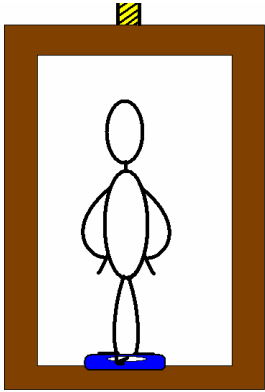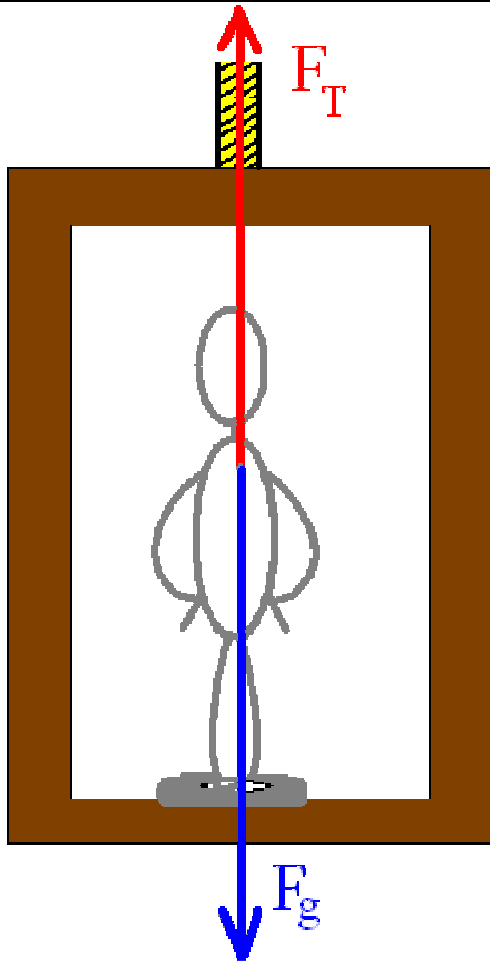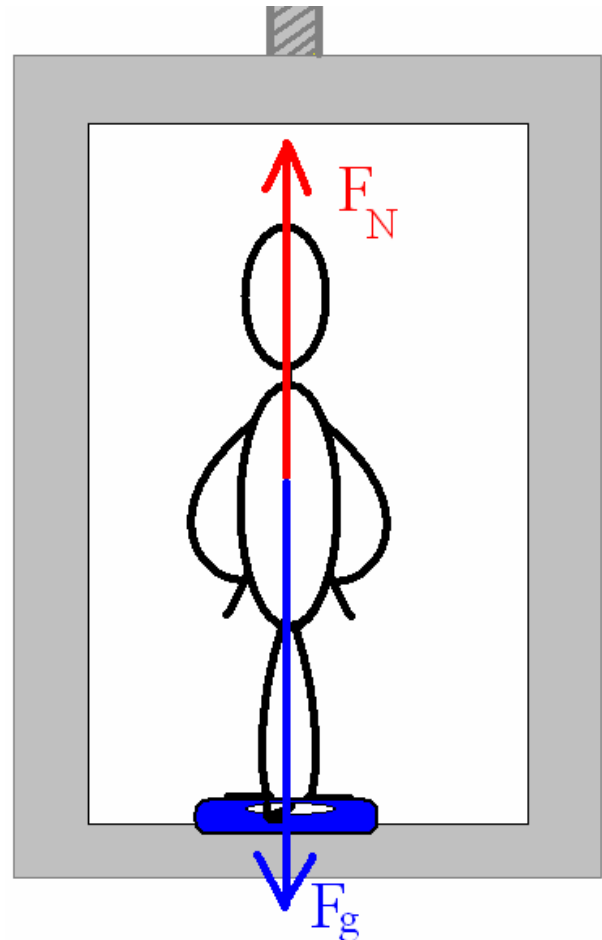# ELEVATORS

YOUR BASIC ELEVATOR PROBLEM HAS TWO TYPES:

1. You look at the Elevator or object being raised up as a whole and your two forces are the Force of Tension (F_T) holding it up and the Force of Gravity (F_g) pulling it down. The mass or weight *must* include the elevator itself in that case.
2. You look at just the person in the elevator and your two forces are the Normal Force of the scale (F_N) pushing up against the Force of Gravity (F_g) pulling *you* down. The mass or weight *must* be for *only* the person.

F_T

CASE 2: The elevator's mass and the tension on the rope holding it up are un-important. The scale reads the Normal Force which is opposed by the Force of Gravity on the person alone.

F_N

F_g

F_g

CASE #1: The force holding up the elevator *and* person is the Force of Tension. This is opposed by the Force of Gravity on the elevator *and* person.

