

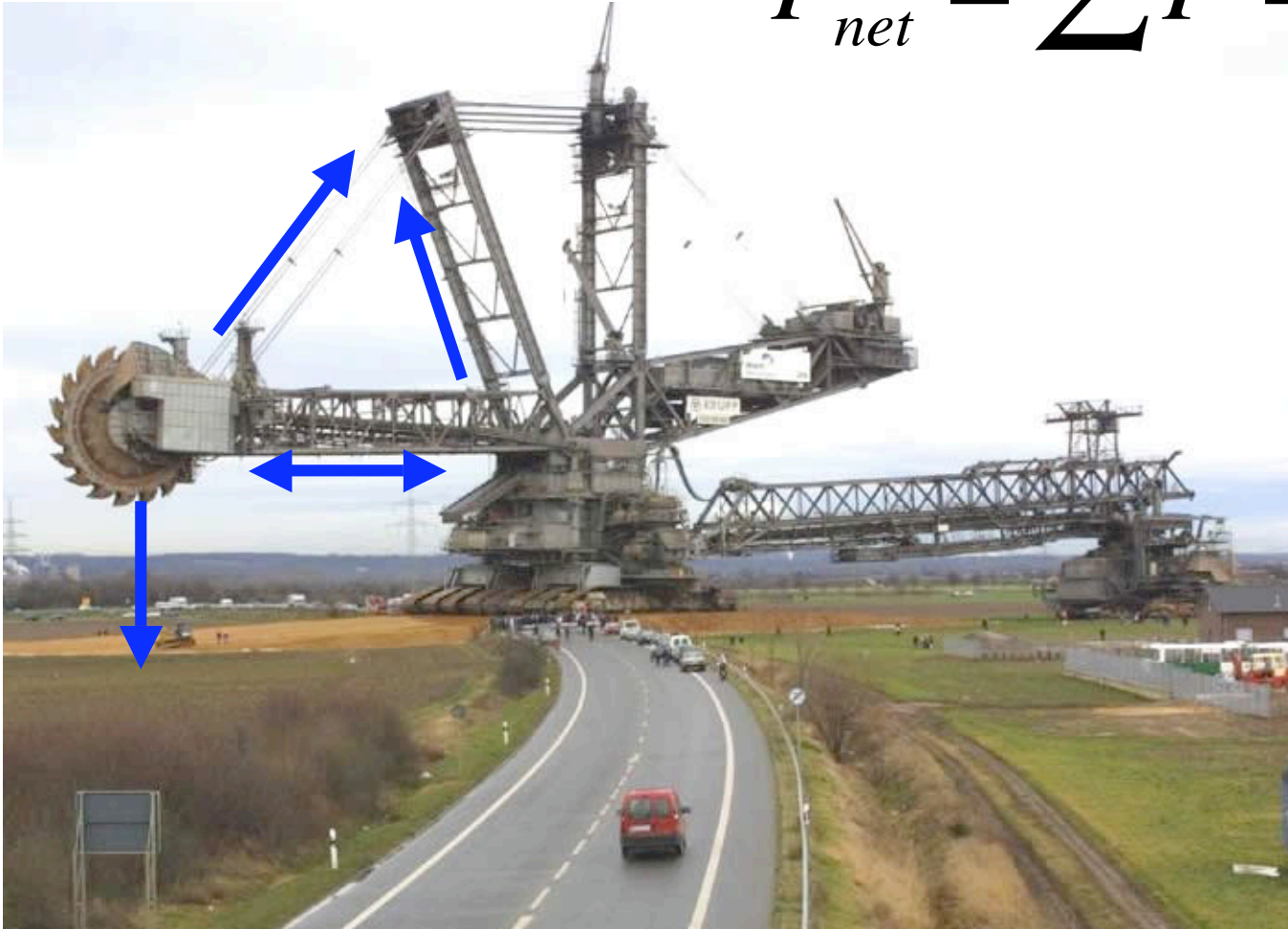
Laws of Motion



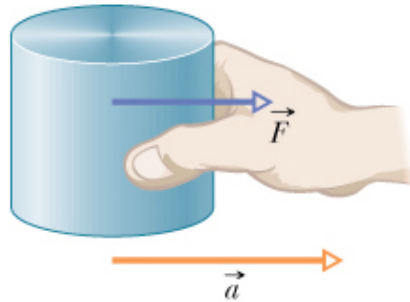
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Newton's 2nd Law

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



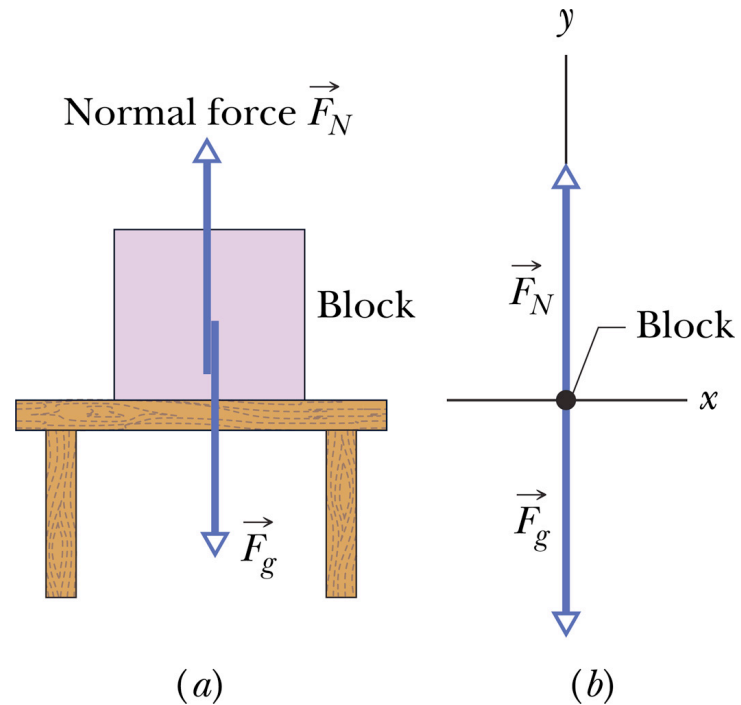
Newton's 2nd Law



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

acceleration \leftrightarrow Net force

Newton's 2nd Law

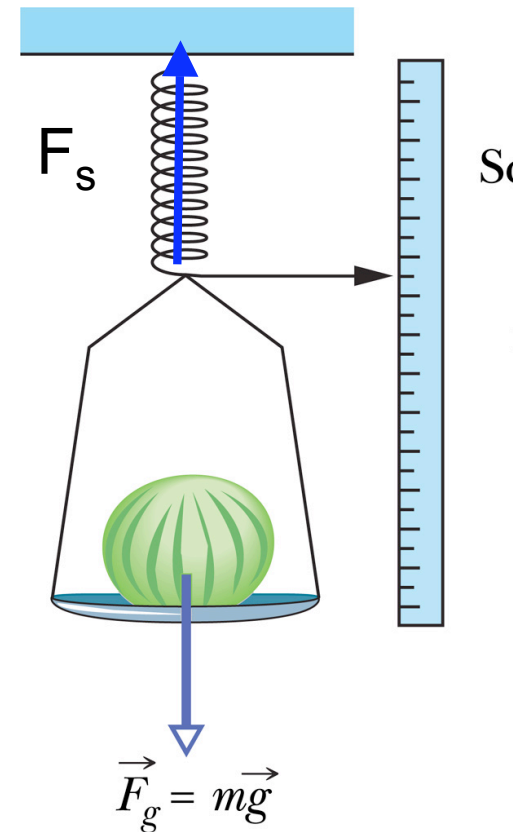


Important consequence: No acceleration
➔ No NET force

Newton's 2nd Law

The force exerted by the spring is:

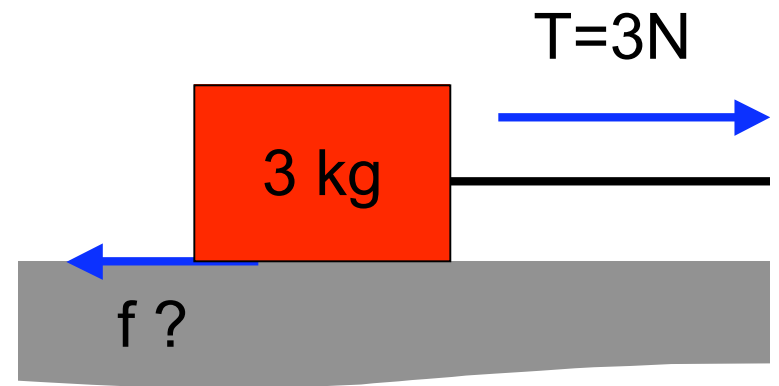
- A There might be no spring force
- B There is a force $F_s < mg$
- C There is a force $F_s = mg$
- D There is a force $F_s > mg$
- E We cannot know about spring forces until we have more information



