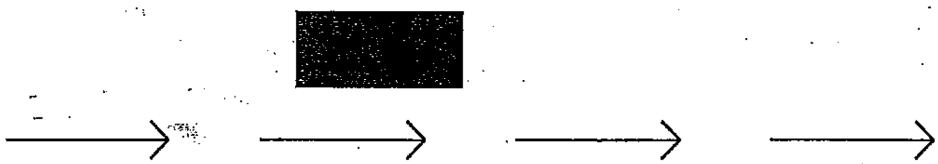
B1

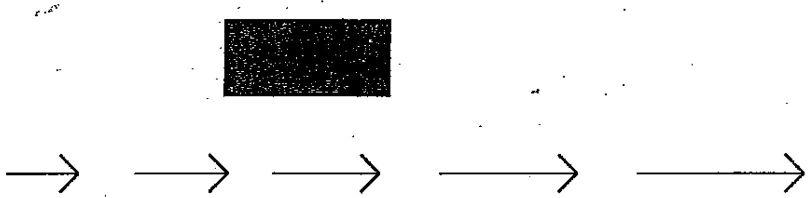
Introduction to Newton's 2nd Law: The relationship between acceleration and net force #1

A puck moves to the right across an air hockey table. This air hockey table is of such high quality that there is no friction between the puck and the table.

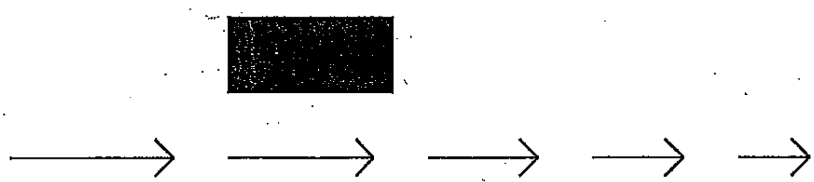
1. The puck is moving to the right across the table. In what direction would we have to exert a force on the puck in order for the puck to *maintain* constant velocity? (Remember there is no friction.)



2. The puck is moving to the right across the table. In what direction would we have to exert a force on the puck in order for the puck to *increase* its velocity? Indicate the direction of the force arrow on the puck.



3. The puck is moving to the right across the table. In what direction would we have to exert a force on the puck in order for the puck to *decrease* its velocity? Indicate the direction of the force arrow on the puck.



Isaac Newton thought about the following questions:

a. What causes an object to accelerate?

b. What is the relationship between the direction of the force and the direction of the acceleration?

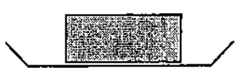
PHY 111,121 **Introduction to Newton's 2nd law: the relationship between acceleration and net force** **#2**

A dog sled is moving on a level surface of snow at a speed of 30 mph. There is a force of friction opposing the motion of the sled. The friction force is equal to 1000 newtons (N).

Situation 1. The dogs are pulling on the sled with a forward force of 1500 N (with 1000 N still opposing the motion).
a) Draw a diagram of the forces on the sled. (One force acts in the forward direction and another in the reverse direction.)
b) What is the net force (ΣF), numerical value and direction, on the sled?
c) What is the direction of the acceleration of the sled?
d) Draw a motion diagram for the sled.

Situation 2. With the dogs pulling on the sled with a forward force of 600 N (with 1000 N still opposing the motion) draw a diagram of the forces on the sled.
a) What is the net force (ΣF), numerical value and direction, on the sled?
b) What is the direction of the acceleration of the sled?
c) Draw a motion diagram for the sled.

Situation 3. With the dogs pulling on the sled with a forward force of 1000 N (with 1000 N still opposing the motion) draw a diagram of the forces on the sled.
a) What is the net force (ΣF), numerical value and direction, on the sled?
b) What is the direction of the acceleration of the sled?
c) Draw a motion diagram for the sled.



Situation 4. With the dogs not pulling on the sled at all (with 1000 N still opposing the motion) draw a diagram of the forces on the sled.
a) What is the net force (ΣF), numerical value and direction, on the sled?
b) What is the direction of the acceleration of the sled?
c) Draw a motion diagram for the sled.

Kinds of Forces/Force Diagrams

A force is a push or pull which acts on an object.

A short list of forces we will be using in this course:

Long range force	symbol	Contact forces	symbol
Gravity	W	Push against a surface (Normal force)	F_N or F_{push}
		String or cable	T
		Friction (static or kinetic)	F_{fric}, F_s, F_k
		Buoyancy	B

This list is by no means complete. Examples of other macroscopic forces are magnetism (long range force), air pressure (contact force), etc.

