KEY

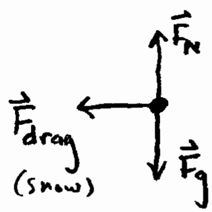
Qualitative Force Problems

1. For the following situations, draw free-body diagrams to indicate all forces acting on the object(s) in question. *Indicate relative magnitudes of forces by drawing long, short, or equal-length vectors.*

(a) An elevator suspended by a cable is descending at a constant velocity.

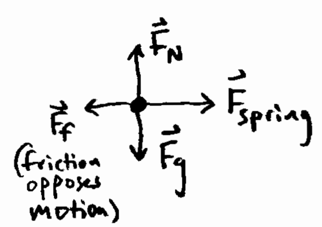
no net force since $\vec{a}=0$

(b) A car on a very slippery (frictionless) icy road is sliding headfirst into a snow bank, where it gently comes to a rest with no one injured.



($\rightarrow \vec{v}$)

(c) A compressed spring is pushing a block across a rough horizontal table.

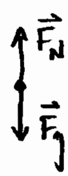


we don't know if $a=0$ or $\neq 0$

($\rightarrow \vec{v}$)

(d) You toss a rock straight up into the air by placing it on the palm of your hand (you're not gripping it) then pushing your hand up very rapidly.

(i) As you hold the rock at rest on your palm, before moving your hand.



($\vec{a}_{net}=0$)

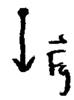
(ii) As your hand is moving up but before the rock leaves your hand.

($\vec{a}_{net}$ is upward)

(iii) One-tenth of a second after the rock leaves your hand.

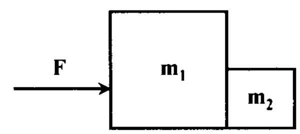
only gravity acts after it leaves your hand

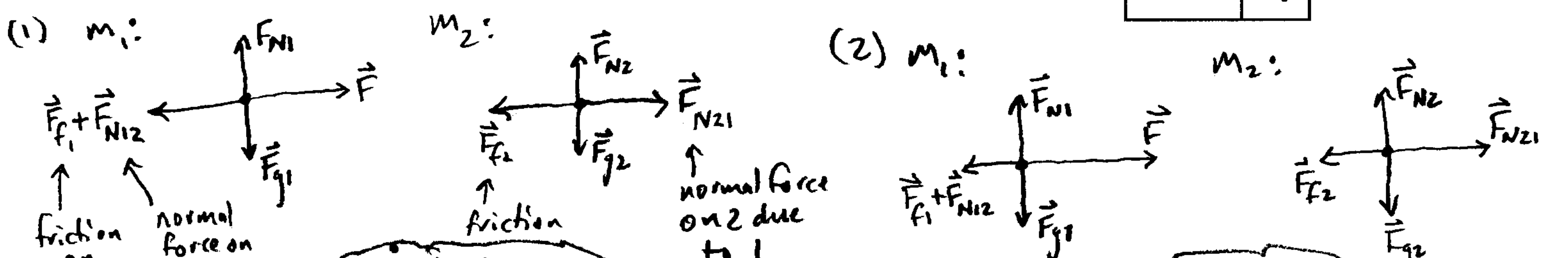
(iv) After the rock has reached its highest point and is now falling straight down.



← $|\vec{F}_g|$ is a constant, regardless of the rock's position after it leaves your hand

(e) Two blocks are pushed to the right across a rough surface with (1) a constant speed, (2) a constantly increasing speed.



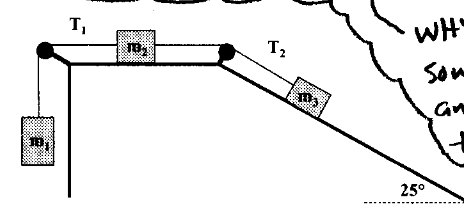


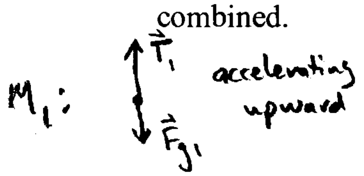
Pay attention to relative vector sizes

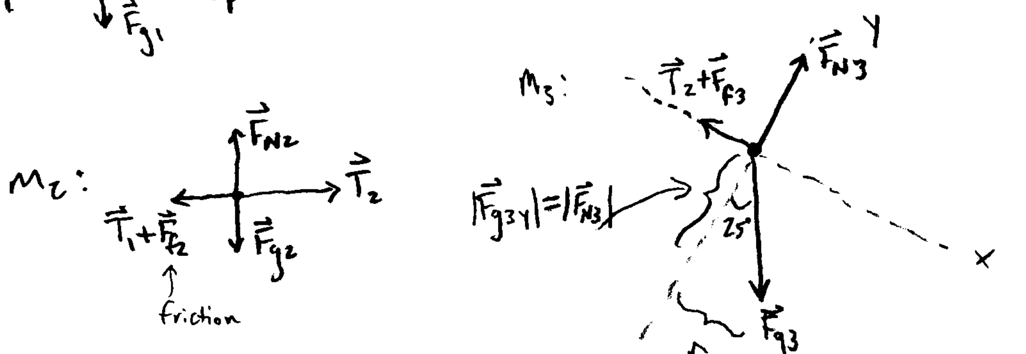
NOTE: In general, $|\vec{F}| \neq |\vec{F}_{N21}| = |\vec{F}_{N12}|$

