5-10 min Writing Review: Friction

Suppose you slowly push and increase the applied force on a heavy crate. Describe the two forces of friction and how they affect the crate's motion from the first push until the crate is moving at a constant velocity. Use as much detail as possible.

Solving Problems with Common Forces

Understanding the concepts discussed thus far is the key to solving mathematical problems involving forces. Along with the strategies we previously used there are a couple more we can use for forces:

- Free Body Diagram.
- Sketch/label a diagram showing forces.

Free-Body Diagrams

"***Physics is all about simplification***."

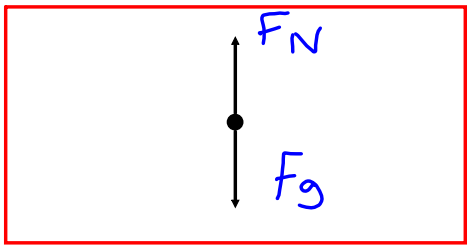
A ***free-body diagram*** (FBD) is a picture that shows ALL the forces acting on an object.

For the sake of simplicity, an object is usually represented by a dot and only the forces acting on the object are included on the diagram. The forces are represented by arrows.

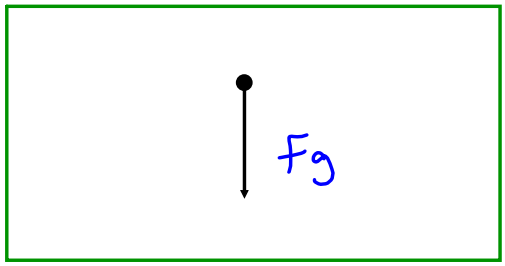
When drawing FBDs, put the tail of the force vectors on the object, with the arrow pointing away from the object. NEVER draw a force vector pointing toward an object.

Examples:

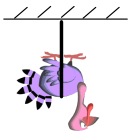
An ***apple*** rests on a desk.

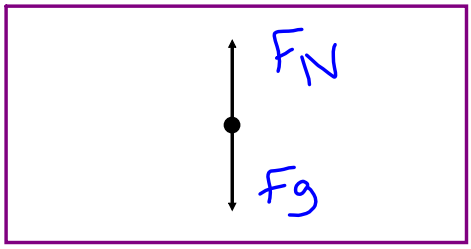


A ***flower pot*** falls in the absence of air resistance.

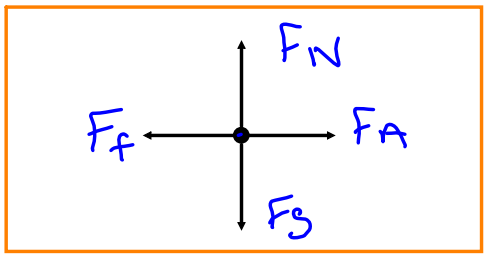


A ***turkey*** is hung from the ceiling of a classroom.

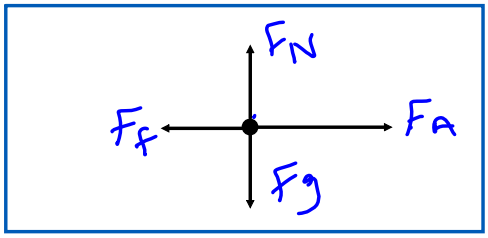




A snail pushes a ***pumpkin*** across the floor at constant speed.



A *car* speeds up while traveling on a dirt road.



A Note about Motion and Forces

When the net force on an object is zero, it is in a state of ***equilibrium***. This means that the object is either at ***rest*** or moving at a ***constant velocity***. ***It cannot be accelerating***.

What determines an object's motion?
Why, the value of the net force of course!

Equilibrium : $\vec{F}_{net} = 0N$

- object at rest
- object moving at constant velocity

$= 0\ N$

If the net force does not equal zero, the object will accelerate at a constant rate!

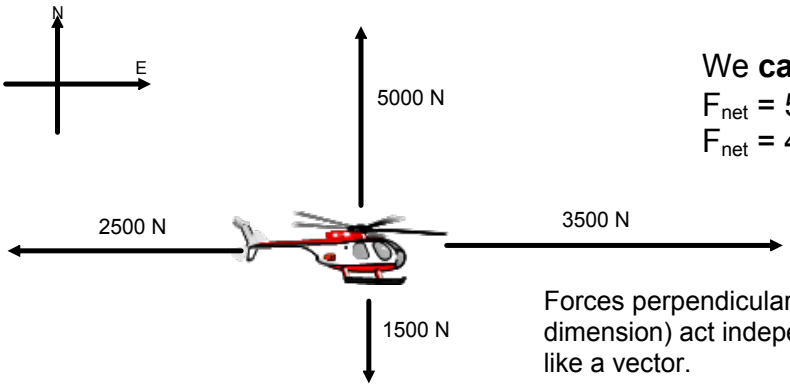
NOTE

The object will accelerate in the direction of the net force.

