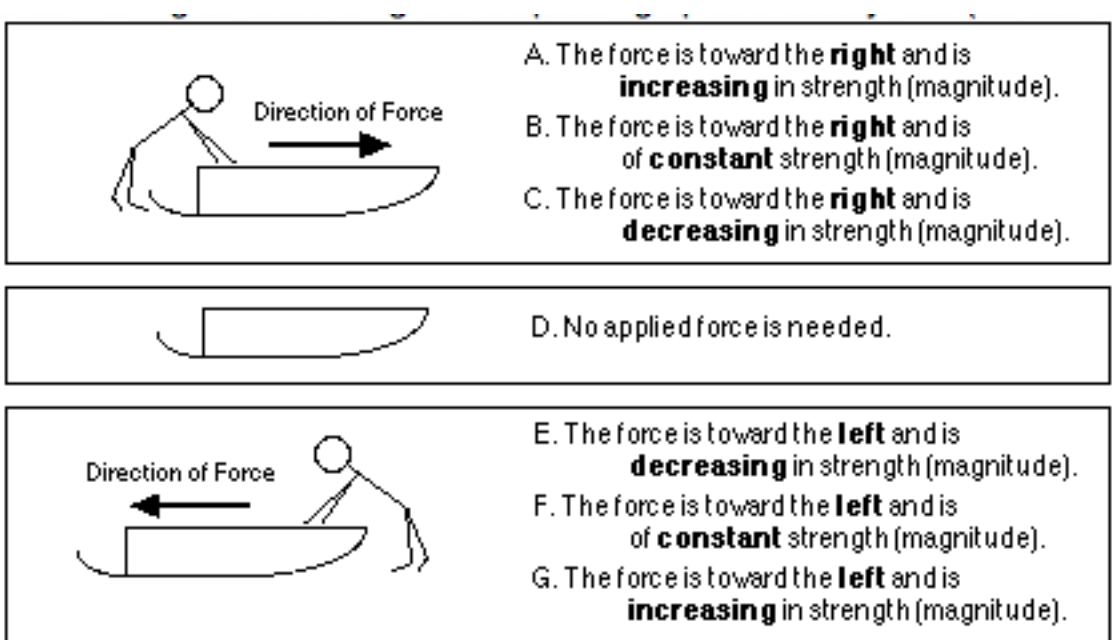
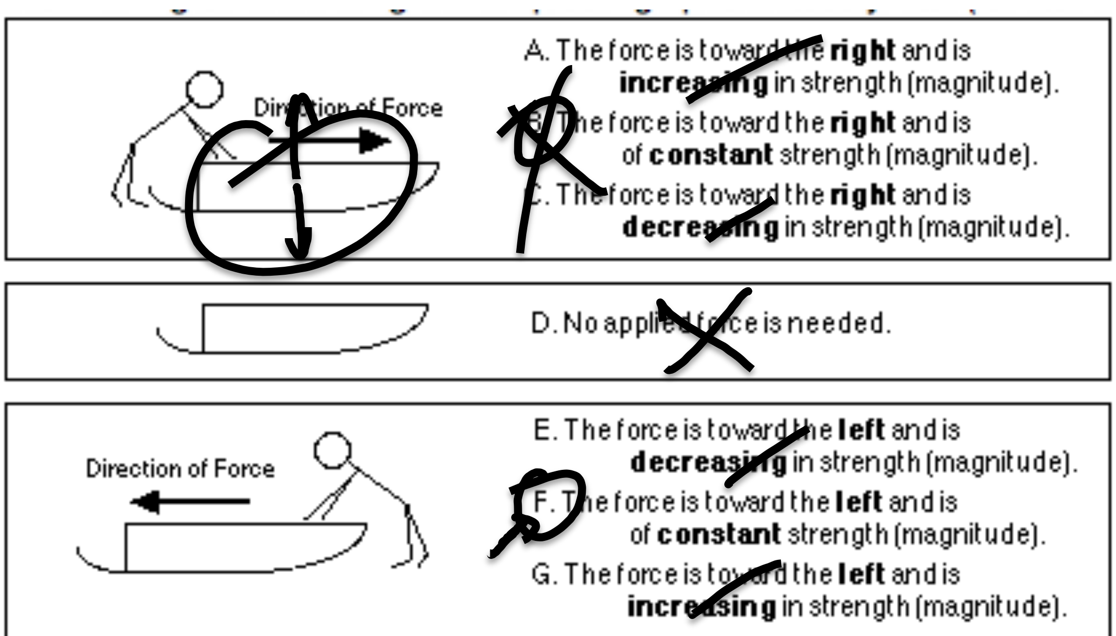
A sled on ice moves so friction is so small that it can be ignored. A person wearing spiked shoes standing on the ice can apply a force to the sled and push it along the ice. Choose the *one* force (or chose none) that would keep the sled moving as described in each statement below. Which force would keep the sled moving toward the left with (a) a constant acceleration (speeding up); (b) a constant velocity; (c) a constant acceleration (slowing down)?

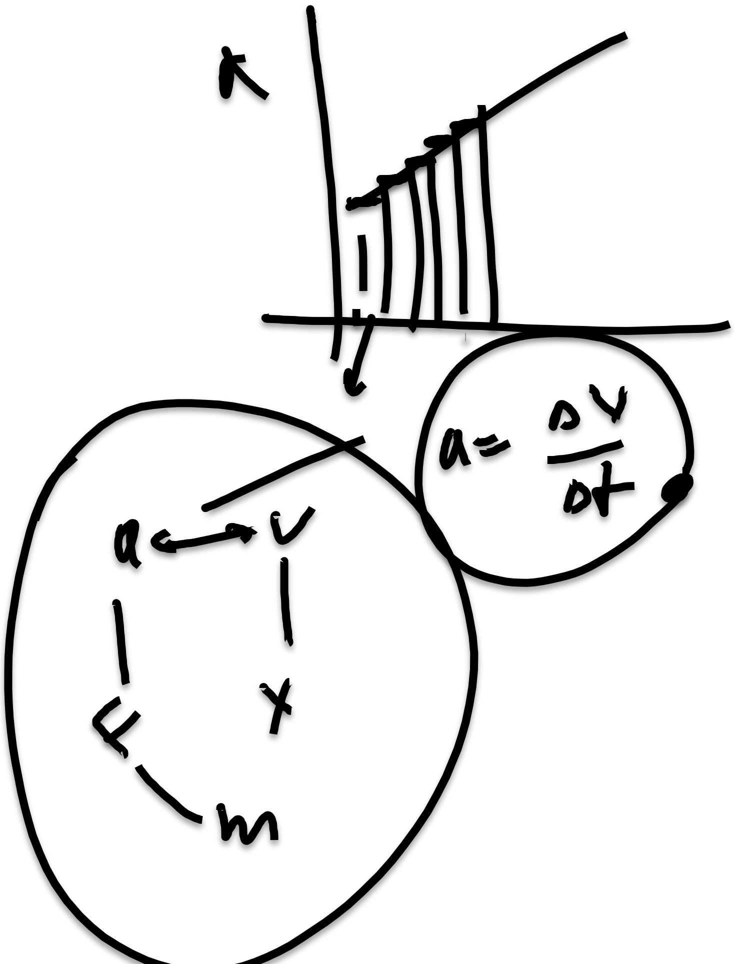


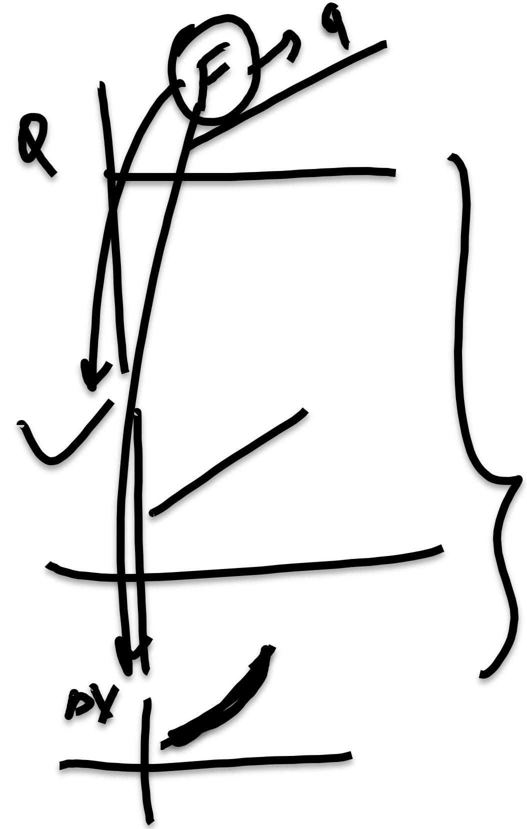
(b) a constant velocity;
(c) a constant acceleration (slowing down);

A sled on ice moves so friction is so small that it can be ignored. A person wearing spiked shoes standing on the ice can apply a force to the sled and push it along the ice. Choose the *one* force (or chose none) that would keep the sled moving as described in each statement below. Which force would keep the sled moving toward the left with (a) a constant acceleration (speeding up); (b) a constant velocity; (c) a constant acceleration (slowing down)?