WHY? plug in some numbers and see. Be sure to let $a_1 = a_2$

(f) Three blocks are connected by strings passing over two pulleys. The surfaces are rough, and m_3 is much more massive than the other two masses combined.

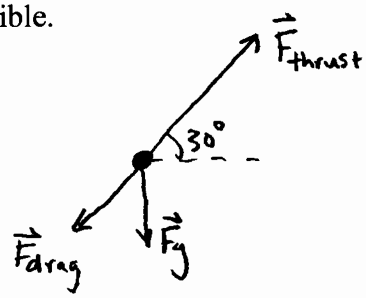






$|\vec{F}_{g3x}| > |\vec{T}_2+\vec{F}_{f3}|$ in order for m_3 to accelerate down incline

(g) A rocket is launched at a 30° angle, and it accelerates very quickly in that direction. Air resistance is not negligible.



2. If an object is rest, can you conclude that there are no forces acting on it? Explain.

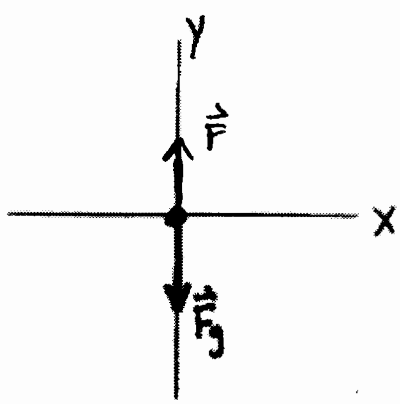
No. There might still be forces, but the net force must equal zero if it's at rest.

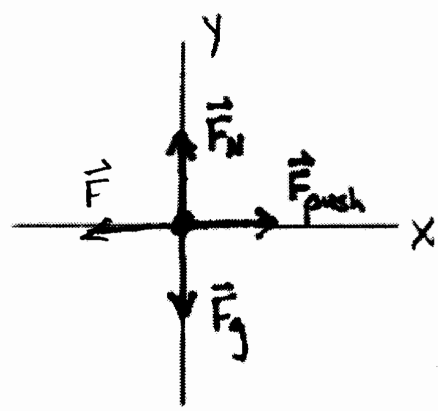
Example: block on table experiences $\vec{F}_g$ and $\vec{F}_N$

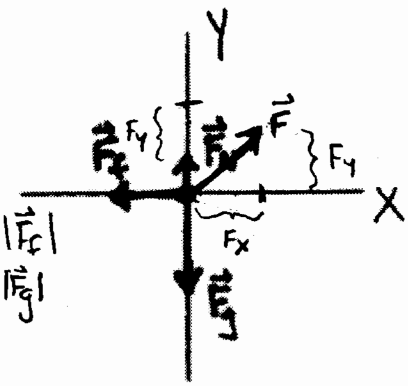
3. If a force is exerted on an object, is it possible for that object to be moving with constant velocity? Explain.

Yes, but only if the sum of the forces equals zero. If there is a net force acting on it, the object will accelerate ($v \neq$ const).

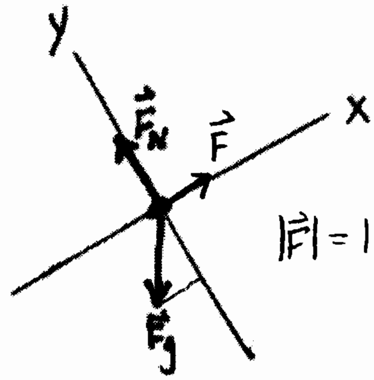
4. The free-body diagrams below show a force or forces acting on an object. Draw and label one more force (one appropriate to the situation) that will cause the object to be in equilibrium.





