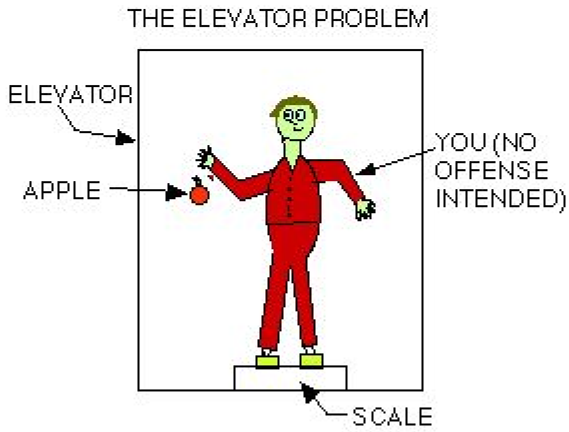
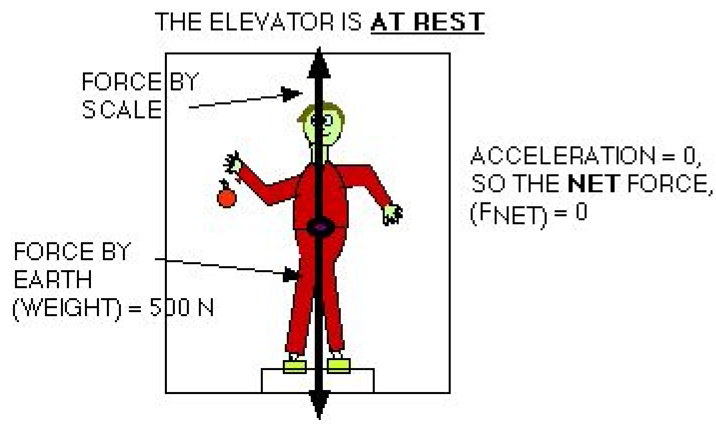


The "Elevator Problem" is a classic problem in physics. The situation is this: "You are standing on a bathroom scale in an elevator. You are holding an apple. (Yes, people *are* staring at you...) You weigh 500 Newtons, so your mass is about 50 kg."

This assignment is a step-by-step analysis of the elevator problem. A good deal of the work has been done for you - in which case it is your job to study the answers given and use them as a pattern and guide for the answers that you supply.



Part A: Elevator Is At Rest.

You have just boarded the elevator, so it (with you inside) is at rest...

Question 1: What does the scale read?

Answer:

There are 2 forces acting on you. (See the diagram at right.) The Earth pulls down on you with the force we call your weight (= mg) of 500 Newtons.

Since the elevator is at rest, your acceleration is 0 m/s^2. Since your acceleration is 0 m/s^2, **Newton's First Law** says the net force on you must be 0 Newtons.

Since the net force on you is 0 Newtons, the upward forces and downward forces on you must balance exactly. Therefore the scale must push on you with a force of (1a) _______ Newtons, and the scale must read (1b) _______ Newtons.

Question 2: If you let go of the apple, what does it do?

Answer:

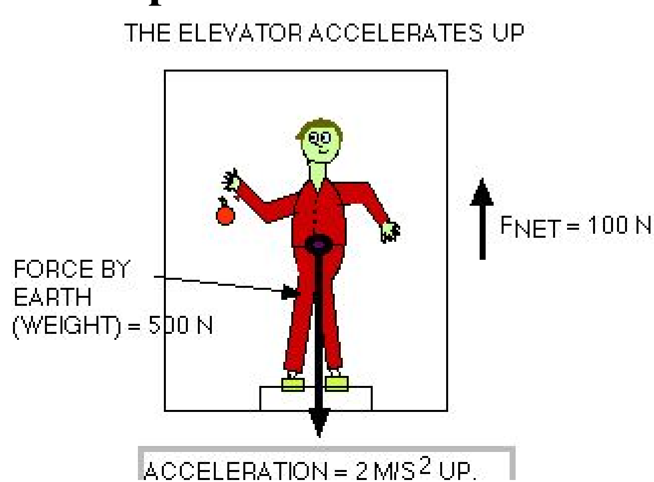
The apple would be in free fall, so its acceleration relative to the earth is 10 m/s^2 downward. Since you are at rest relative to the earth, the apple's acceleration relative to you would be10 m/s^2 also, so the apple would appear to fall just as it does anywhere else on the earth.

Part B: The Elevator Accelerates Upward.

The elevator, (with you inside) begins to accelerate upward from rest at 2 m/s^2.