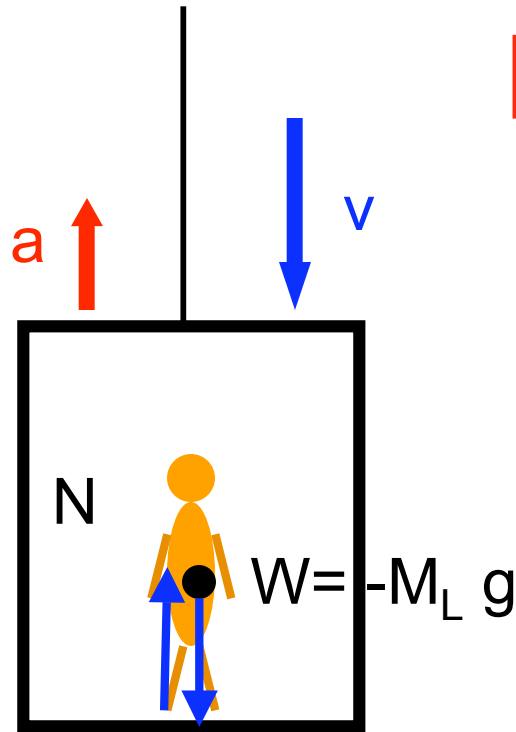
Newton's 2nd Law

A 3 kg block is pulled by a tension force of 3N. It slides at constant speed. We know:

- A There might be no friction force
- B There is a friction force $f < 3\text{N}$
- C There is a friction force $f = 3\text{N}$
- D There is a friction force $f > 3\text{N}$
- E We cannot know about friction until we have more information



Newton's 2nd Law



Linda stands in an elevator going down at $v_y = -2 \text{ m/s}$. It is slowing its descent at a rate $a_y = 1 \text{ m/s}^2$

The normal force from the floor is:

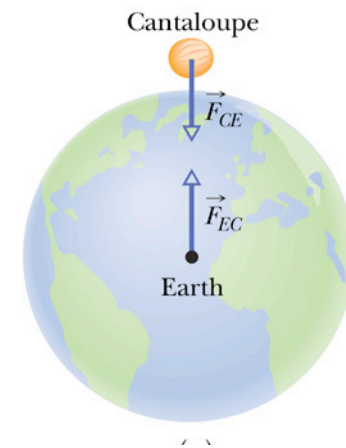
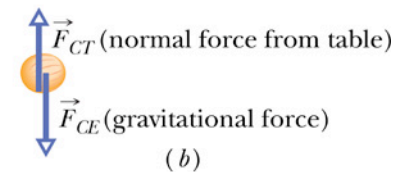
- A There might be no normal force
- B There is a force $N < mg$
- C There is a force $N = mg$
- D There is a force $N > mg$
- E We cannot know about normal forces until we have more information

Which forces?

- Weight - a formula!

$$W = -mg \mathbf{j}$$

Force comes from the Earth: $W = F_{CE}$



Gravity

Gravity always makes things accelerate at

$$a = g = 9.8 \text{ m/s}^2$$

- A Yes
- B No
- C maybe/no opinion

Gravity

Gravity always makes things accelerate at

$$a = g = 9.8 \text{ m/s}^2$$

“Free-fall” → no forces except gravity

$$F_{\text{net}} = F_{\text{mE}} + 0 = -mg = ma$$

$$\rightarrow a = -g$$

- no normal force
- no tension
- no air resistance

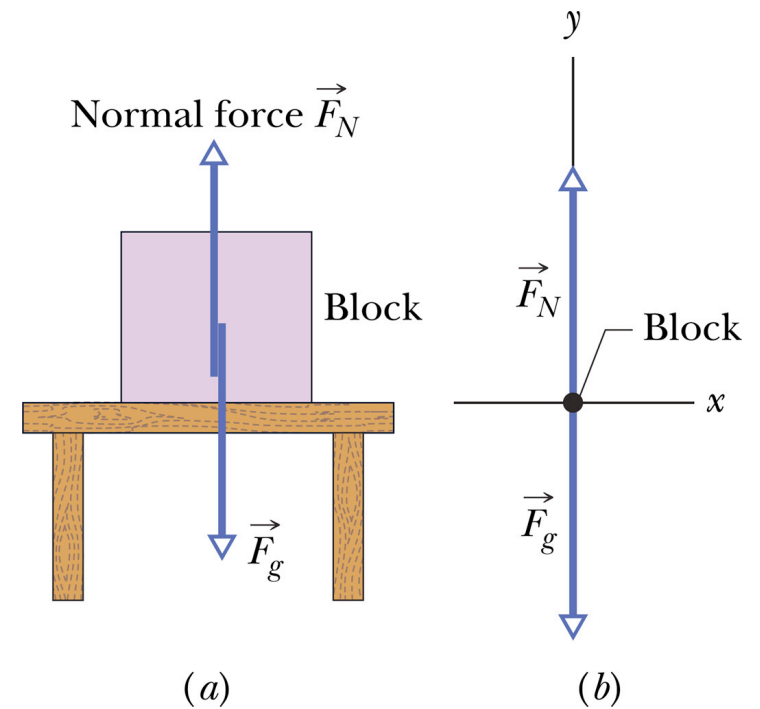
Which forces?

- Normal force: NO formula!

Only a rule:

“whatever force necessary*”

* necessary to keep body from moving through surface



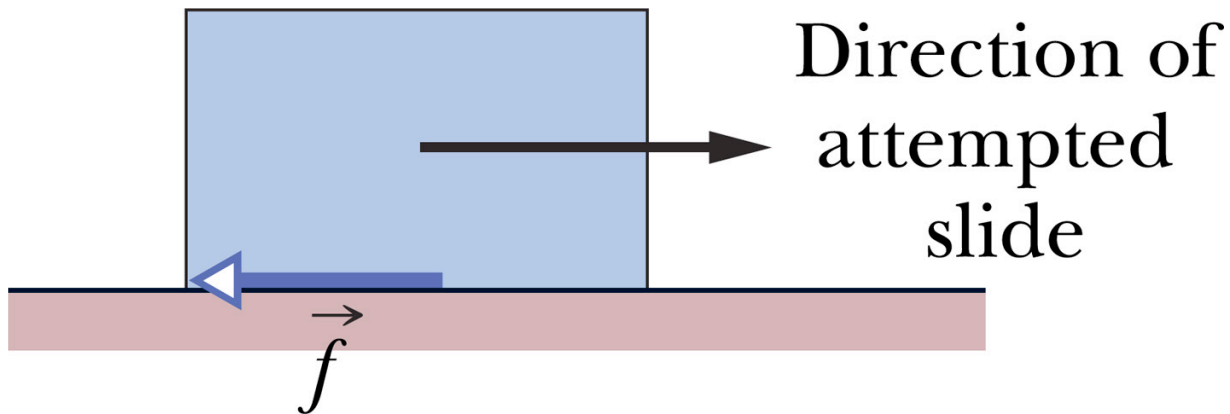
Force is
ALWAYS
NORMAL to
surface

Q: Why?

Which forces?

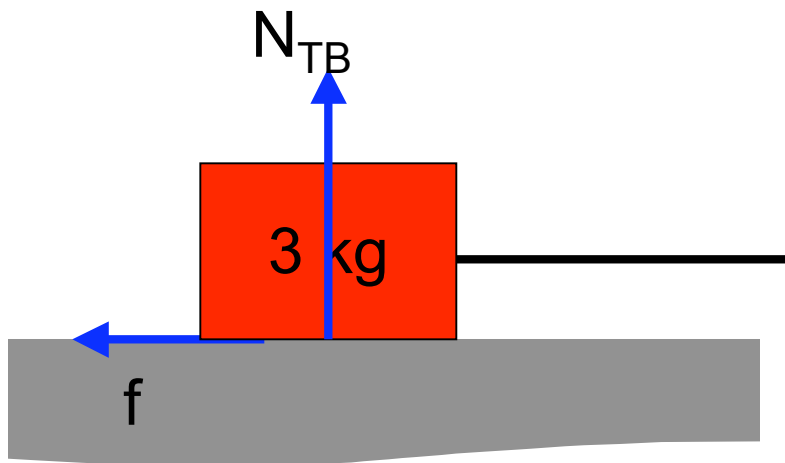
- Friction forces: rules & formulae to come soon

