?

horizontal

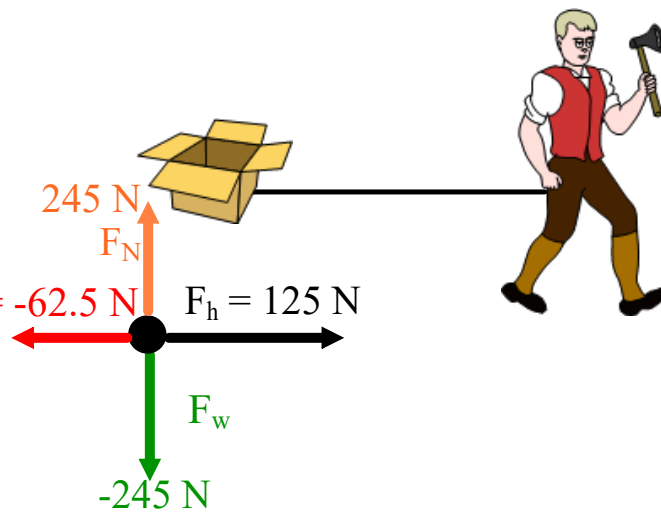
$a \therefore 2^{\text{nd}}$  Law

$$\Sigma F = ma$$

vertical

rest

$$\Sigma F = 0$$

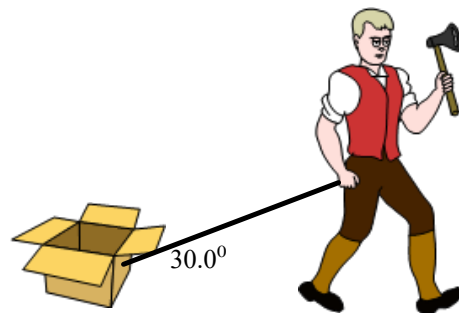


$$\mu = F_f / F_N$$

$$\mu = -62.5 \text{ N} / 245 \text{ N}$$

$$\mu = 0.255$$

You pull a 25.0 kg box across a floor at a constant velocity with a force of 125 N directed  $30.0^\circ$  above the horizontal. What is  $\mu$ ?



You pull a 25.0 kg box across a floor at a constant velocity with a force of 125 N directed 30.0° above the horizontal. What is  $\mu$ ?