Question 3: What will the scale read now?

Answer:



There are 2 forces acting on you. (Complete the diagram.) Your weight pulls down with a force of 500 Newtons. The scale pushes up with a force of (3a) ______ (see below) Newtons.

Since your acceleration is 2 m/s^2 upward, Newton's Second Law says that there must be a net force pushing you upward, and the net force has a magnitude F_{net} = ma. So the net force on you,

F_{net} = (50 kg)(2 m/s^2) = 100 Newtons (upward).

Since the net force on you is100 Newtons, the upward forces and downward forces on you must cancel to leave a 100 Newton upward force. Therefore the scale must push on you with a force of (3b) _______ Newtons, and the scale must read (3c) _______ Newtons as the elevator accelerates upward.

Question 4: If you let go of the apple now, what does it do?

Answer:

The apple would be in free fall, so its acceleration relative to the earth is 10 m/s^2 downward. Since you are accelerating at 2 m/s^2 upward relative to the earth, the apple's acceleration relative to you would be 10 m/s^2 + 2 m/s^2 = 12 m/s^2, so the apple would appear to fall *faster* inside the elevator than it does in "normal" free fall on the earth.

To the occupants of the upwardly accelerating elevator, it *appears that gravity is stronger*, since they *seem to weigh more* (why?) and objects fall faster than "normal."

Part C: The Elevator Moves Up With Constant Velocity.

The elevator (and you) accelerated for 5 seconds, so it is moving upward with a velocity of 10 m/s. It now moves with this constant upward velocity of 10 m/s.

Question 5: What does the scale read now?

Answer:

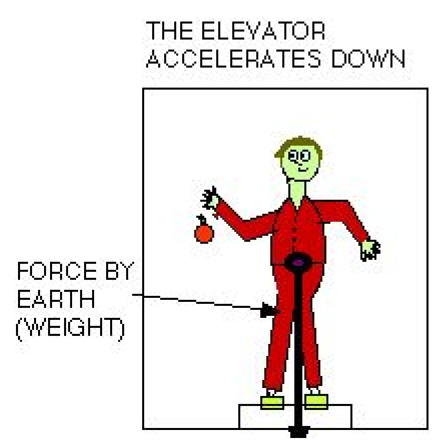
There are 2 forces acting on you. (Complete the diagram.) Your weight pulls down with a force of 500 Newtons. The scale pushes up with a force of (5a) ________ (see below) Newtons.

Since the elevator is moving with constant velocity, your acceleration is (5b) ____ m/s^2. Since your acceleration is (5c) ____ m/s^2, Newton's First Law says the net force on you is (5d) _____ Newtons.

Since the net force on you is (5e) ____ Newtons, the scale must push on you with a force of (5f) _______ Newtons, and the scale must read (5g) _______ Newtons.

Question 6: If you let go of the apple, what does it do?

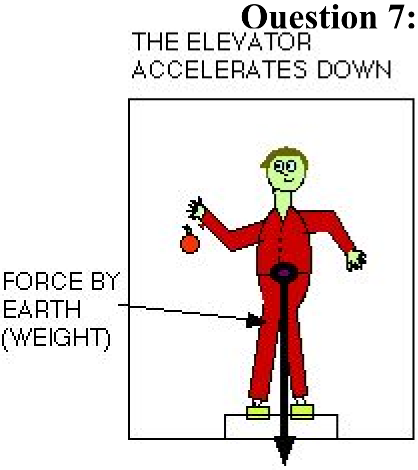
Answer:



Part D: The Elevator Slows Down (While Going Up)

The elevator, (with you inside) begins to slow down as it approaches its destination. Its acceleration (or deceleration) is 2 m/s^2 downward.

Question 7: What does the scale read now?



s acting on you. (Complete the diagram.) The Earth (your weight) pulls down a) _____ Newtons. The scale pushes up with a force of (7b)______ (see below)

ration is 2 m/s^2 downward, Newton's Second Law says that there must be a net downward, and the net force has a magnitude F_{net} = ma. So the net force on

_ kg)((7d) _____ m/s^2) = (7e) ______ Newtons .

e on you is (7f) _____ Newtons downward, the upward forces and downward forces on you must cancel out to leave a (7g) _____ Newton downward force . Therefore the scale must push on you with a force of (7h) _______ Newtons, and the scale must read (7i) _______ Newtons as the elevator accelerates downward.

Question #8: If you let go of the apple now, what does it do?

Answer:

To the occupants of the downwardly accelerating elevator, it *appears that gravity is weaker*, since they *seem to weigh less* (why?) and objects *fall more slowly* than "normal."