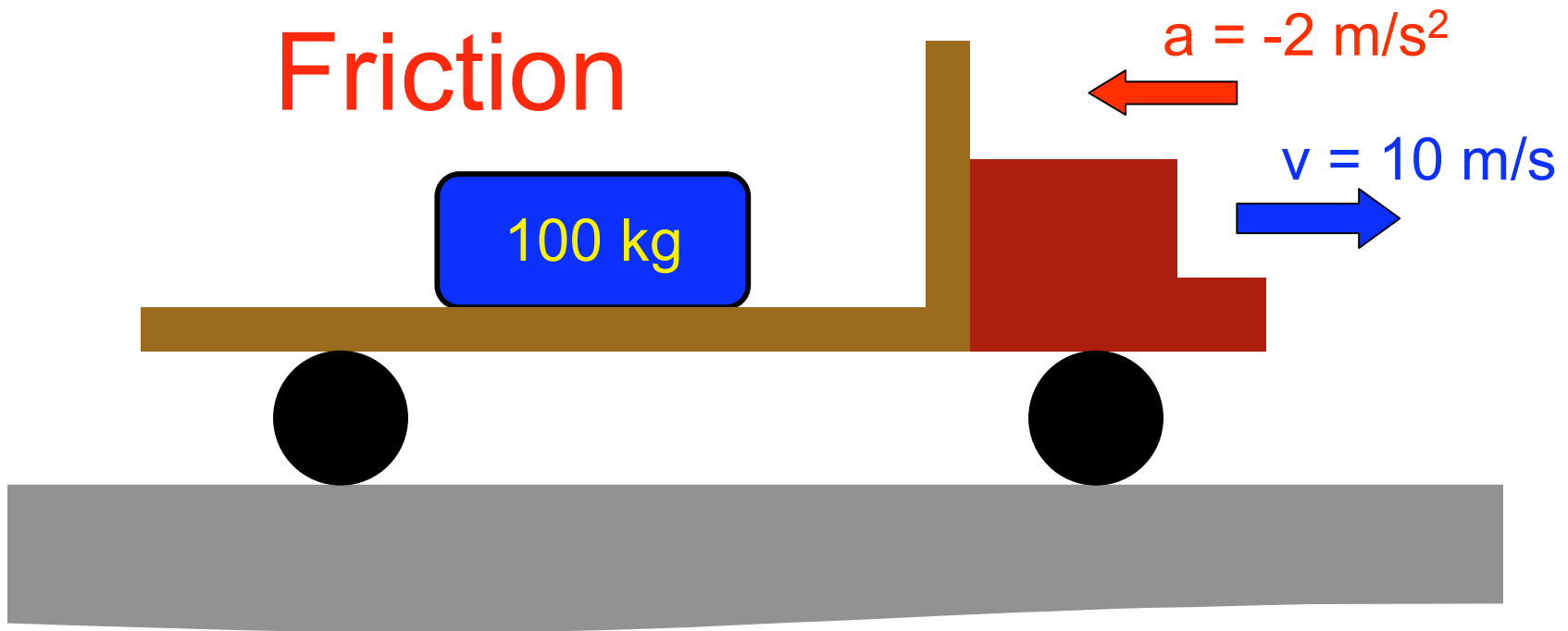
Force is **ALWAYS TANGENT** to surface



Which forces?

- Friction & Normal force:
contact forces - whenever
two bodies are in contact

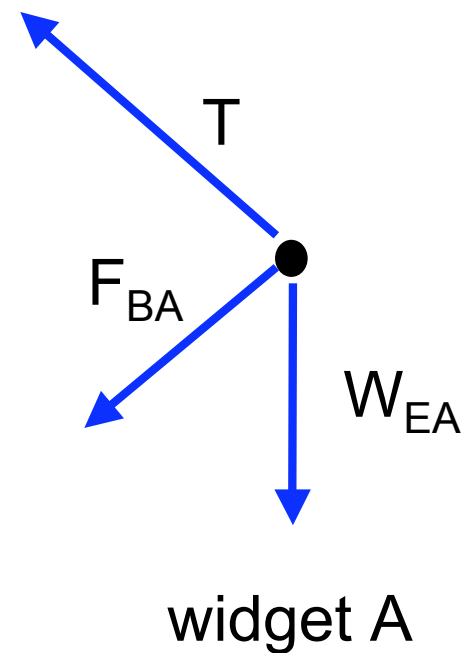




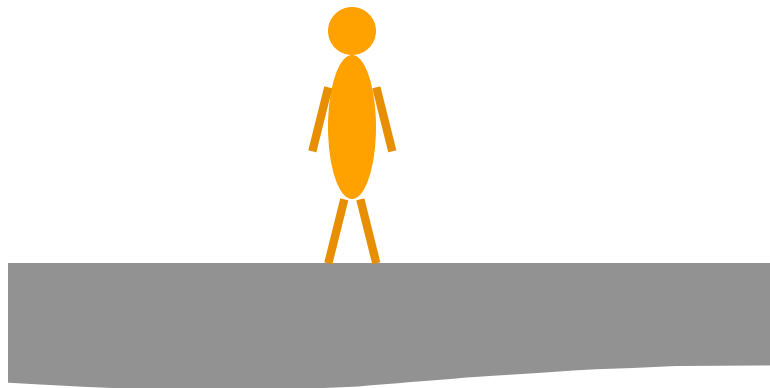
- A There is no friction acting on the crate
- B $f = \mu 980 \text{ N}$
- C $f = +200 \text{ N}$
- D $f = -200 \text{ N}$
- E There is no way to know

Rules for Free Body Diagrams

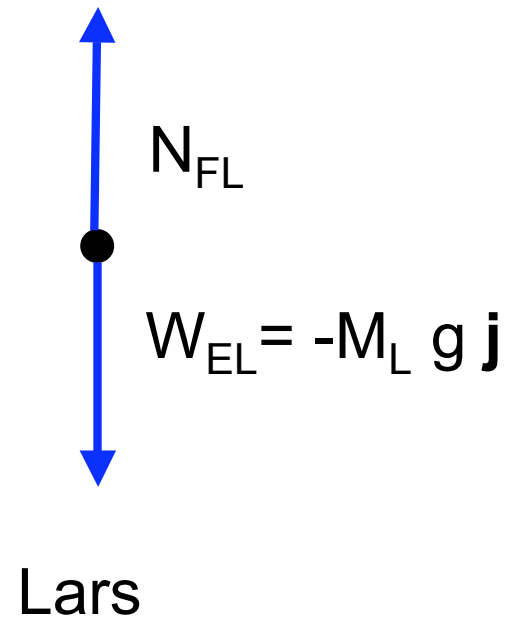
1. Label the free body
2. Draw only Forces
3. Draw only **REAL** forces
4. Draw only the forces acting on that single body
5. Label each force
6. Mark each 3rd law pair w/ a different indicator



Simple(est possible) example



Lars stands on the floor

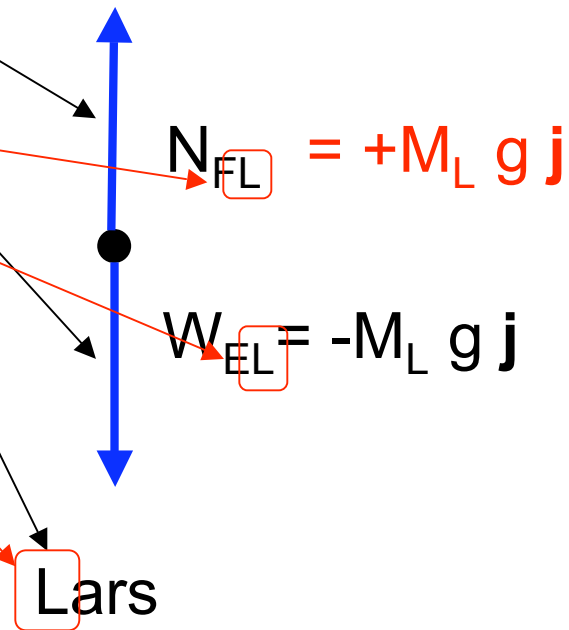


Simple(est possible) example

1. Label the free body
2. Draw only Forces
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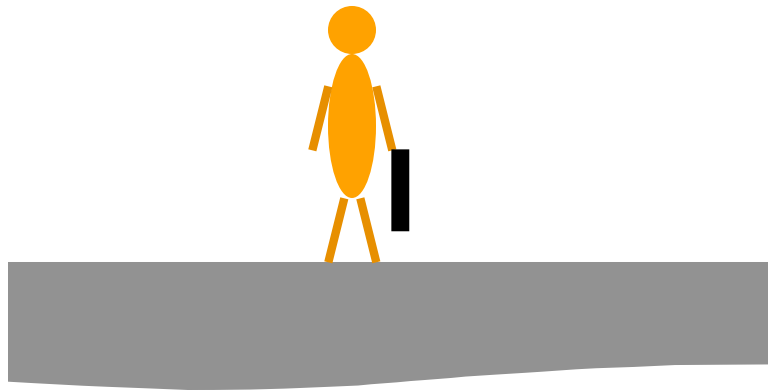