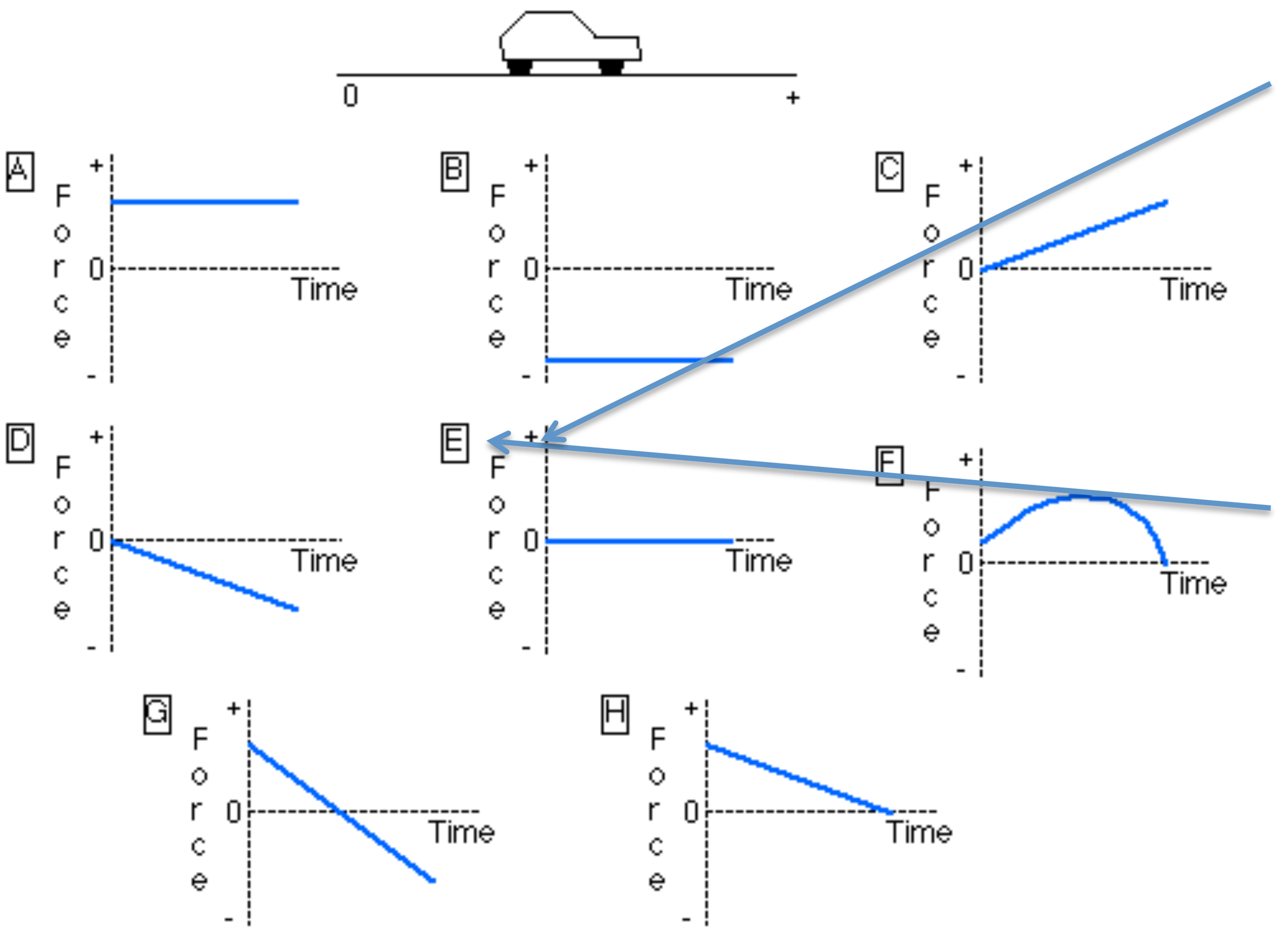


(b) a constant velocity;
(c) a constant acceleration (slowing down);


a
a = Δv/Δt
a
v
F
x
m


F
q
Q
v
Δv

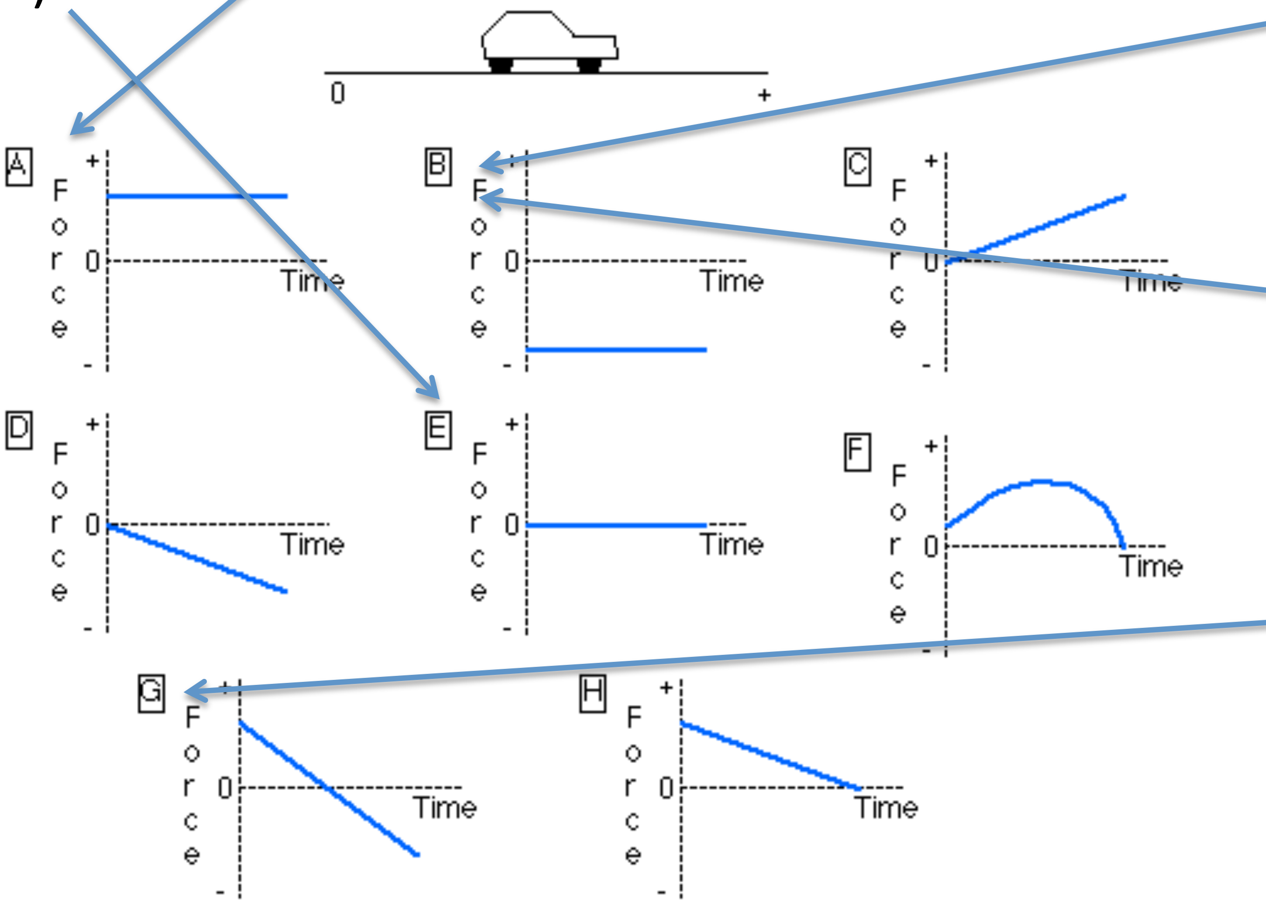
A toy car can move to the right or left along a horizontal line (friction can be ignored). A force is applied to the car. Choose the one force graph which could allow the described motion of the car to continue:



(a) The car moves toward the right (away from the origin) with a steady (constant) velocity.

(b) The car is at rest.