REMEMBER: The scale reads the Normal Force, *equal and opposite* to the Force of Gravity if there is *no acceleration*.

EXAMPLE OF CASE 1: There is an elevator of total mass 1600 kg that is going down at 12 m/s. Over 42 m it comes to a full stop. What was the Force of Tension on this elevator during the time it was accelerated?

You KNOW that something that is accelerating (changing velocity) MUST have a NET FORCE acting on it. F=ma so you will need both the mass of the object and the acceleration.
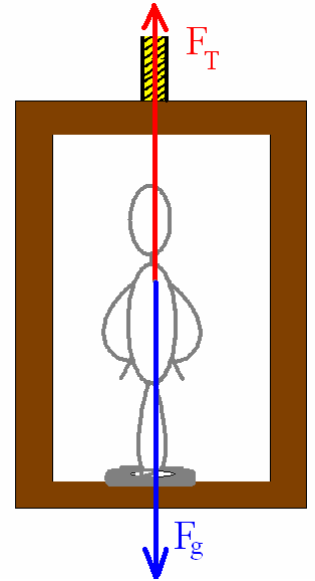
STEPS FOR PROBLEM SOLVING:
1. Draw a picture of the situation with all the forces, label what you can to make it clear.
2. Solve for the acceleration first, then use that to solve for Force of Tension.
3. List your givens and unknowns (**NOTE**: Make sure your initial velocity & displacement are negative!)
4. Solve for Acceleration (**NOTE**: motion is down (negative) but also slowing down (also negative). Two negatives make a positive acceleration!)

$v_i = -12 \frac{m}{s}$ $v_F^2 = v_i^2 + 2ad$

$v_F = 0 \frac{m}{s}$ $(0m/s)^2 = (-12m/s)^2 + 2a(-42m)$

$d = -42m$ $a = 1.7 \frac{m}{s^2}$

$a = ?$

5. Now you have all the information to sum the forces. There are only two forces, acting in the direction of motion, on this system. That net force is equal to the mass times the acceleration you just found. Solve for the Force of Gravity either separately or within the equation.

$$\sum F = F_T + F_g = ma$$

$F_g = ?$ $F_g = mg$ $m = 1600kg$ $\sum F = F_T + (-15680N) = (1600kg)\left(1.7 \frac{m}{s^2}\right)$

$m = 1600kg$ $F_g = (1600kg)\left(-9.8 \frac{m}{s^2}\right)$ $a = 1.7 \frac{m}{s^2}$ $\sum F = F_T + (-15680N) = 2720N$

$g = -9.8 \frac{m}{s^2}$ $F_g = -15680N$ $F_g = -15680N$ $F_T = 2720N + 15680N$

$F_T = ?$ $F_T = 18400N$

When you sum your forces you find that the total Force of Tension is greater than the Force of Gravity. That makes sense! You would have to pull up **HARD** in order to stop something that is already moving down.

EXAMPLE CASE 2: A person of mass 72.2 kg is in an elevator. Determine what the scale they are standing on would read in each of the circumstances:
   a. The elevator is moving up at a constant speed.
   b. The elevator is moving down at a constant speed.
   c. The elevator is accelerating up at 3.20 m/s².
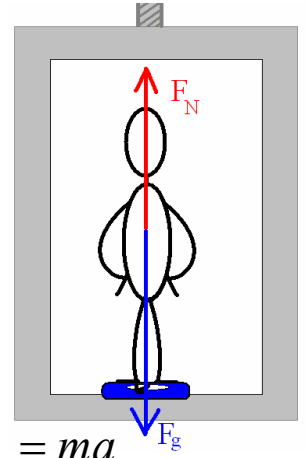   d. The elevator is accelerating downward at 3.20 m/s².

STEPS FOR PROBLEM SOLVING:

1. Draw a picture of the situation with all the forces, label what you can to make it clear.
2. List your givens and unknowns (**NOTE**: make sure you keep your negatives straight)
3. Determine the Force of Gravity (opposite of weight) on the person.

$$m = 72.2kg \qquad F_g = mg$$
$$g = -9.8\,{}^m\!/_{s^2} \quad F_g = (72.2kg)\left(-9.8\,{}^m\!/_{s^2}\right)$$
$$F_g = ? \qquad F_g = -708N$$

4. Sum your forces and solve for the Normal Force. $\sum F = F_N + F_g = ma$

a. The elevator is moving up at a constant speed.

Since the elevator is moving at a constant speed the acceleration is zero. The weight read from the scale would be the same if the elevator was stopped.

$$m = 72.2kg \quad \sum F = F_N + F_g = ma$$
$$a = 0\,{}^m\!/_{s^2} \quad \sum F = F_N + (-708N) = (72.2kg)\left(0\,{}^m\!/_{s^2}\right)$$
$$F_N = ?$$

$$\sum F = F_N + (-708N) = 0N$$
$$F_N = 708N$$

b. The elevator is moving down at a constant speed.