Lars stands on the floor

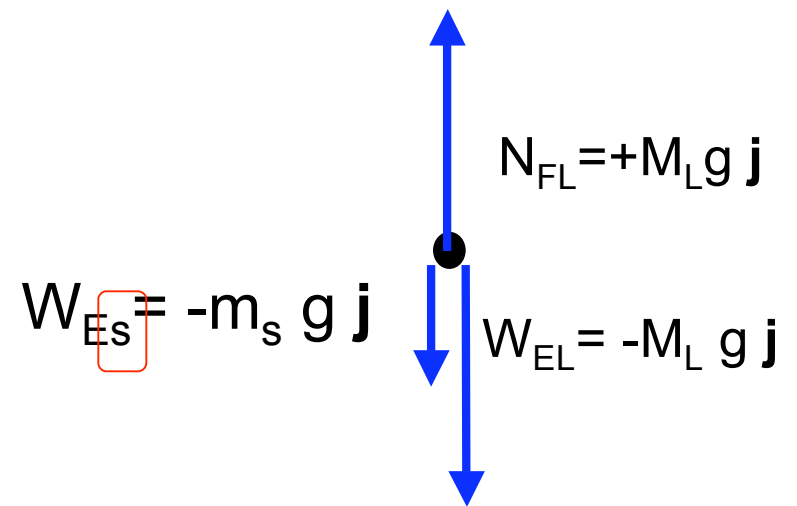


Next-Simplest example

What's wrong w/ this?



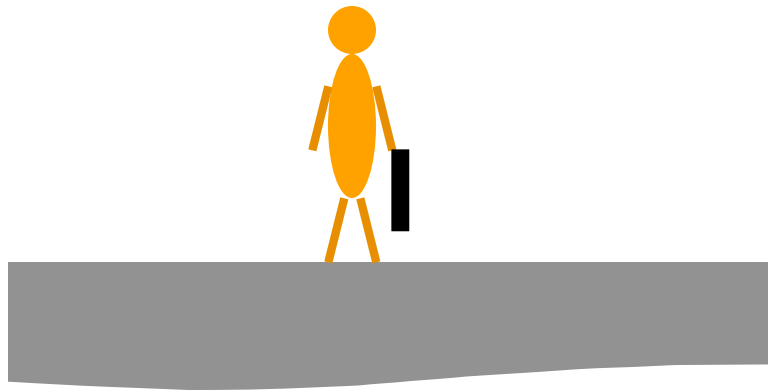
Lars stands on the floor
holding a briefcase
containing \$100,000



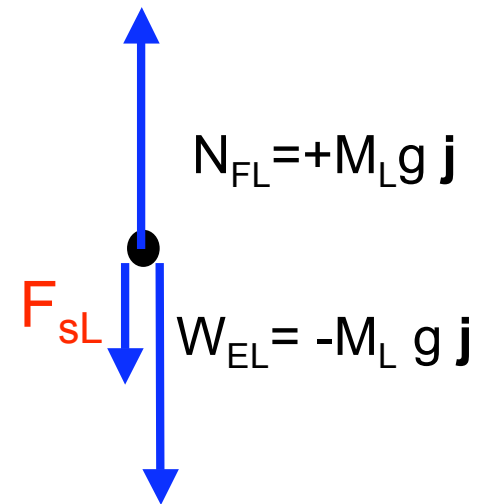
Lars

Next-Simplest example

What's wrong w/ this?

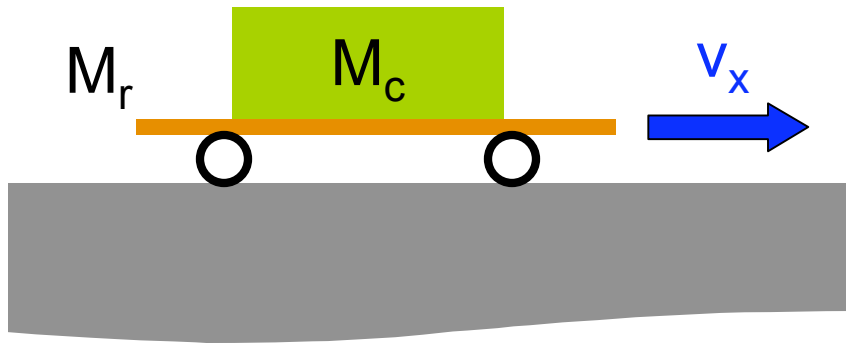


Lars stands on the floor holding a briefcase containing \$100,000



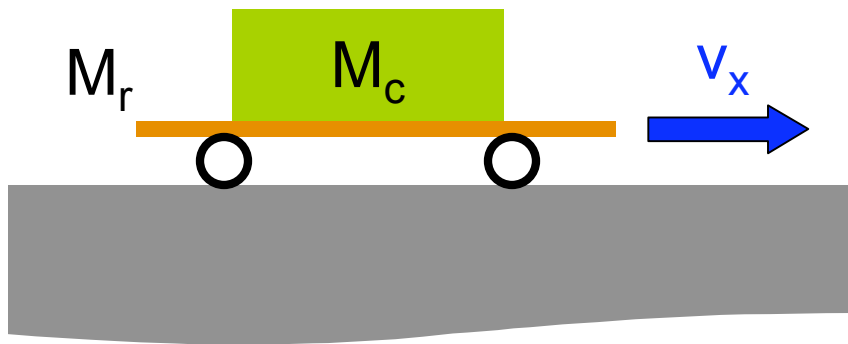
Lars

A railcar (mass M_r), loaded with a container (mass M_c), moves Eastward at $v_x=10$ m/s

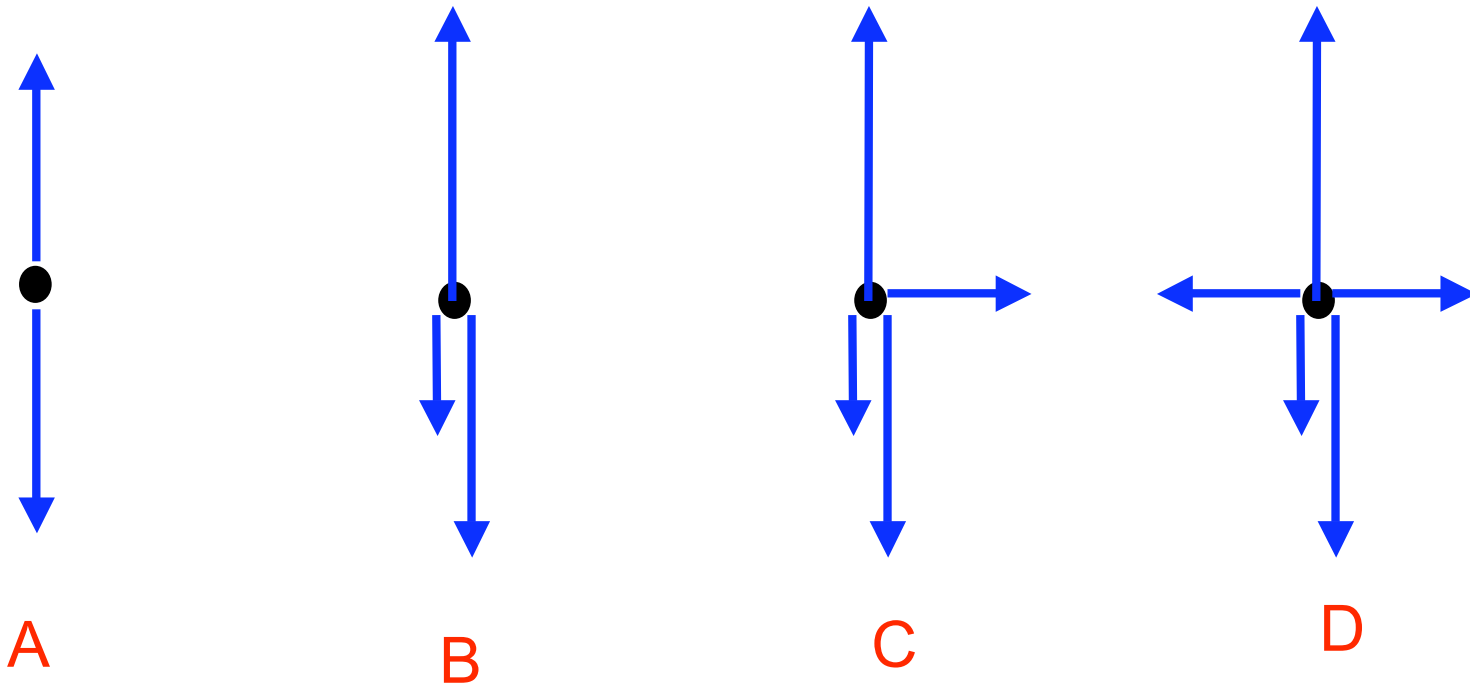


Draw a FBD for the railcar

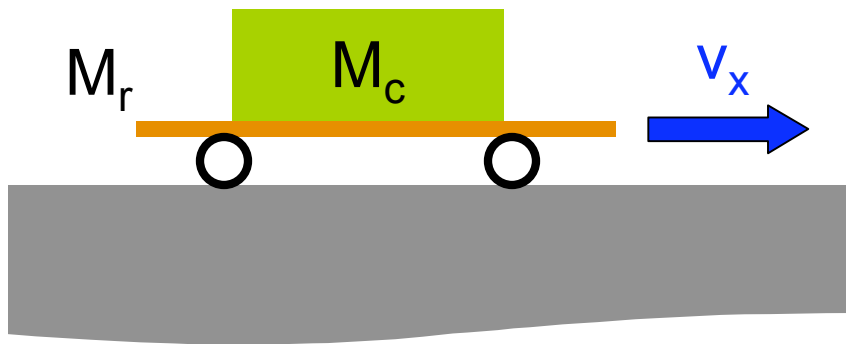
A railcar (mass M_r), loaded with a container (mass M_c), moves Eastward at $v_x=10$ m/s