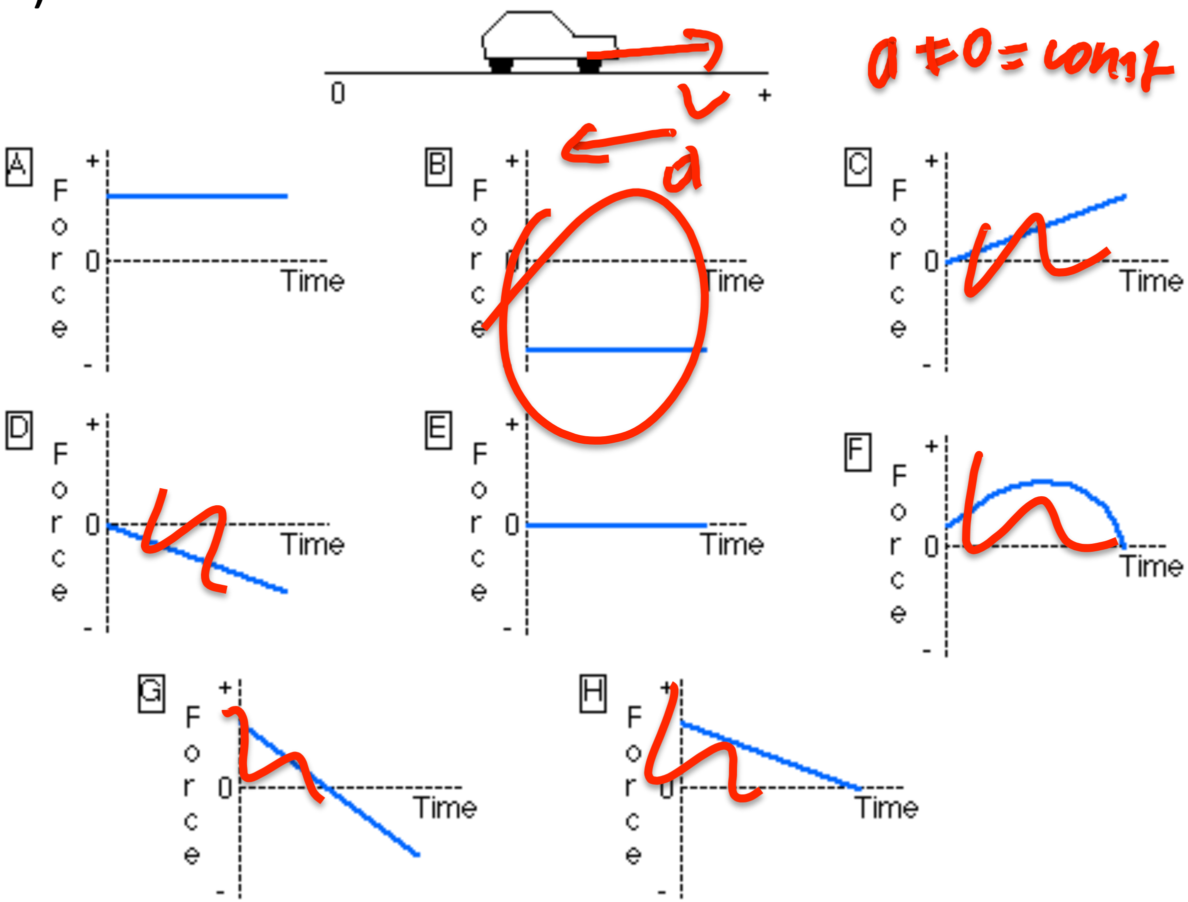
A toy car can move to the right or left along a horizontal line (friction can be ignored). A force is applied to the car. Choose the one force graph which could allow the described motion of the car to continue: (c) it moves to the right and is speeding up at a steady rate. (d) it moves toward the left with a constant velocity. (e) it moves to the right and is slowing down at a steady rate. (f) it moves to the left and is speeding up at a steady rate. (g) it moves to the right, speeds up and then slows down.



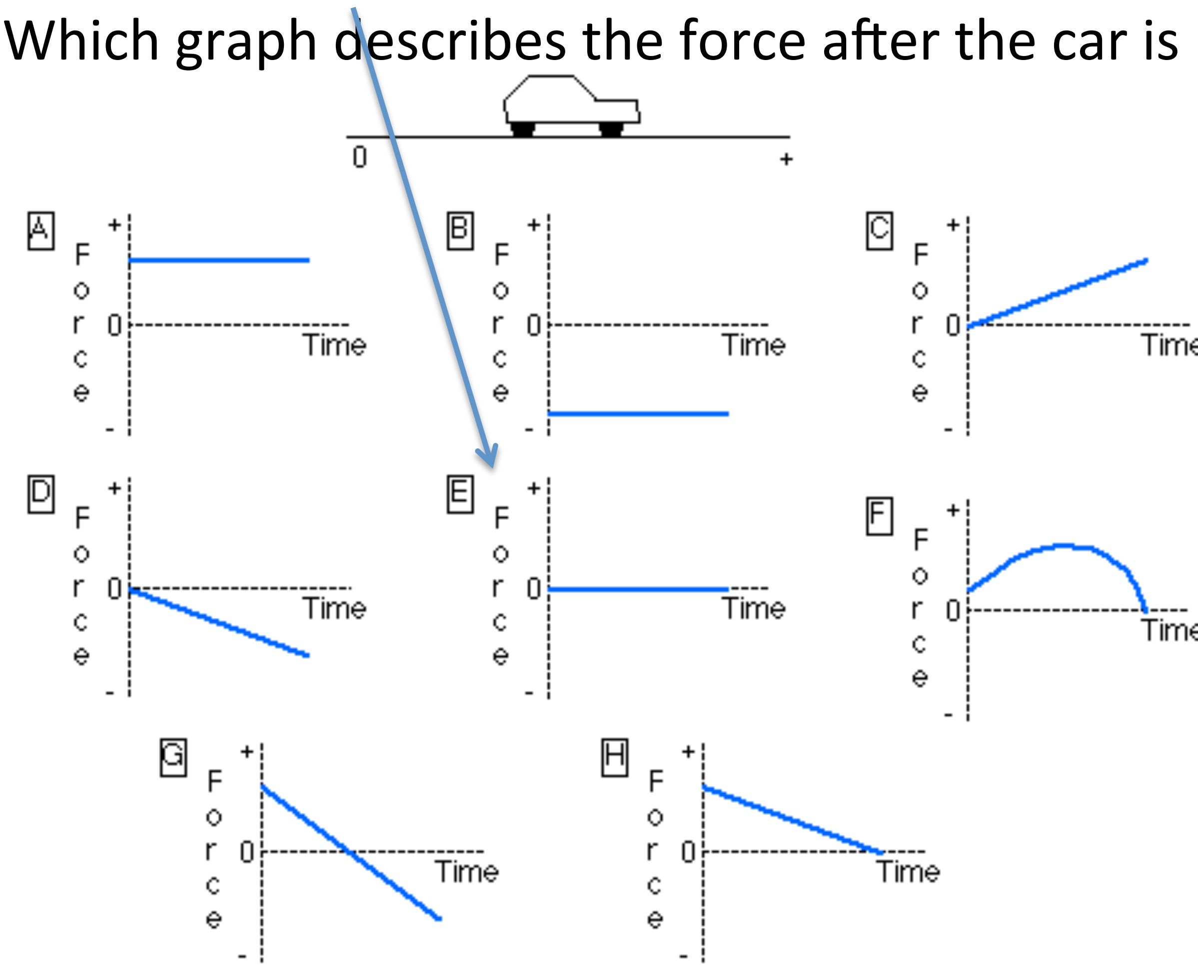
A toy car can move to the right or left along a horizontal line (friction can be ignored). A force is applied to the car. Choose the one force graph which could allow the described motion of the car to continue: (c) it moves to the right and is speeding up at a steady rate. (d) it moves toward the left with a constant velocity. (e) it moves to the right and is slowing down at a steady rate.

(f) it moves to the left and is speeding up at a steady rate.

(g) it moves to the right, speeds up and then slows down.



A toy car can move to the right or left along a horizontal line (friction can be ignored). A force is applied to the car. Choose the one force graph which could allow the described motion of the car to continue: (h) The car was pushed toward the right and then released. Which graph describes the force after the car is released?