A force is a vector; it has a direction and magnitude.

When we draw a force diagram, we focus on the forces acting *on* a specific object (called a system). When drawing a force diagram, it will be important to draw force vectors with appropriate relative length.

When several forces act on a particular object, we will want to consider the sum of all the forces, called the *net force* (symbol: F_{net} or ΣF). We will denote the net force in a diagram with a double arrow (=>).

Introduction to Newton's 2nd Law: The relationship between acceleration and net force #3

The net force is the sum of the individual forces.

In each of the following situations

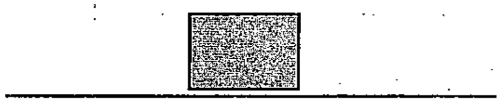
(a) draw a motion diagram including the acceleration arrow.

(b) draw a force diagram showing the individual forces. Show the net force using a different color or style.

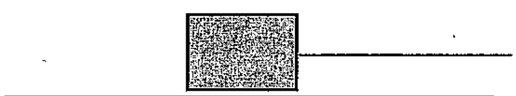
(c) How does the direction of the acceleration arrow compare to the direction of the net force arrow?

A. Block on a table

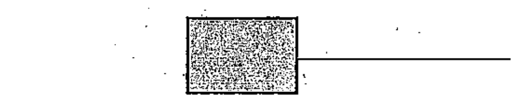
1. Block at rest.



2. Block being pulled by a string to the right at constant speed.



3. Block gaining speed while being pulled by a string to the right.



4. The block, initially moving to the right, is allowed to slow down to a stop.

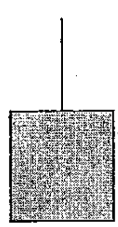
Introduction to Newton's 2nd Law #4

$$a = \frac{\Sigma F}{m} \text{ or } \Sigma F = ma$$

1. A 10-kg block on a frictionless table is being pulled to the right by a force of 15 N.
a) Draw each individual force.
b) Draw the net force (using a double arrow).
c) Determine the direction and magnitude of the acceleration.

2. A 10-kg block on a table is being pulled to the right by a force of 15 N. There is a 10-N force of friction between the block and the table.
a) Draw each individual force.
b) Draw the net force (using a double arrow).
c) Determine the direction and magnitude of the acceleration.

3. A 1000-kg elevator is being pulled upward with a force of 12,000 N.
a) Draw each individual force.
b) Draw the net force (using a double arrow).
c) Determine the direction and magnitude of the acceleration.



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PHY 111 **Newton's 2nd law #4**

4. A car has a mass of 2000 kg and it is initially at rest. There is a force of 6800 N pushing the car forward to the right. There is a force of 800 N opposing the motion of the car.
a) Draw a diagram of all the forces on the car.

b) What is the magnitude and direction of the net force?

c) What is the acceleration of the car?

d) What is the velocity of the car after 5 seconds?

e) How long will it take for the car to reach a speed of 20 m/sec?

5. A 1600-kg car is traveling with a speed of 27 m/sec to the right. The brakes are applied causing a braking force of 7200 N.
a) Draw a diagram of all the forces on the car.

b) What is the magnitude and direction of the net force?

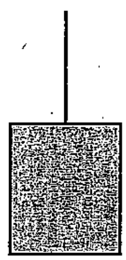
c) What is the deceleration of the car?

d) What is the velocity of the car after 2 seconds?

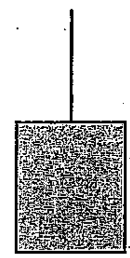
e) How long will it take for the car to come to a stop?

B. Elevator suspended by a cable.

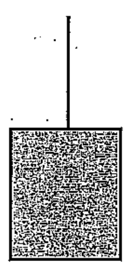
1. Elevator at rest.



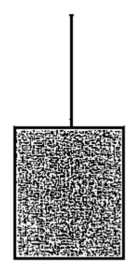
Elevator moving upward at decreasing speed.



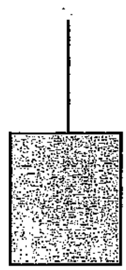
Elevator moving downward at increasing speed.



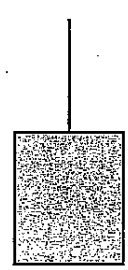
Elevator moving upward at constant velocity.



Elevator moving downward at decreasing speed.



Elevator moving upward at increasing speed.