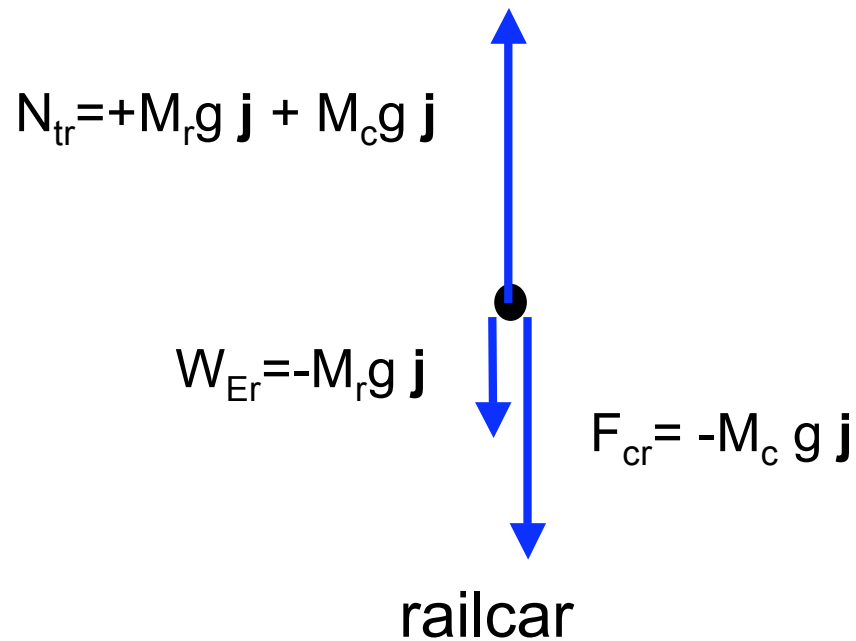
Draw a FBD for the railcar



A railcar (mass M_r), loaded with a container (mass M_c), moves Eastward at $v_x=10$ m/s

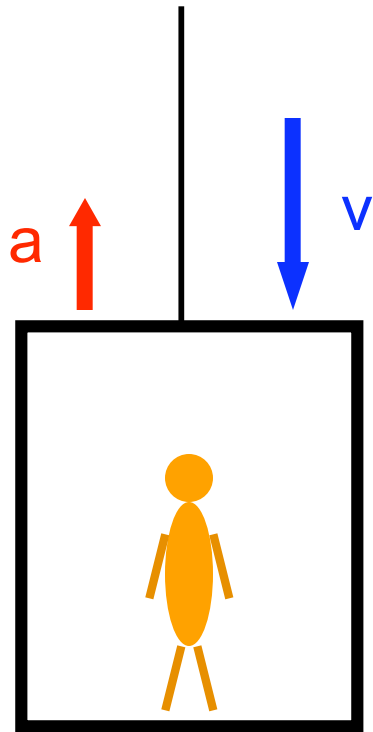


Draw a FBD for the railcar



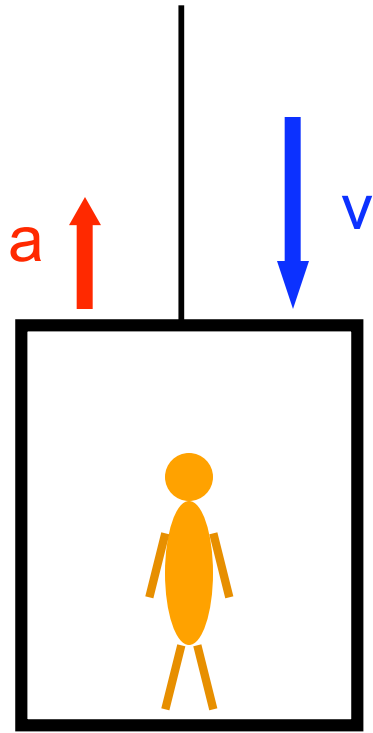
Trickery

Draw a FBD for Linda



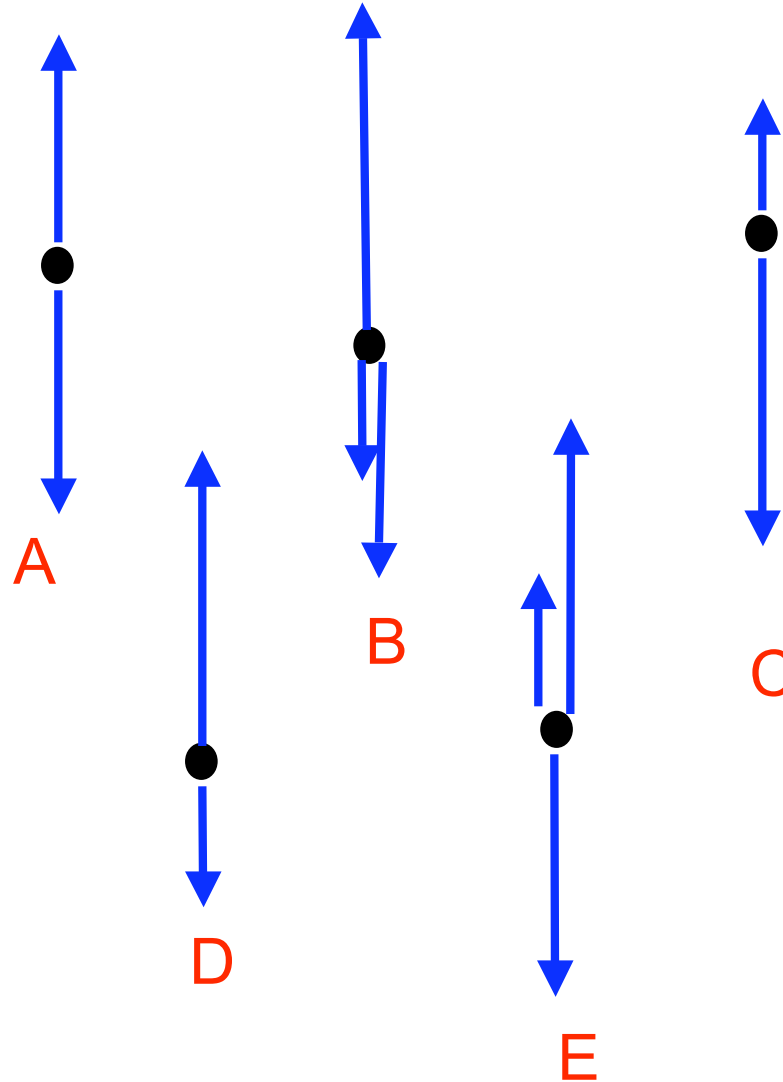
Linda stands in an elevator going down at $v_y = -2 \text{ m/s}$. It is slowing its descent at a rate $a_y = 1 \text{ m/s}^2$

Trickery



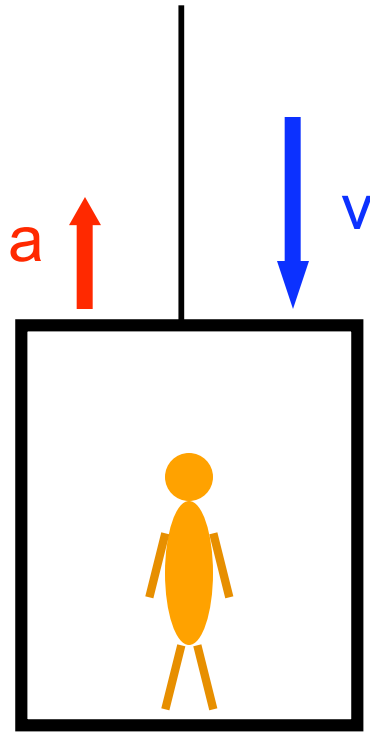
Linda stands in an elevator going down at $v_y = -2 \text{ m/s}$. It is slowing its descent at a rate $a_y = 1 \text{ m/s}^2$