It does not matter if the elevator is going up or down, if it is traveling at a constant speed the acceleration is zero and then the Normal Force (or weight read from the scale), must be the same.

c. The elevator is accelerating up at 3.20 m/s².

$$\sum F = F_N + F_g = ma$$
$$m = 72.2kg$$
$$F_g = -708N \quad \sum F = F_N + (-708N) = (72.2kg)\left(3.2\,{}^m\!/_{s^2}\right)$$
$$a = 0\,{}^m\!/_{s^2} \quad \sum F = F_N + (-708N) = 231N$$
$$F_N = ? \qquad F_N = 708N + 231N$$
$$F_N = 939N$$

d. The elevator is accelerating downward at 3.20 m/s².

$$\sum F = F_N + F_g = ma$$
$$m = 72.2kg \quad \sum F = F_N + (-708N) = (72.2kg)\left(-3.2\,{}^m\!/_{s^2}\right)$$
$$a = 0\,{}^m\!/_{s^2} \quad \sum F = F_N + (-708N) = -231N$$
$$F_N = ? \qquad F_N = 708N - 231N$$
$$F_N = 477N$$
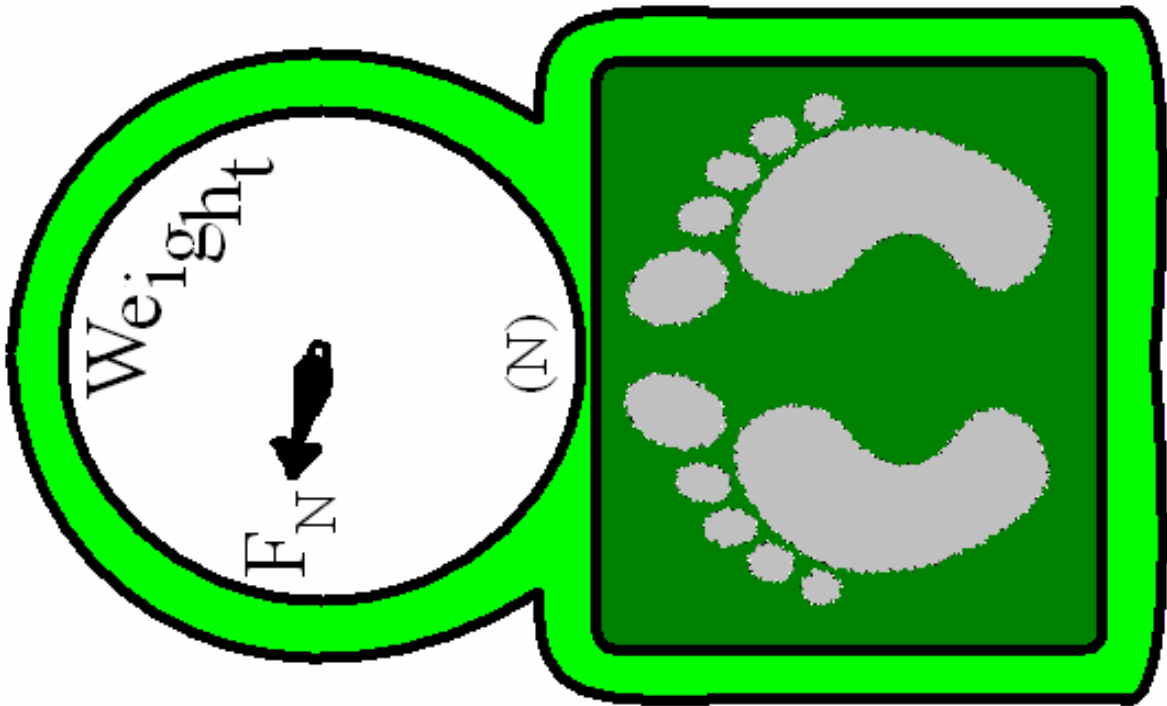
If an elevator is **going up** and **speeding up** then $v_F > v_i$ because it got faster and the **acceleration is positive.**

If an elevator is **going up** and **slowing down** then $v_F < v_i$ because it is slowing down and the **acceleration is negative.**

If an elevator is **going down** and **speeding up** then $v_F > v_i$ *but they are both negative* and the **acceleration is negative**.

If an elevator is **going down** and **slowing down** then $v_F < v_i$ *but they are both negative* and the **acceleration is positive.**

ALWAYS THINK ABOUT HOW HARD THE UPWARD FORCE HAS TO BE COMPARED TO THE MOTION.