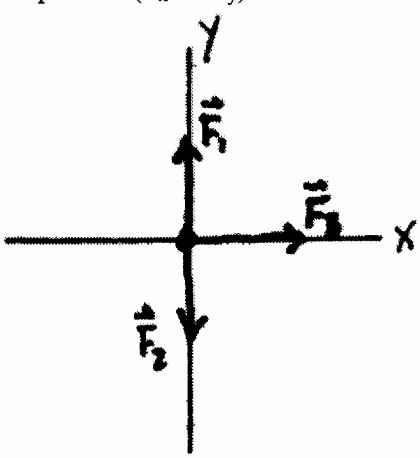


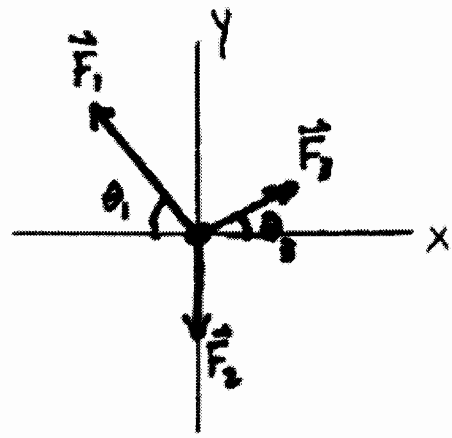
Note that $|\vec{F}_x| = |\vec{F}_f|$
and $|\vec{F}_y + \vec{F}_N| = |\vec{F}_g|$



$|\vec{F}| = |\vec{F}_{gx}|$

5. The figures below show free-body diagrams for an object of mass *m*. Write the *x*- and *y*-components of Newton's second law for each situation. Write your equations in terms of the magnitudes of the forces F_1, F_2, etc., the mass *m*, and the appropriate acceleration component (a_x or a_y).





$\Sigma F_x = ma_x$

$\boxed{F_3 = ma_x}$

$\Sigma F_y = ma_y$ ($a_y = 0$)

$F_1 - F_2 = 0$

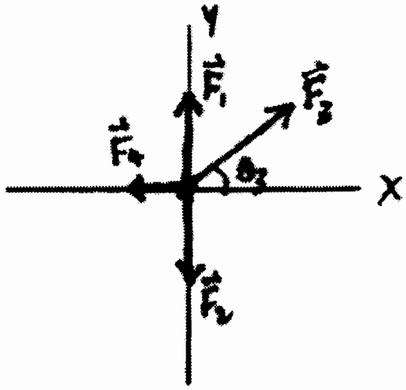
$\boxed{F_1 = F_2}$

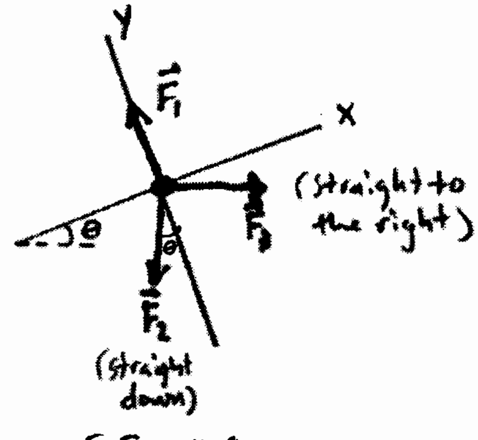
$\Sigma F_x = ma_x$

$\boxed{F_3 \cos\theta_3 - F_1 \cos\theta_1 = ma_x}$

$\Sigma F_y = ma_y$

$\boxed{F_1 \sin\theta_1 + F_3 \sin\theta_3 - F_2 = ma_y}$





$\Sigma F_x = ma_x$

$F_3\cos\theta_3 - F_4 = ma_x$

$\Sigma F_y = ma_y$

$F_1 + F_3\sin\theta_3 - F_2 = ma_y$

$\Sigma F_x = ma_x$

$F_3\cos\theta - F_2\sin\theta = ma_x$

$\Sigma F_y = ma_y$

$F_1 - F_3\sin\theta - F_2\cos\theta = ma_y$

↖ don't forget that one!

6. (a) An elevator travels upward at a constant speed. The elevator hangs by a single cable. Friction and air resistance are negligible. Is the tension in the cable greater than, less than, or equal to the weight of the elevator? Explain. Your explanation should include both a free-body diagram and reference to appropriate physical principles.

If v = const, then $a_{net} = 0 \Rightarrow \Sigma F = 0$, so the tension must equal the weight.

$\Sigma F_y = m\cancel{a_y}$

$T - F_g = 0$

$T = F_g$ (weight)

(b) The elevator travels downward and is slowing down. Is the tension in the cable greater than, less than, or equal to the weight of the elevator? Explain.

If it's slowing down while moving downward, it is experiencing a net upward acceleration. Thus, the net force must be upward. In other words,

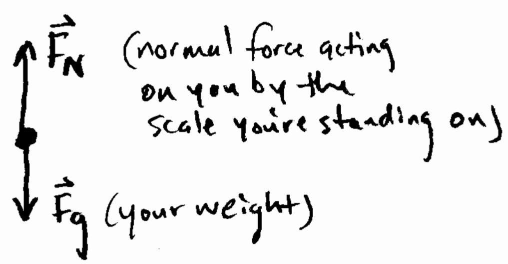
$|\vec{T}| > |\vec{F}_g|$ (weight)

7. Suppose you stand on a spring scale in an elevator as shown in the diagrams on the next page.

(a) What metric unit does the scale use to display your weight?