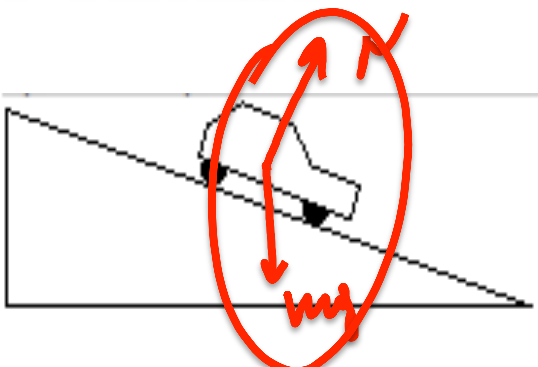


A toy car is given a quick push so it rolls up an inclined ramp. After it is released, it rolls up, reaches its highest point, and rolls back down again. Friction is so small it can be ignored. Describe the net force acting on the car when it: (a) is moving up the ramp just after it is released;

- A - Net constant force down ramp.
- B - Net increasing force down ramp
- C - Net decreasing force down ramp.
- D - Net force zero.
- E - Net constant force up ramp.
- F - Net increasing force up ramp.
- G - Net decreasing force up ramp
- J - None of the above.

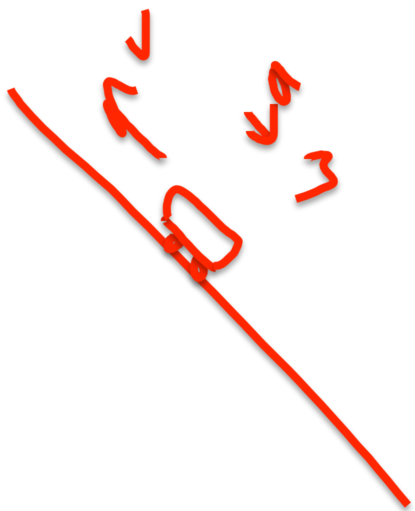
(b) The car is at its highest point.

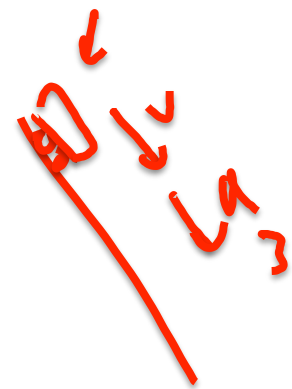
(c) The car is moving down the ramp.



direction of $\bar{a}$

$F_{net} = m a$





Newton's Second Law:

$$\mathbf{a} = \frac{\Sigma \mathbf{F}}{m}$$

In other words, an object's velocity changes at a rate that is given by the net force acting on the object divided by the object's mass.

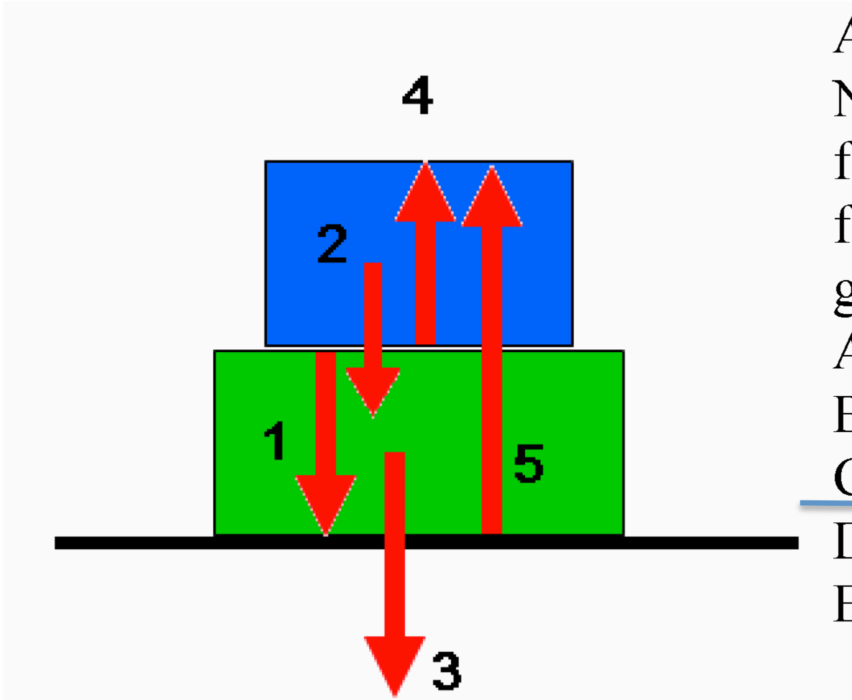
For problem solving: $\Sigma \mathbf{F} = m\,\mathbf{a}$

Newton’s Third Law

When one object exerts a force on a second object, the second object exerts a force of equal magnitude, in the opposite direction, on the first object.

Note that this law relates forces that are acting on different objects belonged to <u>different</u> free body diagrams.

Question



According to the third Newton's Law, which two forces represent a pair of forces acting between the green and blue boxes?

A. 1 and 2
B. 2 and 4
C. 1 and 4
D. 3 and 5
E. None of the above

Two students, student “a” who has mass of 95 kg and student “b” who has mass of 77 kg, sit in Identical office chairs (see the picture). When student “a” pushes on student “b”…

(A) neither student exerts a force on the other.

(B) Student “a” exerts a force on "b”, but "b” doesn't exert any force on "a".

(C) each student exerts a force on the other but "b" exerts the larger force.

(D) each student exerts a force on each other but ”a” exerts the larger force.

(E) each student exerts the same amount of force on the other.

There is a collision between a car and a truck. The truck is much heavier than the car. Describe the magnitude of the forces between the car and the truck for different cases. (a) They are both moving at the same speed when they collide.

A - The truck exerts a larger force on the car than the car exerts on the truck.
B - The car exerts a larger force on the truck than the truck exerts on the car.
C - Neither exerts a force on the other; the car gets smashed simply because it is in the way of the truck.
D - The truck exerts a force on the car but the car doesn't exert a force on the truck.
E - The truck exerts the same amount of force on the car as the car exerts on the truck.
F - Not enough information is given to pick one of the answers above.
J - None of the answers above describes the situation correctly.

There is a collision between a car and a truck. The truck is much heavier than the car. Describe the magnitude of the forces between the car and the truck.

(b) The car is moving much faster than the truck when they collide .

(c) The truck is standing still when the car hits it.

A - The truck exerts a larger force on the car than the car exerts on the truck.

B - The car exerts a larger force on the truck than the truck exerts on the car.

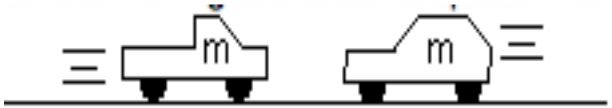
C - Neither exerts a force on the other; the car gets smashed simply because it is in the way of the truck.

D - The truck exerts a force on the car but the car doesn't exert a force on the truck.

E - The truck exerts the same amount of force on the car as the car exerts on the truck.

F - Not enough information is given to pick one of the answers above.

J - None of the answers above describes the situation correctly.



There is a collision between a car and a truck. The truck has the same weight as the car. Describe the magnitude of the forces between the car and the truck.

(a) Both the truck and car are moving at the same speed when they collide.

(b) The truck is standing still when the car hits it.

A - The truck exerts a larger force on the car than the car exerts on the truck.

B - The car exerts a larger force on the truck than the truck exerts on the car.

C - Neither exerts a force on the other; the car gets smashed simply because it is in the way of the truck.

D - The truck exerts a force on the car but the car doesn't exert a force on the truck.

E - The truck exerts the same amount of force on the car as the car exerts on the truck.

F - Not enough information is given to pick one of the answers above.

J - None of the answers above describes the situation correctly.

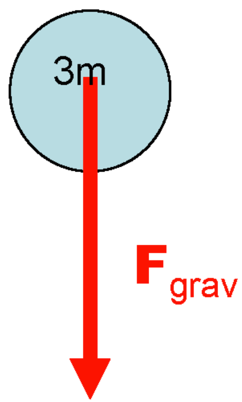
Dropping two objects

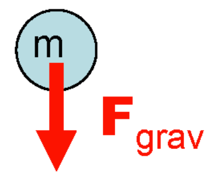
The mass of a baseball is about 2.5 times larger than that of a tennis ball. When they are released simultaneously from rest from the same height, which ball reaches the ground first?

1. The baseball.
2. The tennis ball.
3. Neither – they reach the ground at the same time.

Falling objects, different mass

Sketch two free-body diagrams for two objects, one with three times the mass of the other, as the objects fall.





In free fall, $\Sigma \mathbf{F} = \mathbf{F}_{\mathbf{gravity}}$ = Mg **down**

However $\Sigma \mathbf{F} = M\mathbf{a}$, so the M's cancel

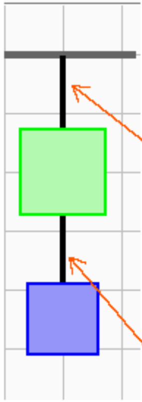
and $\mathbf{a} = g$ **down**,

independent of the mass.