Draw a FBD for Linda



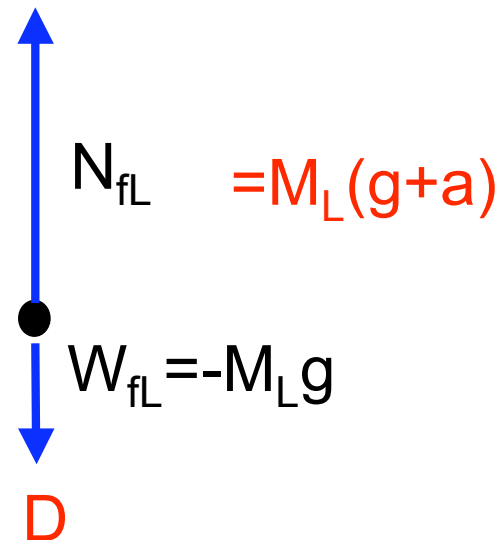
Trickery

Draw a FBD for Linda



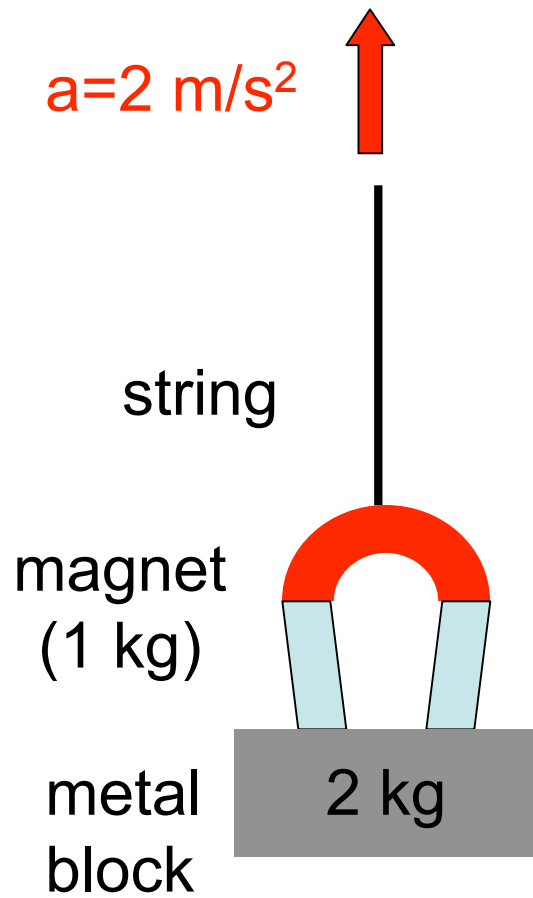
Linda stands in an elevator going down at $v_y = -2$ m/s. It slowing its decent at a rate $a_y = 1$ m/s²