Part E: The Elevator Speeds Up (While Going Down)

The elevator, (with you inside) reaches its floor, stops for a while, and then begins to accelerate downward. Its acceleration is 2 m/s^2 downward.

Question 9: What does the scale read now?

Answer:

There are 2 forces acting on you. (Complete the diagram.) The Earth (your weight) pulls down with a force of (9a) _____ Newtons. The scale pushes up with a force of (9b)______ (see below) Newtons.

Since your acceleration is 2 m/s^2 downward, Newton's Second Law says that there must be a net force pulling you downward, and the net force has a magnitude F_{net} = ma. So the net force on you,

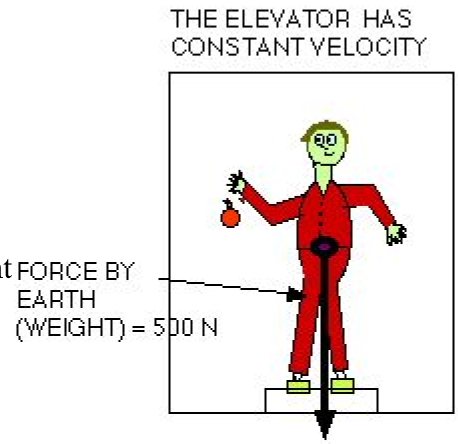
F_{net} = ((9c) _____ kg)((9d) _____ m/s^2) = (9e) ______ Newtons .

Since the net force on you is (9f) _____ Newtons downward, the upward forces and downward forces on you must cancel out to leave a (9g) _____ Newton downward force. Therefore the scale must push on you with a force of (9h) _______ Newtons, and the scale must read (9i) _______ Newtons as the elevator accelerates downward.

Question #10: If you let go of the apple now, what does it do?

Answer

To the occupants of the downwardly accelerating elevator, it *appears that gravity is weaker*, since they *seem to weigh less* (why?) and objects *fall more slowly* than "normal."



Part F: The Elevator Moves Down With Constant Velocity.

The elevator (and you) accelerated for 5 seconds, so it is moving downward with a velocity of 10 m/s. It now moves with this constant downward velocity of 10 m/s.

Question 11: What does the scale read now?

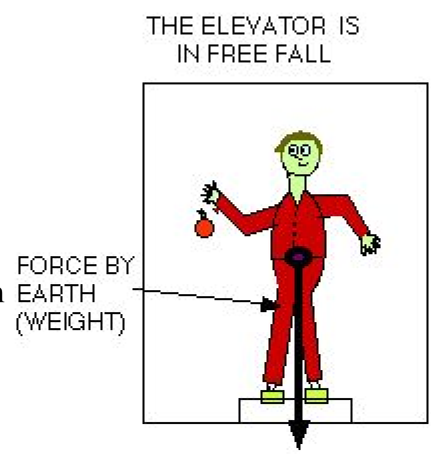
Answer:

There are 2 forces acting on you. (Complete the diagram.) Your weight pulls down with a force of 500 Newtons. The scale pushes up with a force of (11a) ________ (see below) Newtons.

Since the elevator is moving with constant velocity, your acceleration is (11b) ____ m/s^2. Since your acceleration is (11c) ____ m/s^2, Newton's First Law says the net force on you is (11d) _____ Newtons.

Since the net force on you is (11e) ____ Newtons, the scale must push on you with a force of (5f) _______ Newtons, and the scale must read (11g) _______ Newton

Question 12: If you let go of the apple, what does it do?



Part G: Oh, No!

The elevator cable snaps, and the elevator (with you inside!) begins to fall! Perhaps you have time for one last Physics observation!

Question 13: What does the scale read as the elevator falls

There are 2 forces acting on you. (Complete the diagram.) The Earth (your weight) pulls down with a force of (13a) _____ Newtons. The scale pushes up with a force of (13b) _____ (see below) Newtons.

Since the elevator and you are in free fall, your acceleration is (13c) ____ m/s^2 downward. Newton's Second Law says that there must be a net force pulling you downward, and the net force has a magnitude $F_{net} = ma$. So the net force on you,

F_{net} = ma = ((13d) _____ kg)((13e) _____ m/s^2) = (13f) _____ Newtons.

Since the net force on you = (13g) _____ Newtons downward, the upward forces and downward forces on you must cancel out to leave a (13h) _____ Newton downward force . Therefore the scale must push on you with a force of (13i) _______ Newtons, and the scale must read (13j) _______ Newtons as the elevator accelerates downward.