A boy throws a coin straight up. Disregarding any effects of air resistance, describe the force(s) acting on the coin until it returns to the ground, when the coin is: (a) moving upward after it is released; (b) at its highest point; (c) moving downward.

A - The force is down and constant.
B - The force is down and increasing.
C - The force is down and decreasing.
D - The force is zero.
E - The force is up and constant.
F - The force is up and increasing.
G - The force is up and decreasing.
J - None of the above.

Tension



When an object is suspended by a string or rope there is a force of tension in the rope that transmits the force exerted at one end of the rope to the other end.

This force is usually labeled **T** or $\mathbf{F}_T$.

We usually assume that the rope has *no mass*, and *does not stretch* (so, it is *not* a spring or a rubber cord).

One rule to remember - you *can't* push with a rope. The tension force always goes along a string or rope away from the object attached to it.

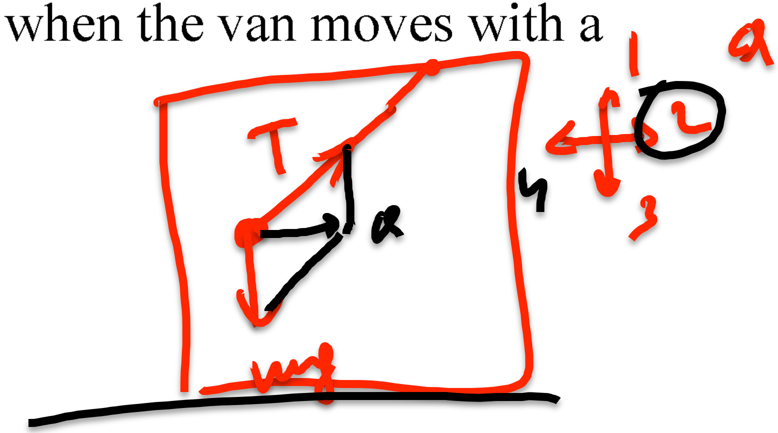
Is the tension 1 equal to the tension 2?

A Problem

A small sphere is hung by a string from the ceiling of a van. When the van is stationary, the sphere hangs vertically. However, when the van accelerates, the sphere swings backward so that the string makes an angle of 10.0° with respect to the vertical.

(1) Find the acceleration of the van.

(2) What is the value of the angle when the van moves with a constant velocity?



A. Still 10.0°

B. It is slightly smaller then 10.0°

C. It is 0

D. It is slightly larger then 0

E. Impossible to answer

A Problem

A small sphere is hung by a string from the ceiling of a van. When the van is stationary, the sphere hangs vertically. However, when the van accelerates, the sphere swings backward so that the string makes an angle of 45^0 with respect to the vertical.

(1) Find the acceleration of the van. **$a = g$**

(2) What is the value of the angle when the van moves with a constant velocity?

A. Still 45^0

B. It is slightly smaller then 45^0

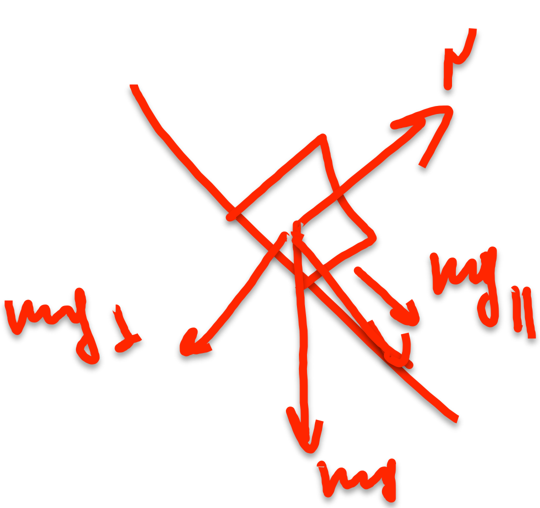
C. It is 0 **($a = 0$!)**

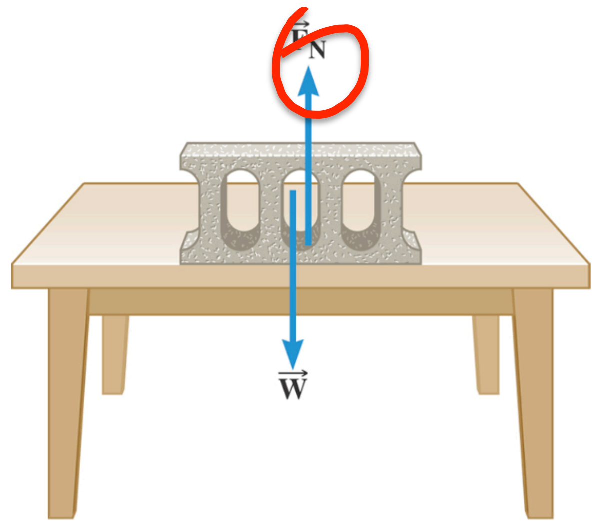
D. It is slightly larger then 0

E. Impossible to answer

Definition of the Normal Force

The normal force is one component of the force that a surface exerts on an object with which it is in contact – namely, the component that is perpendicular
to the surface.





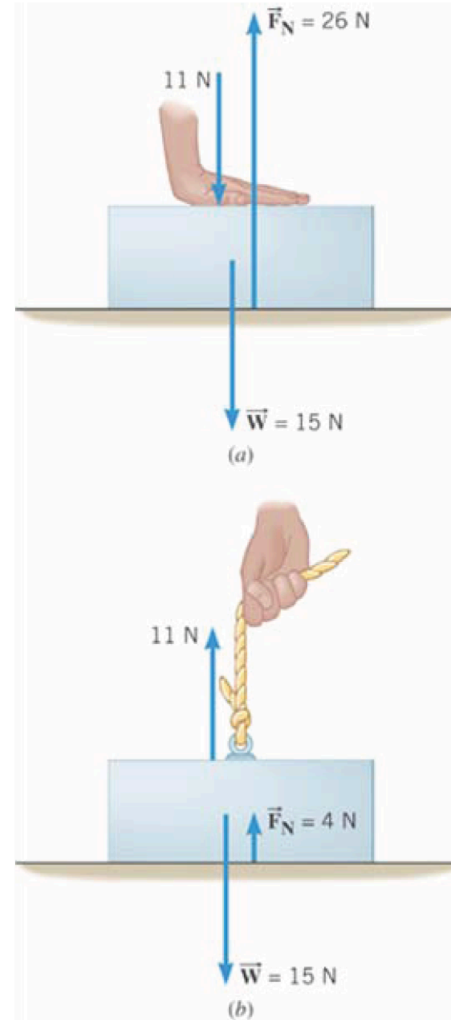
The Normal Force

$$F_N - 11\text{ N} - 15\text{ N} = 0$$

$$F_N = 26\text{ N}$$

$$F_N + 11\text{ N} - 15\text{ N} = 0$$

$$F_N = 4\text{ N}$$



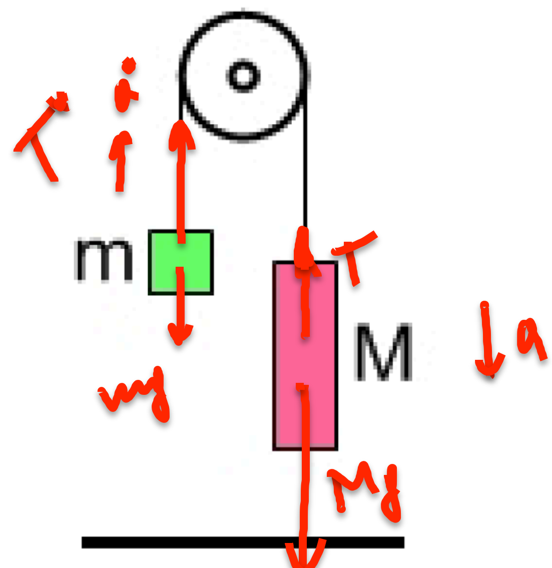
Atwood's machine

Atwood's machine involves one pulley, and two objects connected by a string that passes over the pulley. In general, the two objects have different masses.