$$\sum F_y = N_{fL} - M_L g = M_L a$$

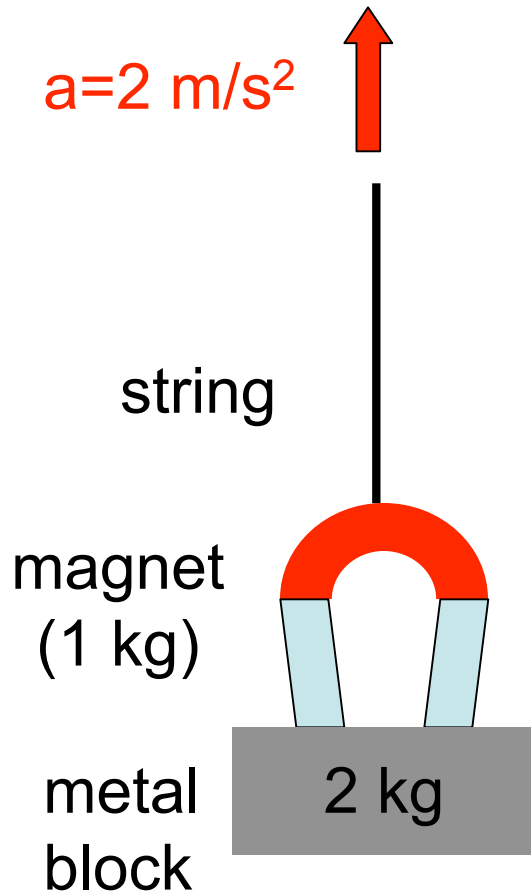


Different Forces

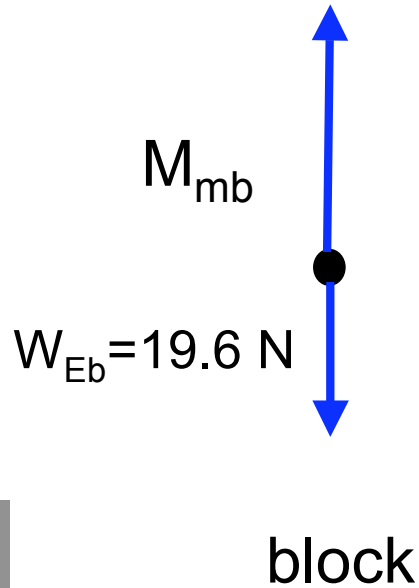
draw FBDs for block



Different Forces



draw FBDs for block



$M_{mb} =$

A 15.6 N

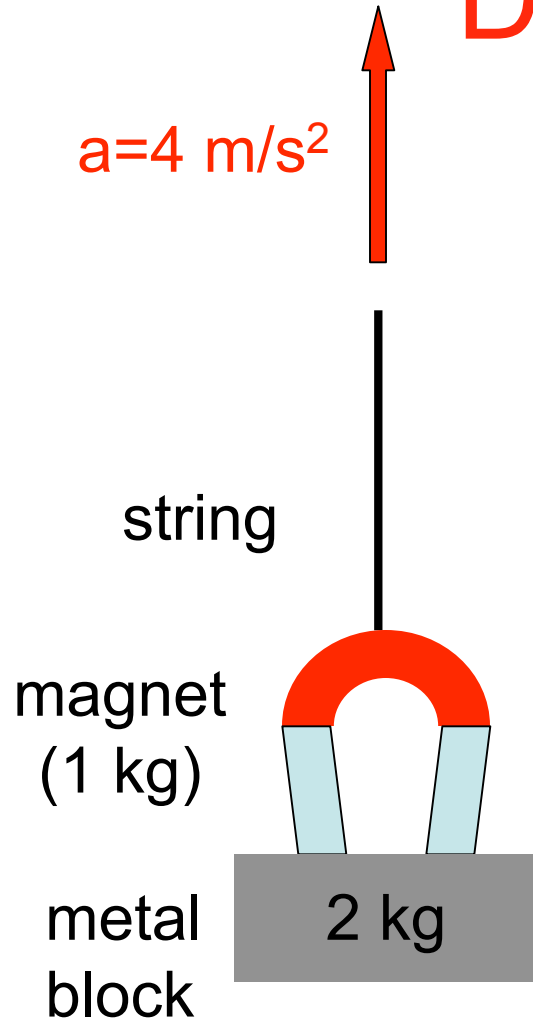
B 19.6 N

C 23.6 N

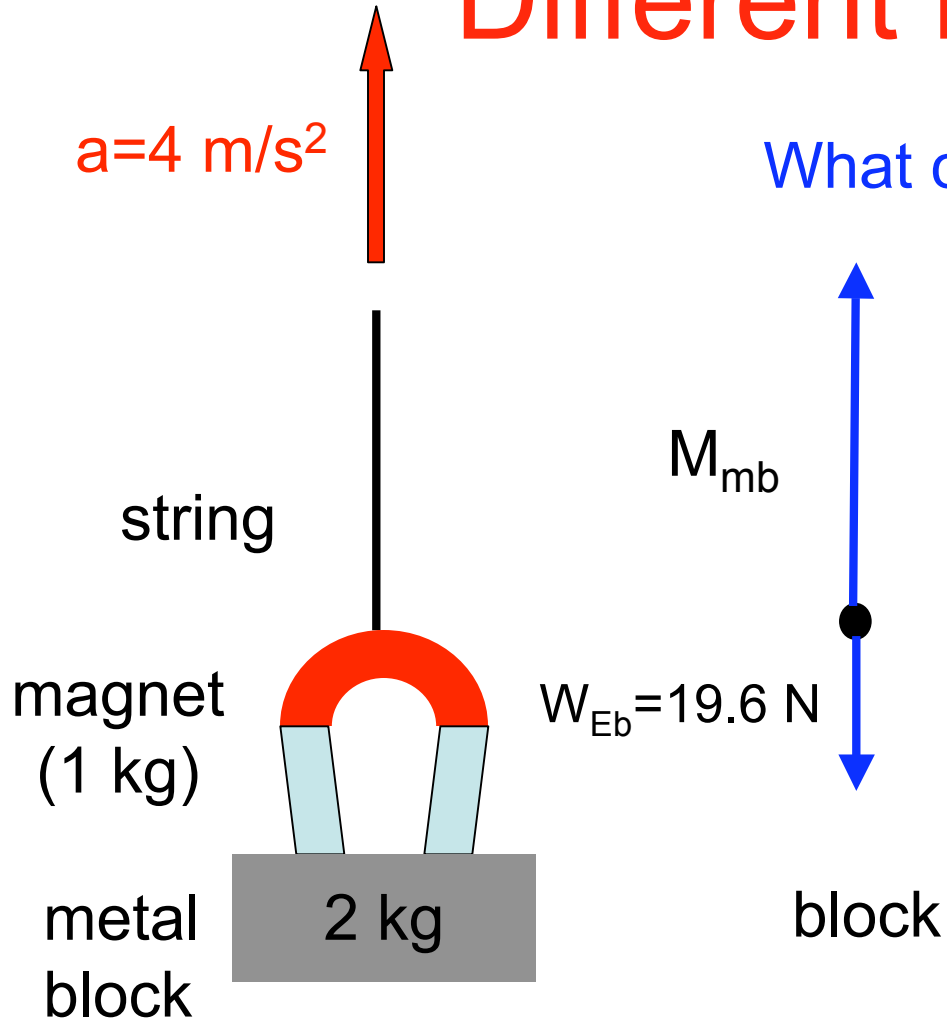
D don't know
formula for
magnetic force

Different Forces

What changes?



Different Forces



$$M_{mb} =$$

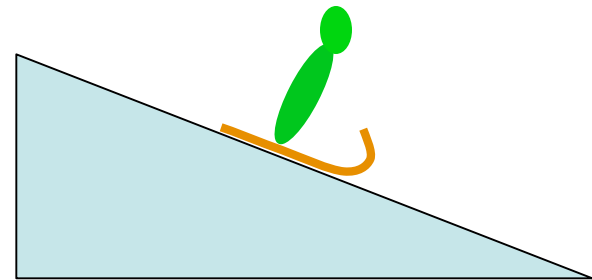
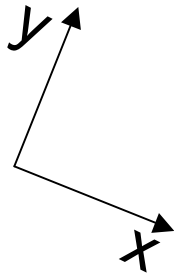
A 19.6 N