$m_{\text{box}} = 25 \text{ kg}$   
 $f_a = 125 \text{ N at } 30.0^\circ$

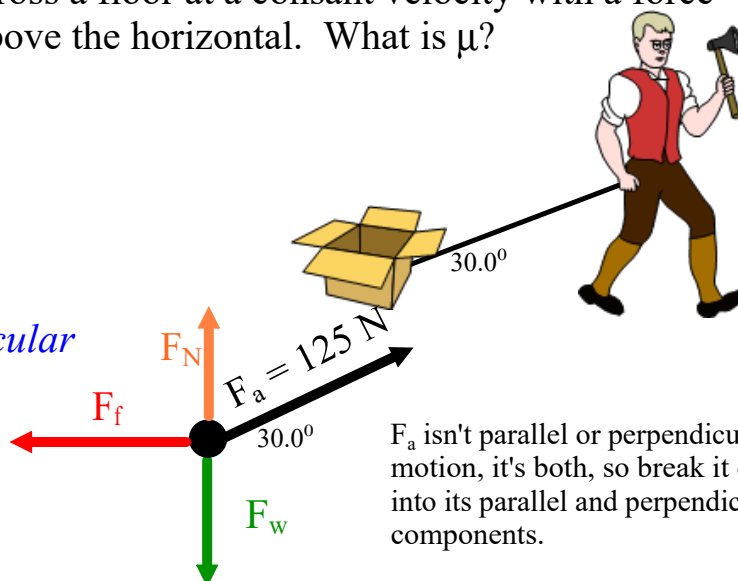
$v_c$   
 $\mu?$

horizontal

*parallel*  
 $v_c \therefore 1^{\text{st}} \text{ Law}$   
 $\Sigma F = 0$

vertical

*perpendicular*  
 rest  
 $\Sigma F = 0$

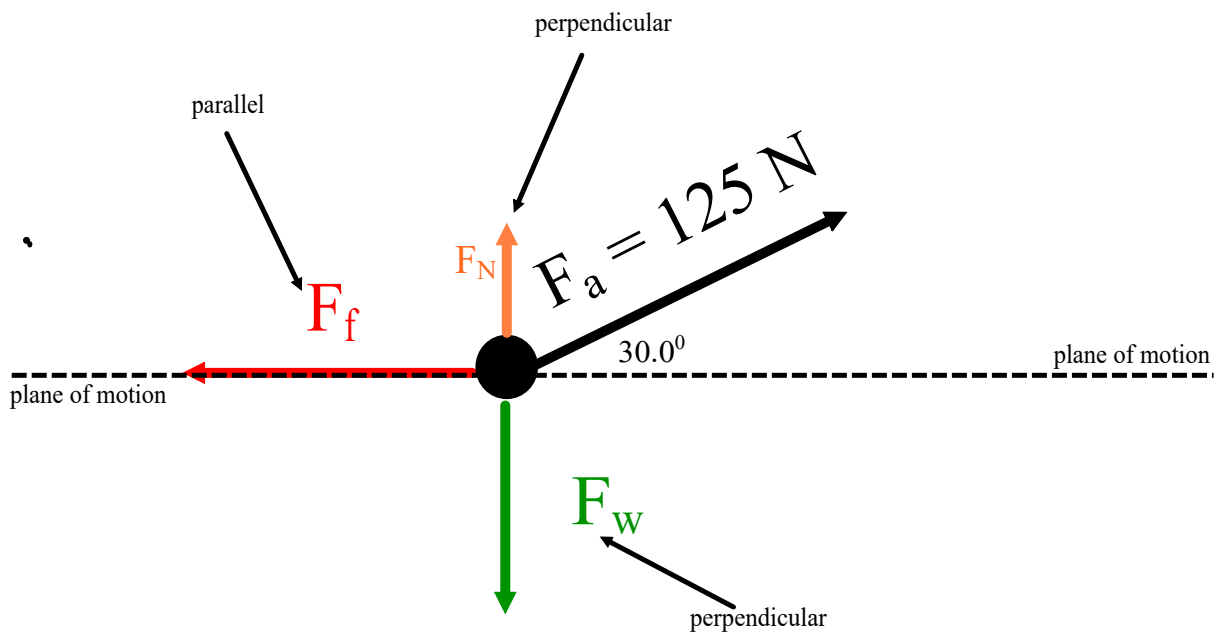


$F_a$  isn't parallel or perpendicular to motion, it's both, so break it down into its parallel and perpendicular components.

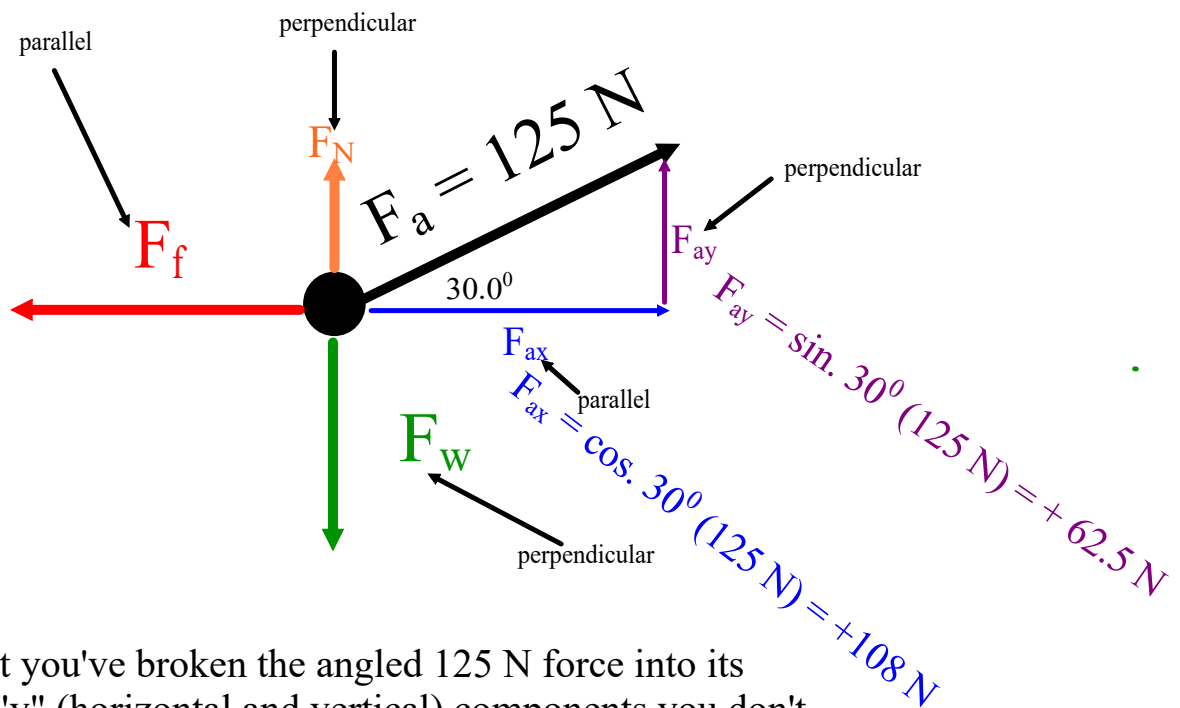
parallel to motion  
 $\mu = F_f / F_N$

perpendicular to motion

break down (resolve) all forces into their parallel and perpendicular components!!!!