$Mg - T = Ma$

$-mg + T = ma'$

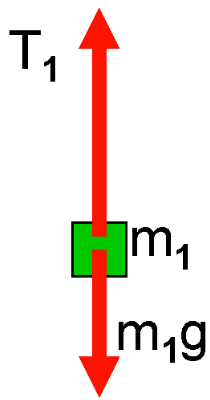
$-mg + T = ma$

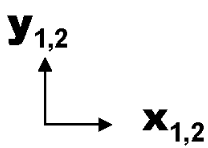


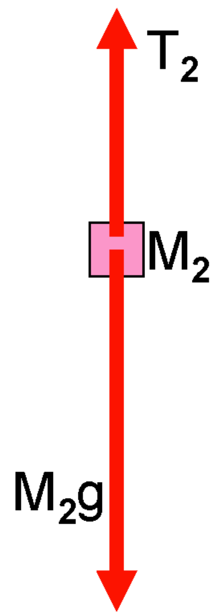
$a = a'$

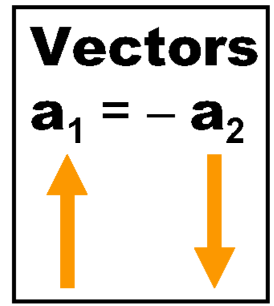
$T' = T$

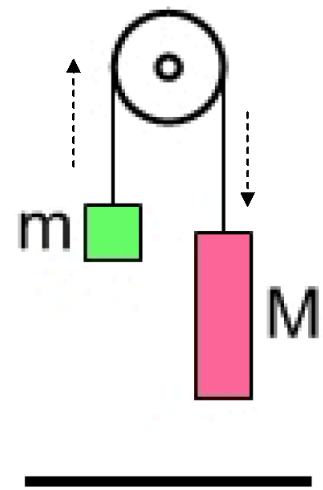
Dealing with pulleys











I choose to use same coordinate system for both

$$T - m_1 g = m_1 a$$

$$T - M_2 g = M_2(-a)$$

$$(M_2 - m_1) g = (M_2 + m_1) a$$

Everything in the x direction is zero. Just do equations for y.

String: $T_{1y} = T \qquad a_{1y} = +a$

$T_{2y} = T \qquad a_{2y} = -a$

Gravity: $W_{1y} = -m_1 g$

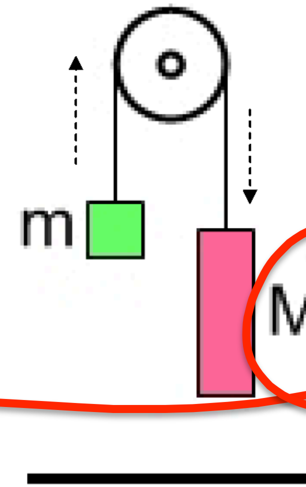
$W_{2y} = -M_2 g$

Dealing with pulleys

$y_{1,2}$ $x_{1,2}$

Vectors

$\mathbf{a_1 = -a_2}$



$$(M_2 - m_1)g = (M_2 + m_1)a,$$

so that

$$\frac{(M_2 - m_1)}{(M_2 + m_1)} g = a$$

$$\frac{2m - m}{2m + m} \cdot g = a$$

$$\frac{m}{3m} g = a$$

$$a = \frac{g}{3}$$

For M > m, a > 0, and m accelerates **up.**

For M = m, a = 0, and m moves with constant velocity up or down, including remaining at rest.

For M < m, a < 0, and m accelerates **down**.

If m = 0, $a_{2y} = -g$, and M falls freely.

Limiting cases:

$$a = \frac{M - m}{M + m} g$$

- m = M then a = 0. Makes sense - the system is balanced.

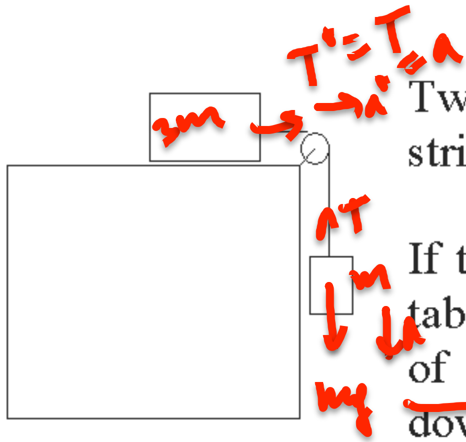
- m = 0 then a = g. M is in freefall.

- If m > M then *a* is negative - the system goes the other way.

Numerical example: M = 210 g and m = 200 g.

$$a = \frac{10}{410} * g = 0.24 \text{ m/s}^2$$

Example



Two blocks are connected by a massless unstretchable string going over the massless frictionless pulley.

If the bigger block (which is sliding on the top of the table with no force of friction acting on it) has the mass of 3 times of the mass of the smaller block (hanging down on the string); try to find:

the acceleration of the big block

the acceleration of the small block

the tension in the string (use $g = 10\ m/s^2$)

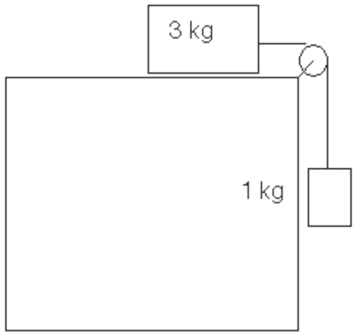
$T = 3m \cdot a$

$mg - T = ma$

$mg - 3ma = ma$

$a = \frac{g}{4}$

Example



Two blocks are connected by a massless unstretchable string going over the massless frictionless pulley.

If the bigger block (which is sliding on the top of the table with no force of friction acting on it) has the mass of 3 times of the mass of the smaller block (hanging down on the string); try to find:

The blocks have the same acceleration!

the acceleration of the big block

$3*a = T$

the acceleration of the small block

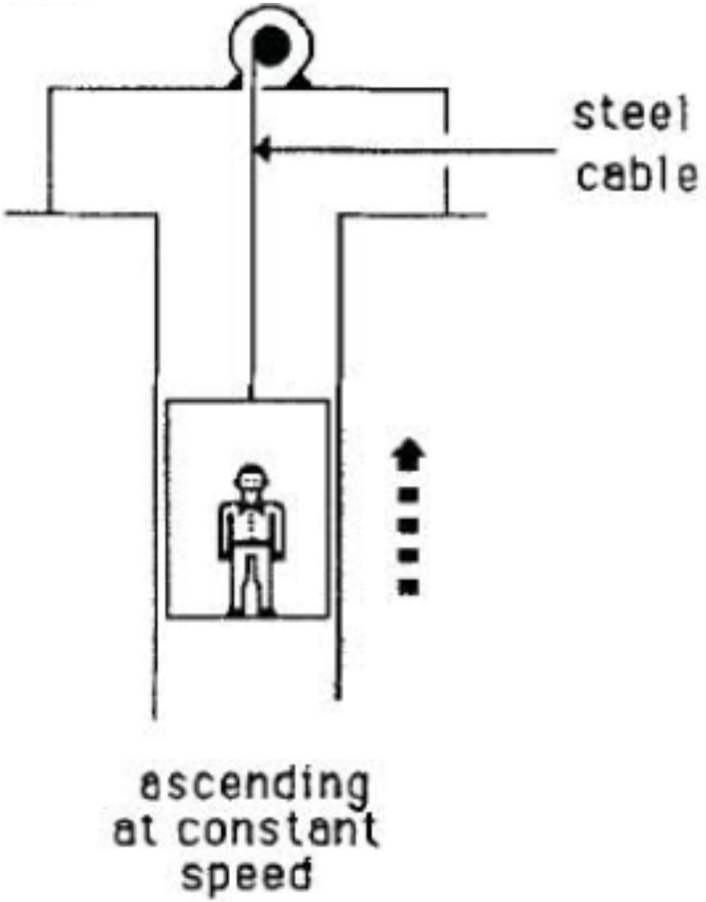
$1*10 - T = 1*a$

$\Rightarrow \quad a = 10/4 = 2.5 \text{ m/s}^2$

the tension in the string (use $g = 10 \text{ m/s}^2$)

$T = 7.5 \text{ N}$

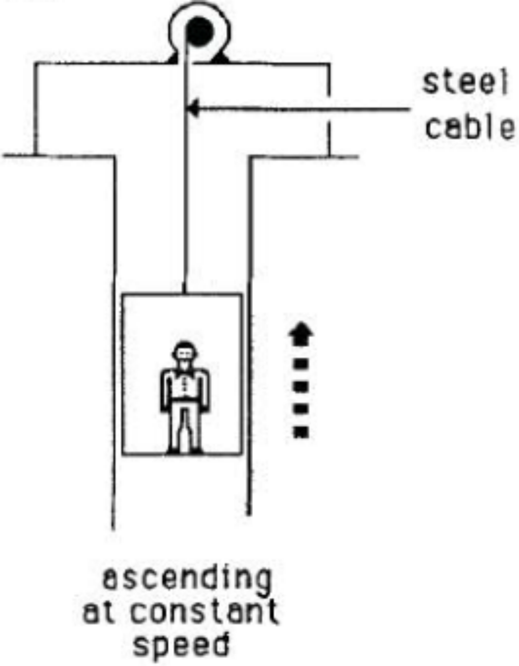
Work together – Elevator Physics



Does the cable exert a force on you?