Net Force

The *net force* is the vector sum of all the forces acting on an object. Only forces acting in the same dimension (i.e. left and right or up and down) can be mathematically added (or subtracted).

Consider the four forces acting on the object below:



We **cannot** say the net force is:
F_{net} = 5000 - 1500 + 3500 - 2500
F_{net} = 4500 N

Forces perpendicular to each other (or in a different dimension) act independently on an object and must be added like a vector.

We can talk about the net force in each dimension:

F_{net} [East] = 3500 N - 2500 N
F_{net} [E] = 1000 N

F_{net} [North] = 5000 N - 1500 N
F_{net} [N] = 3500 N

To find the actual net force on the object we would need to do a scale diagram with the vectors or a calculation (grade 12).

Often to identify which direction we are focusing on we use the subscripts x and y. Like in your math class, x - horizontal direction and y - vertical direction. Directions are all in the way your set up your problem for analysis - your frame of reference.

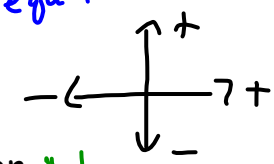
A 62 kg crate is pulled at a constant velocity with an applied force of 337 N.

$F_{net} = 0\ N$, equilibrium.

a. Calculate the force of friction.

b. Calculate the normal force on the crate.

c. Calculate the coefficient of kinetic friction.



a) $F_{net} = \sum Force$

$F_{net} = F_a + F_f$

$0 = 337 + F_f$

$-337 = F_f$

$m = 62\ kg$

$F_a = 337\ N$

$F_{net} = 0\ N$

b) $F_N = ?$

$|F_N| = |F_g| = |mg|$

Keep everything positive

$|F_N| = |mg|$

$= (62)(9.81)$

$F_N = 608\ N$

c) $\mu = ?$

$|F_f| = \mu |F_N|$ ← magnitude only

$337 = \mu(608)$

$\frac{337}{608} = \mu_K$ ← kinetic friction

$0.55 = \mu_K$ Coefficient of Kinetic Friction

A box has a weight of 625 N and is being pulled with a net force of 12 N. The coefficient of kinetic friction is 0.23.

a. What is the mass of the box?

b. What is the force of friction?

c. What is the applied force?

$F_g = -625\ N$

$F_{net} = 12\ N$

$\mu = 0.23$

a) $m = ?$

$F_g = mg$

$-625 = m(-9.81)$

$\frac{-625}{-9.81} = m$

$63.7\ kg = m$

b) $F_f = ?$ $\quad |F_f| = \mu F_N$ $\quad * F_N = \text{weight} = mg \text{ or } F_g$

$|F_f| = (0.23)(625)$ $\quad F_N = |F_g|$

$|F_f| = 143\ N$

c) $F_a = ?$ $\quad F_{net} = \sum \text{Forces}$

$F_{net} = F_a + F_f$

$12 = F_a + (-143)$ $\quad \uparrow$ opposite direction of motion

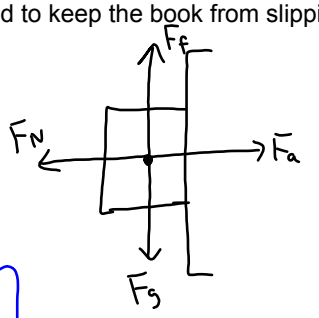
$12 + 143 = F_a$

$155\ N = F_a$

A 3.4 kg book is pressed against the wall. The coefficient of static friction between wall and book is 0.23. Calculate the minimum applied force needed to keep the book from slipping down.

$m = 3.4\text{kg}$

$\mu = 0.23$



$F_f = \mu F_N$

$|F_N| = |F_a|$

$|F_g| = |F_f|$

} $\sum$ all forces is zero

Horizontal direction

$F_{net} = \sum$ Forces

$F_{net} = F_N + F_a$

$0 = F_N + F_a$

So, $-F_N = F_a$ or $|F_N| = |F_a|$

Vertical Direction

$F_{net} = \sum$ Forces

$F_{net} = F_g + F_f$

$0 = F_g + F_f$

$-F_g = F_f$ or $|F_g| = |F_f|$

So

$F_f = \mu F_N$

Replace F_g for F_f and F_a for F_N

$F_g = \mu F_a$

$mg = \mu F_a$

$(3.4)(9.81) = 0.23 F_a$

$33.35 = 0.23 F_a$

$\frac{33.35}{0.23} = F_a$

$145\text{N} = F_a$

A 4.2 kg book is pressed up against the wall using an applied force of 75 N. For the book not to fall, calculate the minimum coefficient of static friction necessary between the wall and the book. ($\mu = 0.55$)