Now that you've broken the angled 125 N force into its "x" and "y" (horizontal and vertical) components you don't use it (the 125 N force), you just use its components!!!

You pull a 25.0 kg box across a floor at a constant velocity with a force of 125 N directed  $30.0^\circ$  above the horizontal. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$F_a = 125 \text{ N at } 30.0^\circ$$

$$v_c$$

$$\mu?$$

horizontal

*parallel*

$v_c \therefore 1^{\text{st}} \text{ Law}$

$$\Sigma F = 0$$

$$\Sigma F = 0$$

$$F_f + F_{ax} = 0$$

$$F_f = -F_{ax}$$

$$F_f = -(108 \text{ N})$$

$$F_f = -108 \text{ N}$$

vertical

*perpendicular*

rest

$$\Sigma F = 0$$

$$\Sigma F = 0$$

$$F_w + F_N + F_{ay} = 0$$

$$F_N = -F_w - F_{ay}$$

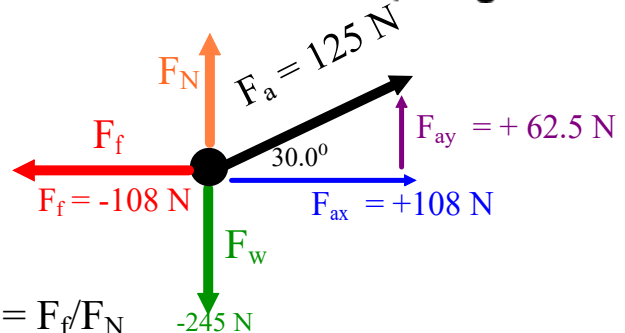
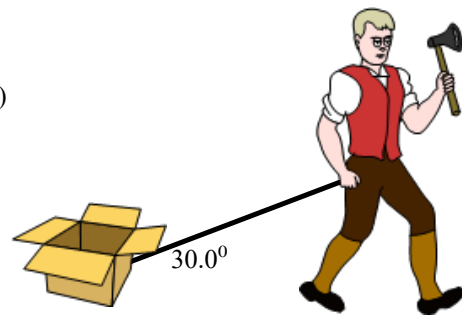
$$F_N = -(-245 \text{ N}) - (62.5 \text{ N})$$

$$F_N = 182.5 \text{ N}$$

$$F_w = mg$$

$$F_w = 25 \text{ kg} (-9.8 \text{ m/s}^2)$$

$$F_w = -245 \text{ N}$$

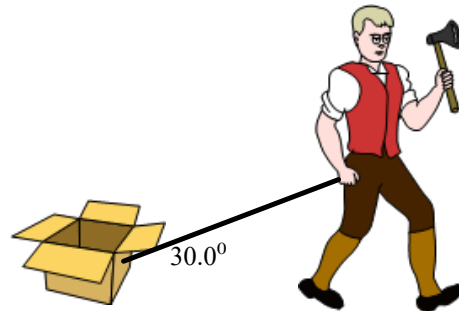


$$\mu = F_f / F_N$$

$$\mu = -108 \text{ N} / 182.5 \text{ N}$$

$$\mu = 0.592$$

You pull a 25.0 kg box across a waxed floor with an acceleration of  $2.00 \text{ m/s}^2$  with a force of 125 N directed  $30.0^\circ$  above the horizontal. What is  $\mu$ ?