1. Yes (and it is very painful)

2. No (the cable does not touch me)



An elevator is being lifted up with a constant velocity by a steel cable . Ignoring the effects of friction

(A) the upward force on the elevator by the cable is greater than the downward force of gravity.

(B) the amount of upward force on the elevator by the cable equals to that of the downward force of gravity.

(C) the upward force on the elevator by the cable is Jess than the downward force of gravity.

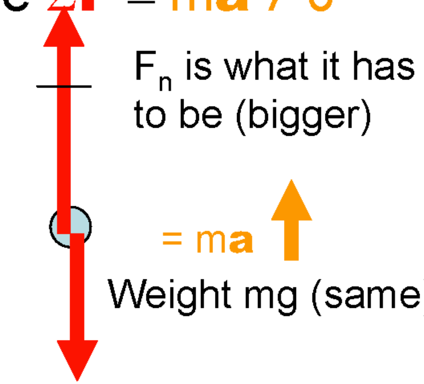
(D) it goes up because the cable is being shortened, not because of the force being exerted on the elevator by the cable.

(E) the upward force on the elevator by the cable is greater than the downward force due to the combined effects of air pressure and the force of gravity.

An elevator of mass M contains a person of mass m, and is suspended by a cable with tension T.

If the elevator has $a \neq 0$ (up) Therefore $\Sigma \mathbf{F} = m\mathbf{a} \neq 0$

1) Free body diagram for you as a separate object. →



Eqn 1:

$$F_n - mg = ma \neq 0$$

$$F_n = mg + ma$$

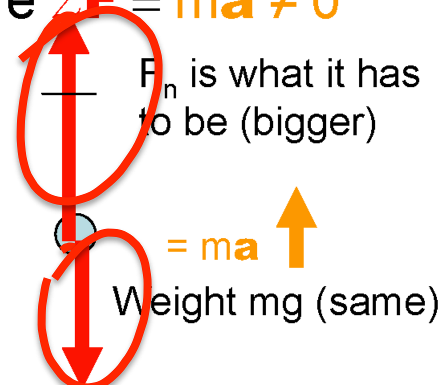
Put all forces on free body diagram; set equal to separate diagram of ma

Keep the **Forces** on one side and the "ma" on the other!

1. <90 2. 90 3. >90

An elevator of mass M contains a person of mass m, and is suspended by a cable with tension T.
If the elevator has $a \neq 0$ (up) Therefore $\Sigma \mathbf{F} = ma \neq 0$

1) Free body diagram for you as a separate object.



Eqn 1: $F_n - mg = ma \neq 0$

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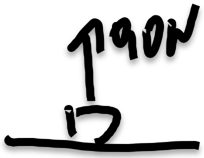
Put all forces on free body diagram; set equal to separate diagram of ma

Keep the **Forces** on one side and the "ma" on the other!



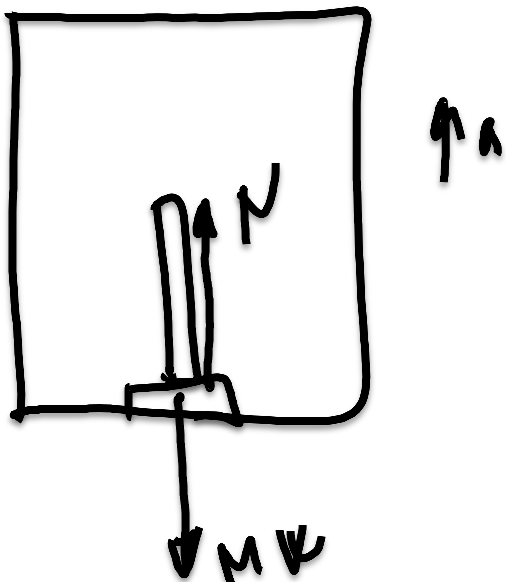
$N_{rest} = W = mg$

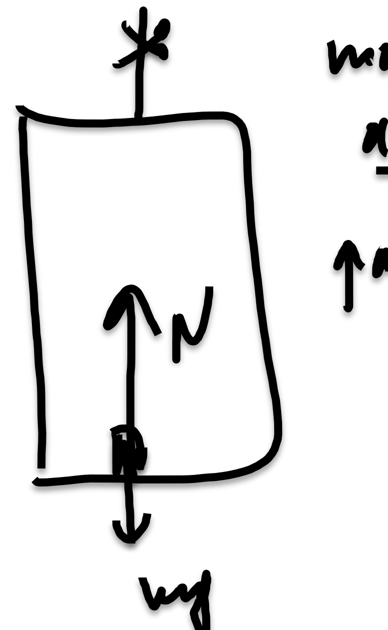
$MW = N$

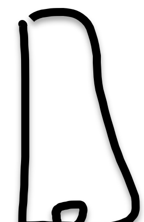
$N = mg + ma$

$ma = N - mg$

$a > 0 \Rightarrow N > mg$



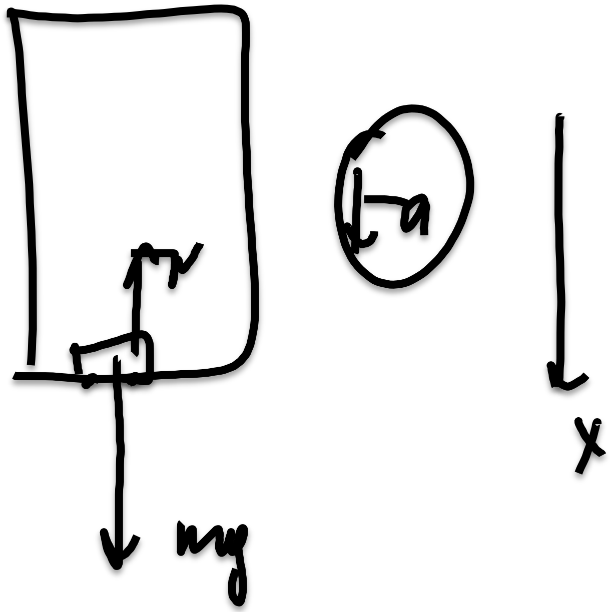




const v $\Rightarrow a = 0$

$\Rightarrow N = mg$

read 9D



$ma = mg - N$

$N = mg - ma$

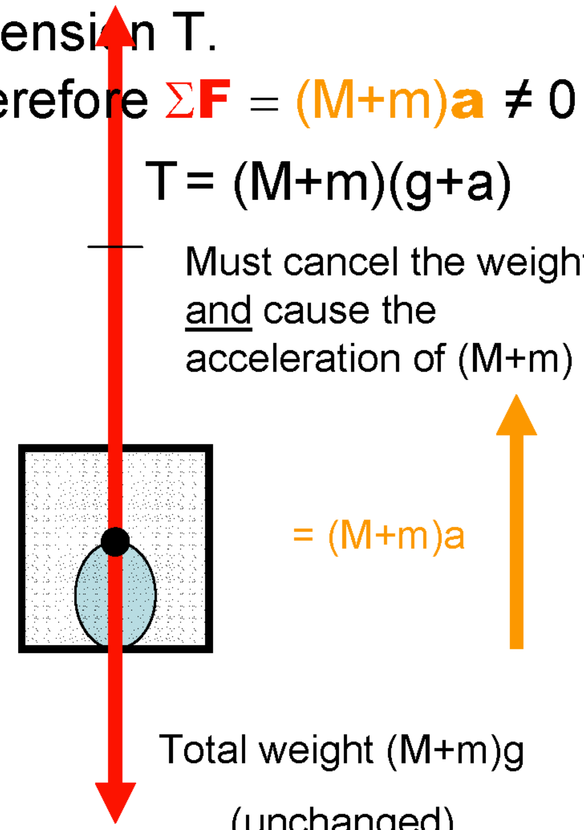
Free fall: $a = g$

$N = mg - mg = 0$

An elevator of mass M contains a person of mass m, and is suspended by a cable with tension T.

If the elevator has $a \neq 0$ (up) Therefore $\Sigma \mathbf{F} = (M+m)\mathbf{a} \neq 0$

2) For you and the elevator as one object.



Eqn 2: $T - (M+m)g = (M+m)a \neq 0$

$$T = (M+m)g + (M+m)a$$

$$T = (M+m)(g+a)$$

Normal Force and Apparent Weight

Objects in contact generally exert forces on one another. A book rests on a table: the book exerts a downward force on the table, and the table exerts an upward force on the book. We call this the normal force - "normal" is the technical physics word for perpendicular.

The normal force is perpendicular to the interface where the objects are in contact.

The normal force is one component of the *contact force between objects*, the other component being **the frictional force**. The normal force is usually symbolized by **N** or $\mathbf{F_N}$. The force of friction is noted as $\mathbf{F_{fr}}$.