Mass and Weight

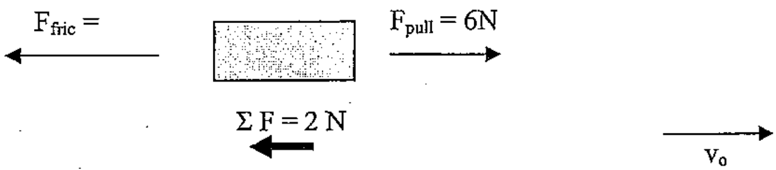
Answer each of the following questions. If needed, use a value for the gravitational constant on the earth of $g = 10\ m/s^2$ and on the moon of $2\ m/s^2$. Save space below for answers.

1. What is the SI unit for mass?		
2. What is the SI unit for weight?		
3. What is the mass of a 3-kg object when on the earth? 4. When on the moon?		
5. What is the weight of a 3-kg object when on the earth? 6. When on the moon?		
7. An object weighs 60 N when on the earth. What is the mass of the object? 8. What is the weight of this object on the moon?		
9. Another object weighs 60 N when on the moon. What is the mass of that object?		

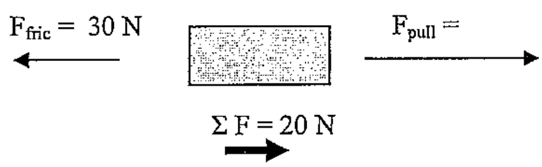
PHY 111

a) From the given information, find the unknown force(s).
b) Given the direction of v_o, finish the motion diagram.

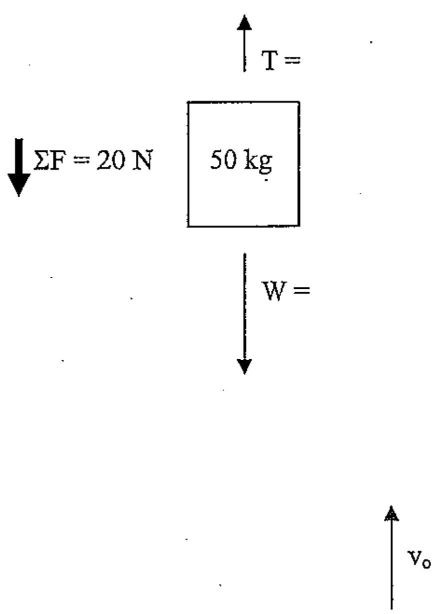
1)



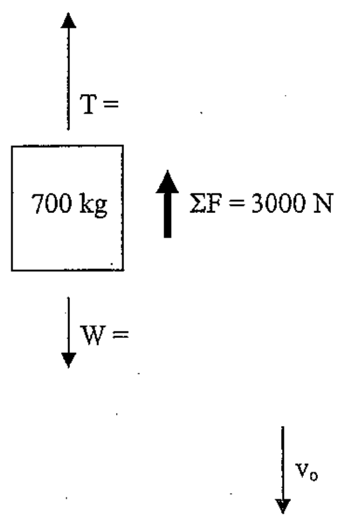
2)



3)



4)



PHY 111 Using Newton's 2nd law with a single unopposed force

A single unopposed force is the same as the net force.

1. A 2000-kg car moving to the right decelerates from 30 to 10 m/sec in 10 seconds.
a) Draw a motion diagram for the car.

b) Find the deceleration of the car.

c) Draw a force diagram of the forces on the car.

d) Give the numerical value (in newtons) of each of the forces.

2. A 2000-kg car moving to the right accelerates from 0 to 20 m/sec in 4 seconds.
a) Draw a motion diagram for the car.

b) Find the acceleration of the car.

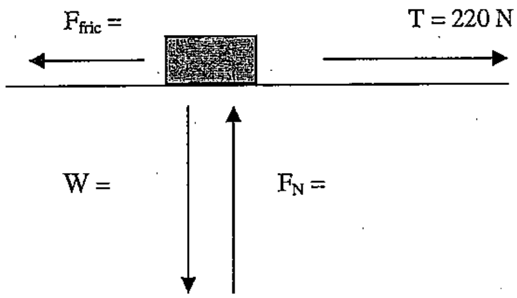
c) Draw a force diagram of the forces on the car.

d) Give the numerical value (in newtons) of each of the forces.