You pull a 25.0 kg box across a waxed floor with an acceleration of  $2.00 \text{ m/s}^2$  with a force of 125 N directed  $30.0^\circ$  above the horizontal. What is  $\mu$ ?

$$m_{\text{box}} = 25 \text{ kg}$$

$$f_a = 125 \text{ N at } 30.0^\circ$$

acceleration

$\mu$ ?

horizontal

*parallel*

$a \therefore 2^{\text{nd}}$  Law

$$\Sigma F = ma$$

$$F_f + F_{ax} = ma$$

$$F_f = ma - F_{ax}$$

$$F_f = 25.0 \text{ kg}(2.00 \text{ m/s}^2) - (108 \text{ N})$$

$$F_f = -58 \text{ N}$$

vertical

*perpendicular*

rest

$$\Sigma F = 0$$

$$\Sigma F = 0$$

$$F_w + F_N + F_{ay} = 0$$

$$F_N = -F_w - F_{ay}$$

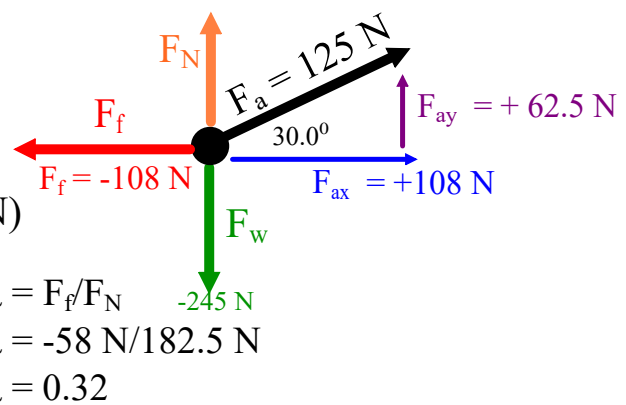
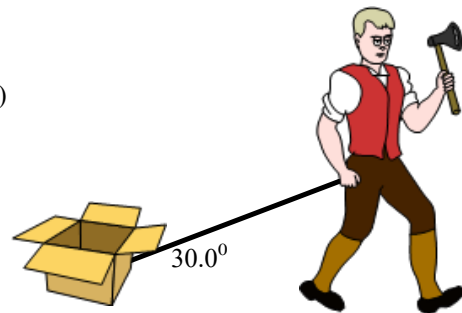
$$F_N = -(-245 \text{ N}) - (62.5 \text{ N})$$

$$F_N = 182.5 \text{ N}$$

$$F_w = mg$$

$$F_w = 25 \text{ kg} (-9.8 \text{ m/s}^2)$$

$$F_w = -245 \text{ N}$$



1) You pull a 25.0 kg box across a waxed floor with an acceleration of 2.00 m/s<sup>2</sup> with a force of 125 N directed 30.0° above the horizontal. What is  $\mu$ ?

$m_{\text{box}} = 25 \text{ kg}$

$f_a = 125 \text{ N at } 30.0^\circ$

acceleration

$\mu$ ?

horizontal

*parallel*

$a \therefore 2^{\text{nd}} \text{ Law}$

$\Sigma F = ma$

vertical

*perpendicular*

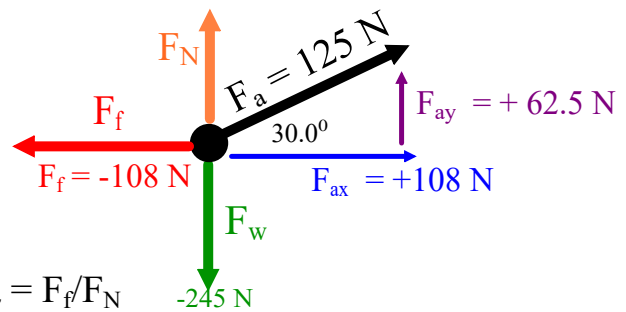
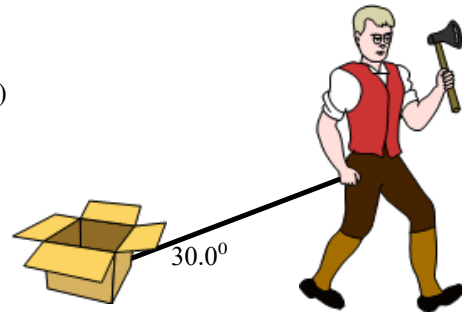
rest

$\Sigma F = 0$

$F_w = mg$

$F_w = 25 \text{ kg} (-9.8 \text{ m/s}^2)$

$F_w = -245 \text{ N}$



$F_f + F_{ax} = ma$   
 $F_f = ma - F_{ax}$

$\Sigma F = 0$   
 $F_w + F_N + F_{ay} = 0$   
 $F_N = -F_w - F_{ay}$   
 $F_N = -(-245 \text{ N}) - (62.5 \text{ N})$

$\mu = F_f / F_N$   
 $\mu = -58 \text{ N} / 182.5 \text{ N}$   
 $\mu = 0.32$

$F_f = 25.0 \text{ kg} (2.00 \text{ m/s}^2) - (108 \text{ N})$   
 $F_f = -58 \text{ N}$