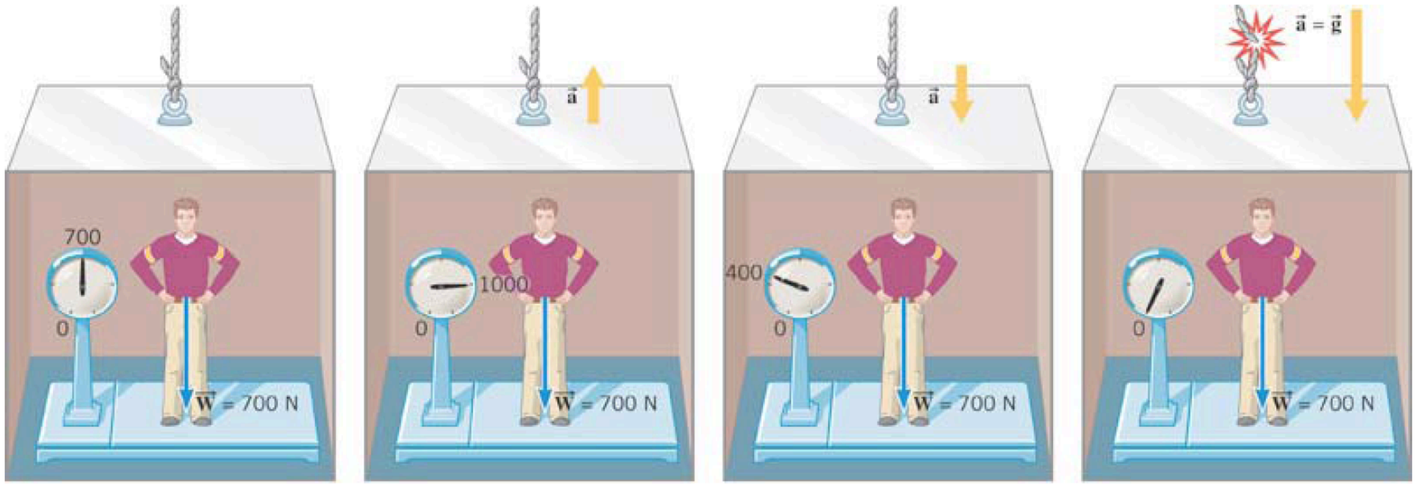
When objects loose contact with one another
the normal force goes to zero.

Apparent Weight of an object is the force acting from the object on the support. $|\mathbf{AW}| = |\mathbf{N}|$ (The III N L)

Apparent Weight

The apparent weight of an object is the reading of the scale.

It is equal to the normal force the man exerts on the scale.



(a) No acceleration ($\vec{v}$ = constant) (b) Upward acceleration (c) Downward acceleration (d) Free-fall

Find the acceleration!

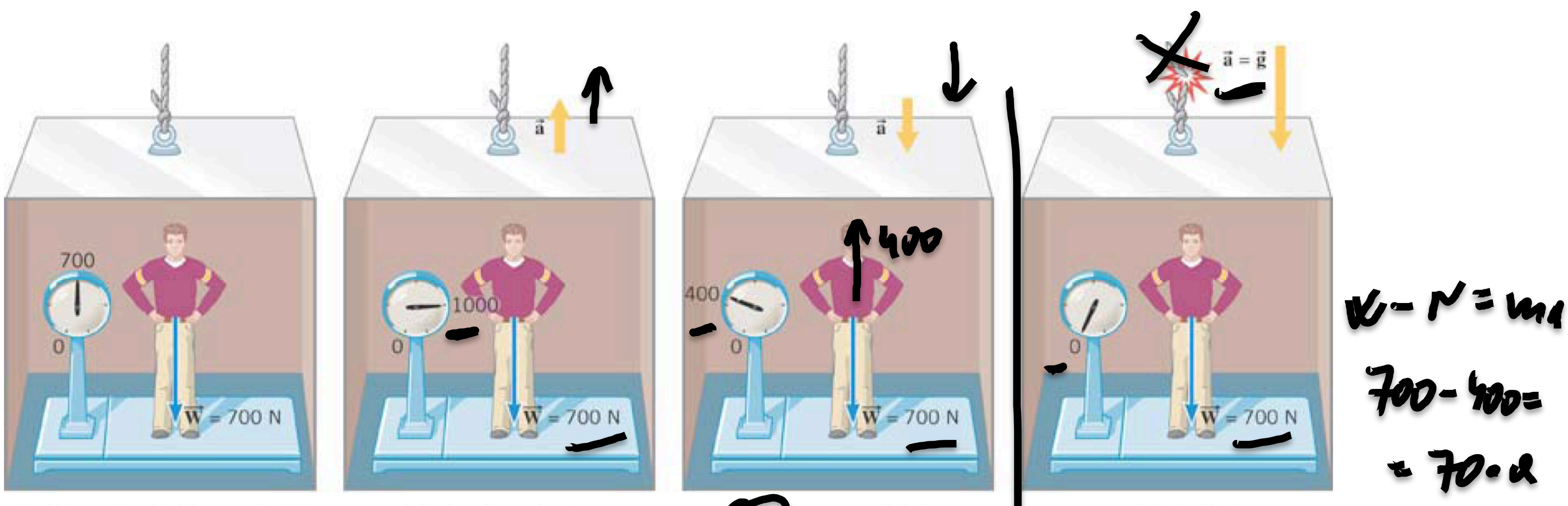
The Normal Force

$700N = m \cdot g = m \cdot 10 \Rightarrow m = 70kg$

Apparent Weight

The apparent weight of an object is the reading of the scale.

It is equal to the normal force the man exerts on the scale.



(a) No acceleration (v⃗ = constant) (b) Upward acceleration (c) Downward acceleration (d) Free-fall

Find the acceleration!

A question

A 10-kg suitcase is placed on a scale that is in an elevator. Is the elevator accelerating up or down when the scale reads (a) 75 N and (b) 120 N?

A. it depends on what is in that suitcase.
B. up when 75 N and down when 120 N
C. down when 75 N and up when 120 N
D. up in both cases
E. down in both cases

Is the elevator moving *up* or *down*?

1. **Up**
2. **Down**
3. **Not sure**

A question

1. A 10-kg suitcase is placed on a scale that is in an elevator. Is the elevator accelerating up or down when the scale reads (a) 75 N and (b) 120 N?

A. it depends on what is in that suitcase.
B. up when 75 N and down when 120 N
C. down when 75 N and up when 120 N
D. up in both cases
E. down in both cases

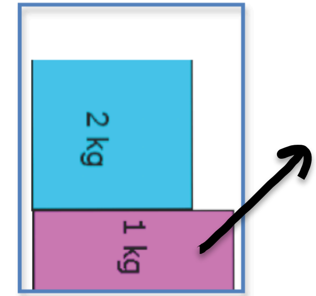
Does it *move* up or down (in both cases)?

We do NOT know, because the velocity can be directed in ANY direction!

Example

Physics of elevators.

Let's put the same two blocks in an elevator.



Find all possible forces when the elevator is:

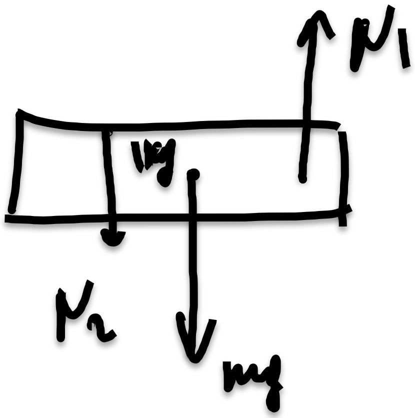
a) moving up with constant velocity

b) moving down with constant velocity

c) moving up with constant acceleration of 2 m/s^2 (what can we say about its velocity?)

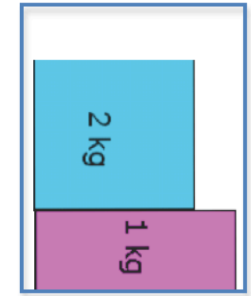
d) moving up with constant acceleration of 2 m/s^2 (what can we say about its velocity?)

$\uparrow a = 2\,m/s^2$



$$ma = N_1 - N_2 - mg$$

Example



Physics of elevators.

Let's put the same two blocks in an elevator.

Find all possible forces when the elevator is:

a) moving up with constant velocity

when v = const => a = 0 !

b) moving down with constant velocity

c) moving up with constant acceleration of 2 m/s^2 (what can we say about its velocity?)

a = 2 m/s^2 **v (speeding up)**

d) moving up with constant acceleration of -2 m/s^2 (what can we say about its velocity?)

a = - 2 m/s^2 **v (slowing down)**