$F_f = \mu F_N$

$F_a = F_N$

$F_f = F_g$

Replace

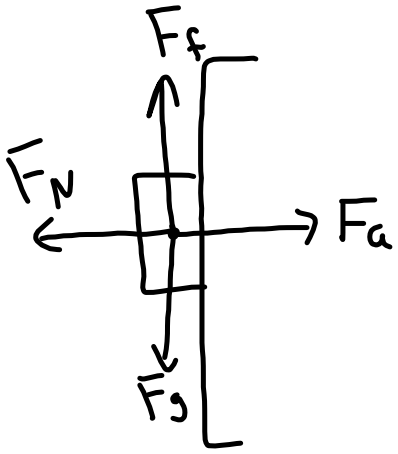
$F_g = \mu F_a$

$mg = \mu F_a$

$(4.2)(9.81) = \mu(75)$

$\frac{(4.2)(9.81)}{75} = \mu$

$\boxed{0.55 = \mu}$



$\mu =$?

No units

Physics 112 Forces in 1D

F_g $F_{net} = 0\ N$ F_a

1. A 25 kg crate is pulled at a constant velocity with an applied force of 125 N.
   a. Calculate the force of friction. (-125 N)
   b. Calculate the normal force on the crate. (245 N)
   c. Calculate the coefficient of kinetic friction. (0.51).

a) $F_{net} = \sum Forces$

$F_{net} = F_f + F_a$

$0 = F_f + 125$

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

b) $F_N = F_g$ ← mg

$F_N = mg$

$F_N = (25)(9.81)$

$\boxed{F_N = 245\ N}$

c) $|F_f| = \mu |F_N|$

$\mu = \frac{F_f}{F_N} = \frac{125}{245} = \boxed{0.51}$

Physics 112 Forces in 1D

2. A sled has a weight of 75 N and is being pulled with a net force of 15 N. The coefficient of kinetic friction is 0.19.

$F_g = F_N$ F_{net}

μ

a. What is the mass of the sled? (7.6 kg)
b. What is the force of friction? (14.25 N)
c. What is the applied force? (29.25 N)

a) $F_g = mg$, $g = 9.81\ m/s^2$

$75 = m(9.81)$

$\frac{75}{9.81} = m$ ⟩ $\boxed{m = 7.6\ kg}$

b) $F_f = ?$ Same as F_g

$F_f = \mu F_N$

$F_f = (0.19)(75\ N)$

$\boxed{F_f = 14.25\ N}$

c) $F_a = ?$

$F_{net} = \sum Forces$

$F_{net} = F_a + F_f$

$15 = F_a + (-14.25)$

$\boxed{29.25\ N = F_a}$

Physics 112 Forces in 1D

3. A 55 kg box is moved with a net force of 28 N. The applied force necessary is 185 N.
   a. What is the force of friction? (-157 N)
   b. What is the normal force? (540 N)
   c. What is the coefficient of kinetic friction? (0.29)

a) $F_{net} = \sum Forces$

$F_{net} = F_a + F_f$

$28 = 185 + F_f$

$-157\ N = F_f$

b) $F_N = F_g$

$F_N = mg$

$F_N = (55\ kg)(9.8\ m/s^2)$

$F_N = 540\ N$

c) $F_f = \mu F_N$

$\mu = \frac{F_f}{F_N}$

$\mu = \frac{157}{540} = 0.29$

Physics 112 Forces in 1D

4. A box is being pulled across the floor at a constant velocity with an applied force of 184 N. The coefficient of kinetic friction is 0.26. μ
   a. What is the force of friction? (-184 N)
   b. What is the force of gravity on the box? (708 N)
   c. What is the mass of the box? (72.2 kg)

$F_{net} = 0\ N$ F_a

a) $F_{net} = \sum Forces$

$F_{net} = F_a + F_f$

$0 = 184 + F_f$

$-184\ N = F_f$

b) $F_g = mg$

$F_g = F_N$

$F_f = \mu F_N$ Replace

$\Rightarrow F_f = \mu F_g$

$-184 = (0.26) F_g$

$-708\ N = F_g$

c) $m = ?$

$F_g = mg$

$-708\ N = m(-9.81\ m/s^2)$

$72.2\ kg = m$

Physics 112 Forces in 1D

m, F_g

5. A 46 kg object is being pulled with an applied force of 200 N. The coefficient of kinetic friction is 0.18.
   a. What is the force of gravity on the object? (451 N)
   b. What is the force of friction acting on the object? (81 N)
   c. What is the net force acting on the object? (119 N)

F_a μ

a) $F_g = mg$

$= (46)(-9.81)$

$F_g = -451$ N (downward)

$|F_g| = +451$ N

b) $F_f = ?$

$F_g = F_N \rightarrow 451$

$F_f = \mu F_N$

$F_f = (0.18)(451)$

$F_f = 81$ N

c) $F_{net} = \sum$ Forces

$F_{net} = F_a + F_f$

$= 200$ N $+ (-81$ N$)$

$F_{net} = 119$ N