Newtons (weight is a force)

(b) Draw a free-body diagram of *your body* while it's in the elevator. Label all forces acting on it, and write down Newton's second law for this situation (don't worry about the details of the motion just yet—be generic).



$$\Sigma F_y = ma_y$$

$$\boxed{F_N - F_g = ma_y}$$

✱ By the way, $\vec{F}_N$ equals $\vec{T}$, the tension in the rope pulling the elevator upwards. But, since $\vec{T}$ doesn't act directly on your body ($\vec{F}_N$ does), you shouldn't include $\vec{T}$ in your free-body diagram.

(c) What force in your diagram tells you exactly what the scale will read? Explain your answer and solve for this force in your expression for Newton's second law.

The scale reads whatever force pushes downward on it. That force is the contact (normal) force exerted on the scale by your body:

$$\vec{F}_{N,\text{ on scale due to you}} = -\vec{F}_{N,\text{ on you due to scale}}$$

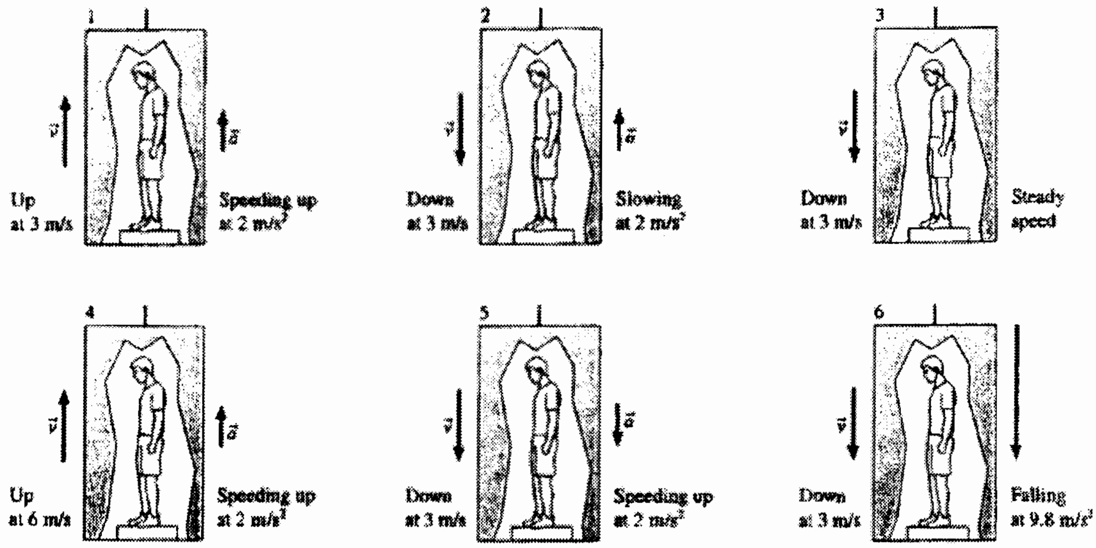
(Newton's 3rd Law)

So, if you know $|\vec{F}_N|$ from part (b), you know what the scale will read:

$$\boxed{F_N = ma_y + F_g}$$

If you accelerate upward, $a_y > 0$ and F_N increases (you appear to weigh more). Vice versa for accelerating downward.

(d) Now consider the six different types of elevator motion shown below. Rank in order, from largest to smallest, the six scale readings S_1 to S_6. Some might be equal. Give your answer in the form A>B=C>D (using S_1 to S_6).



Order: $S_1 = S_2 = S_4 > S_3 > S_5 > S_6$

Explanation:

Just consider direction of $\vec{v}$ along with $\vec{a}$.

You can ignore the speeds! The scale measures a force that depends only on mass and acceleration.

From (c), we know that the scale reads the most if $\vec{a}_y$ is positive (going upward), and it reads the least if $\vec{a}_y$ is negative (going downward).

In situations 1,2,4: $a_y = +2 \Rightarrow$ scale reads $F_N = 2m + F_g$

" " 5: $a_y = -2 \Rightarrow$ scale reads $F_N = -2m + F_g$

" " 3: $a_y = 0 \Rightarrow$ scale reads $F_N = F_g$ (normal weight)

" " 6: $a_y = -9.8 \Rightarrow$ " " $F_N = -9.8m + F_g = 0$ (since $F_g = 9.8m$) Free Fall!

Note: $0 < -2m + F_g$ (you weigh slightly less than your normal weight, but not zero, in 5)