PHY 111 Introduction to Newton's 2nd Law #5: Solving for unknown forces

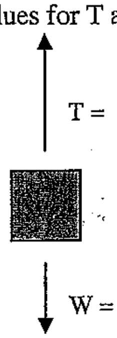
1. A 40-kg object is being pulled to the right with a rope. The tension in the rope is 220 N. The acceleration of the object is 4 m/sec^2 toward the right.

a) Draw a motion diagram (including the acceleration vector).
b) Find the net force and show its direction on the force diagram.
c) Write the values for F_{fric}, W and F_N.



2. An 80-kg box is being lifted by a rope. The box is being accelerated upward at 3 m/sec^2.

a) Draw a motion diagram (including the acceleration vector).
b) Find the net force and show its direction on the force diagram.
c) Write the values for T and W.



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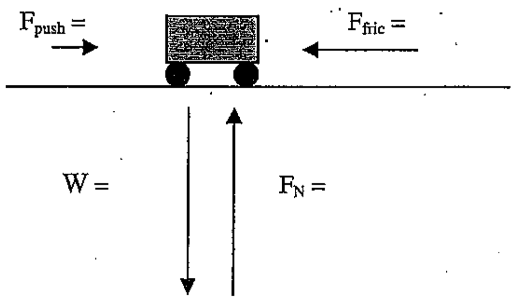
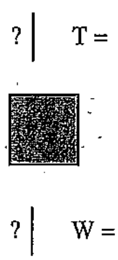
3. A 120-kg cart is being pushed to the right by a person. The cart was initially moving quickly to the right but it is slowing down at a rate of 0.5 m/sec^2 even as the person is pushing it. The force of friction on the cart is 80 N.

a) Draw a motion diagram (including the acceleration vector).
b) Find the net force and show its direction on the force diagram.
c) Write the values for F_{push}, W and F_N.



4. A 40-kg crate is being lowered by a rope. As it is lowered, its speed is decreasing at a rate of 1.5 m/sec^2.

a) Draw a motion diagram (including the acceleration vector).
b) Find the net force and show its direction on the force diagram.
c) Write the values for T and W.



Coefficients of friction between various surfaces

Maximum static friction: $F_s = \mu_s F_N$

Kinetic friction: $F_k = \mu_k F_N$

Material	μ_s	μ_k
Steel on ice	0.1	0.05
Steel on steel—dry	0.6	0.4
Steel on steel—greased	0.1	0.05
Rope on wood	0.5	0.3
Teflon on steel	0.04	0.04
Shoes on ice	0.1	0.05
Climbing boots on rock	1.0	0.8
Leather-soled shoes on carpet	0.6	0.5
Leather-soled shoes on wood	0.3	0.2
Rubber-soled shoes on wood	0.9	0.7
Auto tires on dry concrete	1.0	0.75
Auto tires on wet concrete	0.7	0.5
Auto tires on icy concrete	0.3	0.02
Rubber on asphalt	0.60	0.40
Teflon on Teflon	0.04	0.04
Wood on wood	0.5	0.3
Ice on ice	0.05−0.15	0.02
Glass on glass	0.9	0.4

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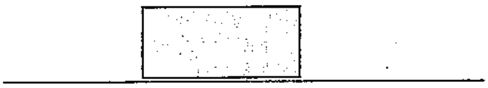
PHY 111 Introduction to coefficient of friction A

1. A 20-kg smooth wood box is at rest on a smooth wood floor. (a) How many newtons of force are needed to start the box moving? (b) Once the box is moving, how many newtons of force are needed to keep it moving?

2. A 50-kg smooth wood box is at rest on a smooth wood floor. (a) How many newtons of force are needed to start the box moving? (b) Once the box is moving, how many newtons of force are needed to keep it moving? (c) If the same force found in part (a) continues to be applied after the box has begun moving, what will the acceleration of the box be?

PHY 111 **Coefficient of kinetic friction: Block of wood on table (using spring scales)**

Draw a force diagram for a block being pulled to the right along the surface of a table at constant velocity.



Since the acceleration of the object is zero, the force of friction will be equal to ____________.

According to theory, the coefficient of friction only depends on the surfaces. It does not depend on the normal force. **Our purpose is to test that theory.**

You will pull the block with one extra kg of mass and then again with two extra kg of mass. Be careful not to accelerate while pulling.

Block plus one extra kg of mass, constant speed

Mass pulled (block + 1 kg): __________ kg

$F_N = W =$ ___________ N

$F_{pull} = F_{fric} =$ ___________ N

$\mu_k =$

Block plus two extra kg of mass, constant speed

Mass pulled (block + 2 kg): __________ kg

$F_N = W =$ ___________ N

$F_{pull} = F_{fric} =$ ___________ N

$\mu_k =$

Do you find that the coefficient of friction μ is relatively independent of normal force?