B 23.6 N

C 27.6 N

D 31.6 N

2d Example

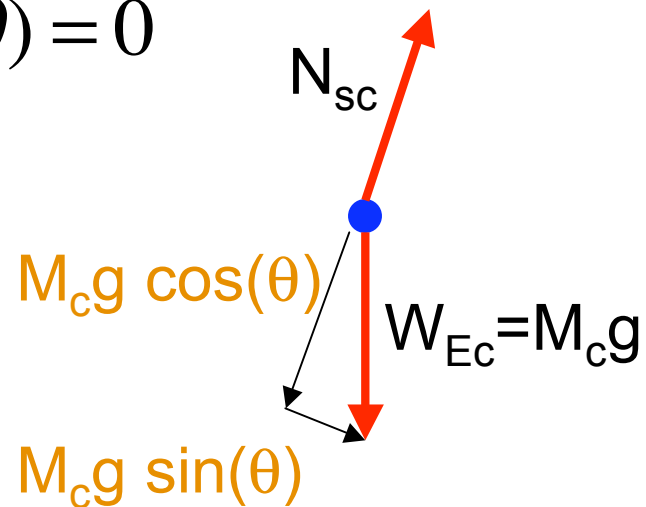


$$F_y = M_c a_y = N_{sc} - M_c g \cos(\theta) = 0$$

$$N_{sc} = M_c g \cos(\theta)$$

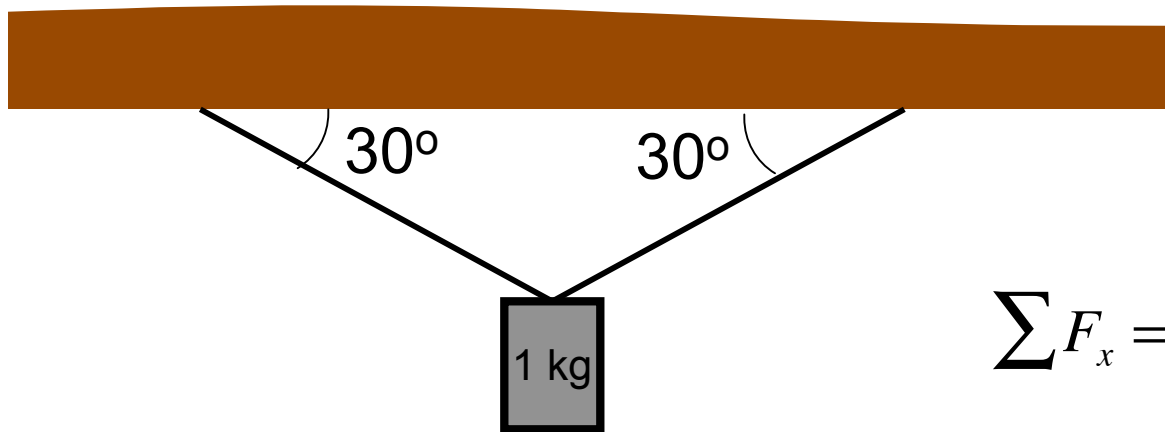
$$F_x = M_c a_x = M_c g \sin(\theta)$$

$$a_x = g \sin(\theta)$$



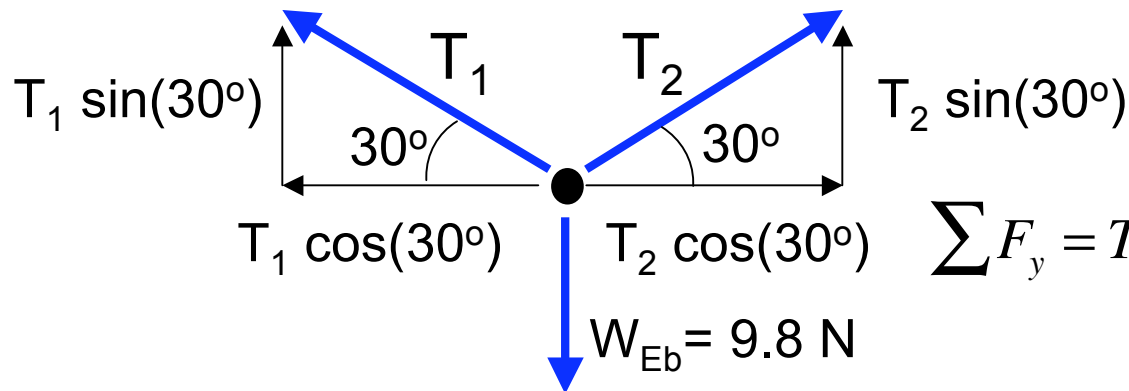
Carl+sled

Complicated 2d example



$$\sum F_x = T_2 \cos 30^\circ - T_1 \cos 30^\circ = 0$$

$$T_2 = T_1$$

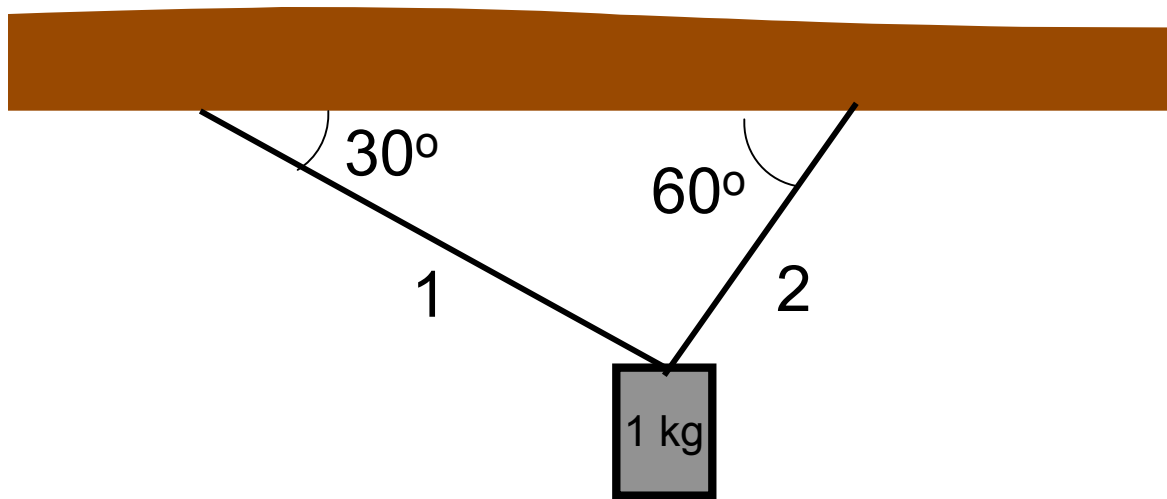


$$\sum F_y = T_2 \sin 30^\circ + T_1 \sin 30^\circ - 9.8 \text{ N} = 0$$

$$2T_1 \sin 30^\circ = 9.8 \text{ N}$$

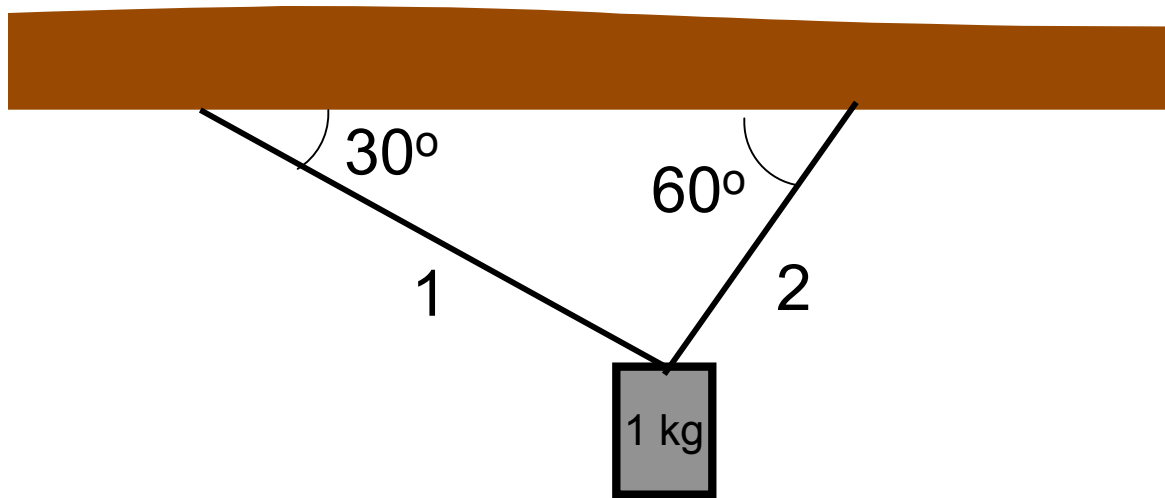
$$T_2 = T_1 = 9.8 \text{ N}$$

block



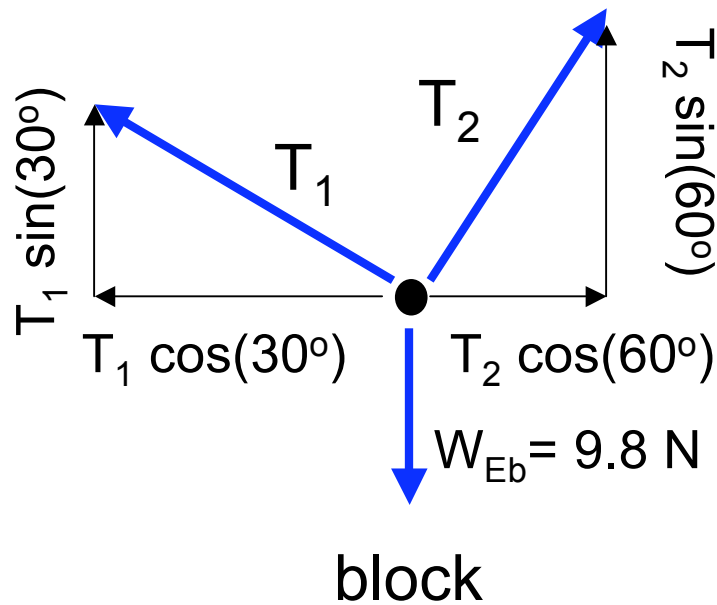
Which wire has greater tension?

- A $T_1 > T_2$
- B $T_1 = T_2$
- C $T_1 < T_2$
- D Cannot tell



Which wire has greater tension?

- A $T_1 > T_2$
- B $T_1 = T_2$
- C $T_1 < T_2$**
- D Cannot tell



$$\sum F_x = T_2 \cos 60^\circ - T_1 \cos 30^\circ = 0$$

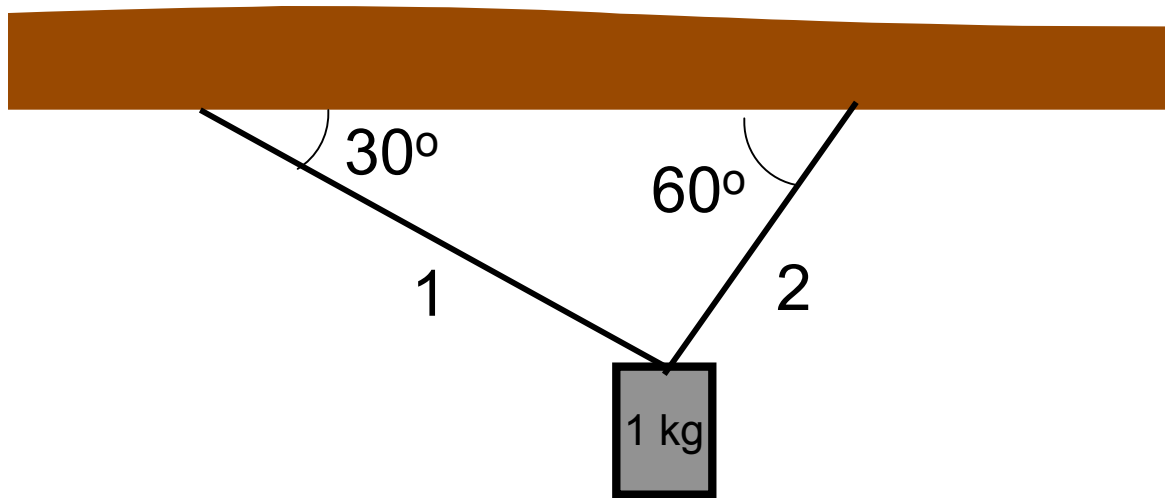
$$T_2 = \frac{\cos 30^\circ}{\cos 60^\circ} T_1 = \sqrt{3} T_1$$

$$\sum F_y = T_2 \sin 60^\circ + T_1 \sin 30^\circ - 9.8 \text{ N} = 0$$

$$(3T_1 + T_1)/2 = 9.8 \text{ N}$$

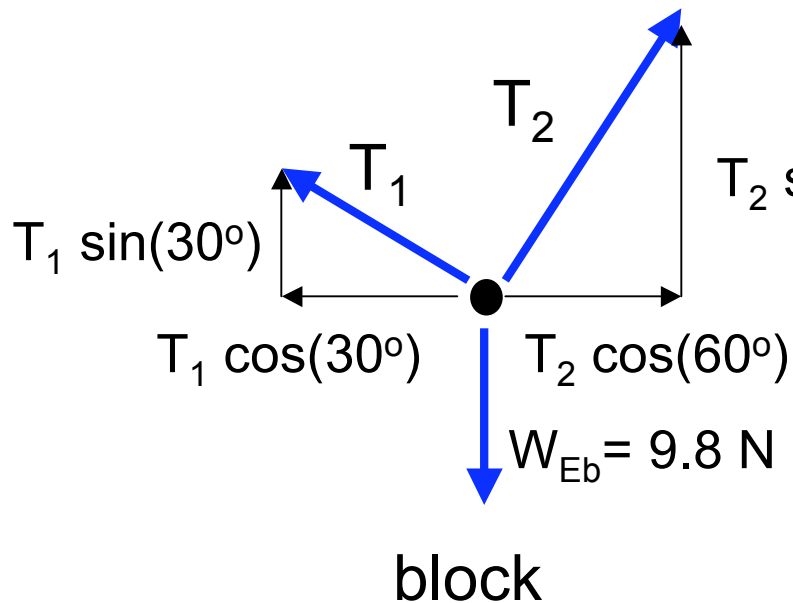
$$T_1 = 4.9 \text{ N}$$

$$T_2 = 8.5 \text{ N}$$



Which wire has greater tension?

- A $T_1 > T_2$
- B $T_1 = T_2$
- C $T_1 < T_2$**
- D Cannot tell



$$\sum F_x = T_2 \cos 60^\circ - T_1 \cos 30^\circ = 0$$

$$T_2 = \frac{\cos 30^\circ}{\cos 60^\circ} T_1 = \sqrt{3} T_1$$

$$\sum F_y = T_2 \sin 60^\circ + T_1 \sin 30^\circ - 9.8 \text{ N} = 0$$

$$(3T_1 + T_1)/2 = 9.8 \text{ N}$$

$$T_1 = 4.9 \text{ N}$$