Question #14: If you let go of the apple now, what does it do?

Question #15: "Weightlessness"

Weightlessness is a phenomenon that we most often associate with astronauts in space, but it is not necessary to be floating in space to be "weightless." Describe what you could do, right here and now, to be "weightless." (Hint: An elevator is not necessary!)

Answers

A. Elevator At Rest

What does the scale say?

a. scale pushes with a force of **500** Newtons (to balance the Earth's pull)
b. scale says **500** Newtons (equal to the scale's push)

What does the apple do? **Falls down, silly.**

B. Elevator Accelerates Up

3. What does the scale read? To complete the force diagram you need to an upward force on you due to the scale. This force turns out to be 600 Newtons - see below.
    a. the scale pushes with a force of **600** Newtons, since when the scale's force is combined with the Earth's force (weight = 500 Newtons) there has to be a 100 Newton force (upward) left over - the net force.
    b. **600** Newtons (same as part a)
    c. **600** Newtons (same as the force the scale exerts)
4. What does the apple do? **Falls down (apparently faster), silly.**

C. Elevator at Constant Velocity

3. What does the scale read? To complete the force diagram, you need to add an upward force on you due to the scale. This force turns out to be 500 Newtons - see below.
    a. The scale's force on you is **500** Newtons. (see below)
    b. Your acceleration is **0** m/s^2 (since your velocity is constant)
    c. **0** m/s^2 (same as part b)
    d. The net force must be **0** Newtons (if the acceleration is 0 m/s^2).
    e. **0** Newtons (same as part d)
    f. The scale's force must be **500** Newtons since it must exactly balance your weight (500 Newtons) so that the net force is 0 Newtons.
    g. The scale reads **500** N (same as the scale's force).
4. What does the apple do if you let go? The apple would be in free fall, so its acceleration relative to the Earth would be 9.8 m/s^2. Its acceleration relative to you would be the same (since your acceleration is 0 m/s^2) so **the apple would fall exactly as it would if the elevator were at rest**.

D. Elevator Accelerates Downward (While Going Up)

3. What does the scale read? To complete the diagram, add an upward force on you due to the scale. This force turns out to be 400 Newtons - see below.
    a. Your weight is **500** Newtons (given in the problem)
    b. The scale's force is **400** Newtons (see below)
    c. Your mass is **50** kilograms (given in the problem)

d. Your acceleration is **2** m/s^2
e. The net force is **100** Newtons (= (50 kg)(2 m/s^2))
f. **100** N (same as part e)
g. **100** N (same as part e)
h. The scale's force is **400** Newtons, since it must combine with your weight (500 Newtons) to leave a net downward force of 100 Newtons.
i. The scale reads **400** Newtons (same as scale's force)

4. What does the apple do if you drop it? Relative to the Earth, the apple accelerates toward the Earth at about 10 m/s^2, but you are accelerating toward the Earth, too, at 2 m/s^2. The apple's acceleration relative to you is 10 m/s^2 - 2 m/s^2 = 8 m/s^2 - **the apple seems to fall slower** than "normal" free fall.

E. The Elevator Speeds Up - While Going Down - This is **exactly the same as Part D**! The direction the elevator moves doesn't matter - only the direction the elevator accelerates. Since the elevator is accelerating downward in both cases, the situation inside the elevator is identical!

F. The Elevator Moves Down With Constant Speed - **This is exactly the same as Part C**! The direction that the elevator moves doesn't matter - only the elevator's acceleration. In both cases, the elevator's acceleration is 0 m/s^2, so the situation inside the elevator is the same in both cases.

G. Oh! No!

3. What does the scale read?
   a. 500 Newtons
   b. 0 Newtons
   c. 10 m/s/s (= g)
   d. 50 kg (your mass)
   e. 10 m/s/s (= g)
   f. 500 Newtons
   g. 500 Newtons
   h. 500 Newtons
   i. 0 Newtons
   j. 0 Newtons
4. If you let go of the apple, what does it do? Your acceleration and the apple's acceleration are equal (10 m/s^2 downward, so you both fall at the same rate. Relative to you, the apple stays right where you let go of it - it appears to float. In other words, the apple appears to be weightless, just as it would aboard the space shuttle orbiting the earth!
5. What can you do to be weightless? You could jump up in the air, or jump off a chair. While you are falling, you are weightless! If you jump off a chair holding an apple, and let go of the apple, the apple will appear to float right where you left it (relative to you) - it is (**apparently**) weightless!