PHY 111 Introduction to coefficient of friction: Stopping a car

A 1500-kg car skids to a stop on a wet road. Its initial velocity is 20 m/s.
a) Draw a force diagram and a motion diagram for the car. (Is there a forward force on the car?)
b) What is the force of friction stopping the car?
c) What is the deceleration of the car?
d) What is the stopping distance of the car?

Name ______________________________ Date __________

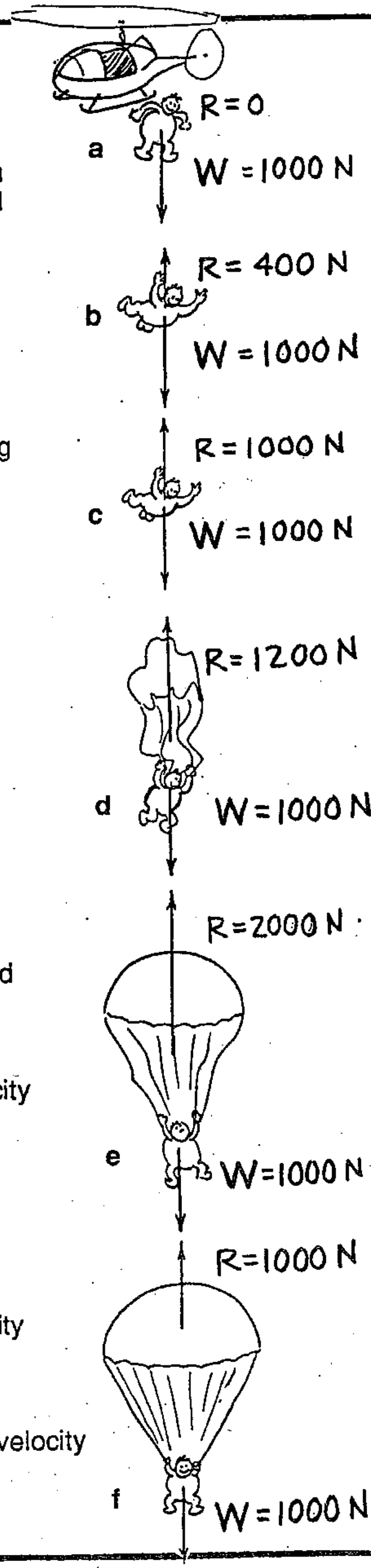
CONCEPTUAL **Physics** PRACTICE SHEET

Chapter 4: Newton's Laws of Motion
Newton's 2nd Law

Bronco Brown skydives and parachutes from a stationary helicopter. Various stages of fall are shown in positions a through f. Using Newton's 2nd law,

$$a =$$

find his acceleration at each position (mark your answers in the blanks to the right). You need to know that Bronco's mass *m* is 100 kg so his weight is a constant 1000 N. Air resistance *R* varies with speed and cross-sectional area as shown.



a = __________

a = __________

a = __________

a = __________

a = __________

a = __________

Circle the correct answer.

1. When Bronco's speed is least, his acceleration is (least)(most).

2. In which position(s) does Bronco experience a downward acceleration? (a)(b)(c)(d)(e)(f)

3. In which position(s) does Bronco experience an upward acceleration? (a)(b)(c)(d)(e)(f)

4. When Bronco experiences an upward acceleration, his velocity is (still downward)(upward also).

5. In which position(s) is Bronco's velocity constant? (a)(b)(c)(d)(e)(f)

6. In which position(s) does Bronco experience terminal velocity? (a)(b)(c)(d)(e)(f)

7. In which position(s) is terminal velocity greatest? (a)(b)(c)(d)(e)(f)

8. If Bronco were heavier, his terminal velocity would be (greater)(less)(the same).

PHY 111 The forces needed to move a heavy object

1. A heavy 200-lb. trunk of a tree is lying on the ground. You and a friend each grab lift up the trunk at each end (100 lbs. each). What force do you have to work against to lift the tree trunk?

2. Instead of lifting the trunk, you tie a rope to the end of the truck and drag it. What force do you have to work against to move the trunk?

3. Moving a heavy object in a weightless environment: Suppose you are an astronaut in the space shuttle and you are doing research on elephants in space. You want to move a 4000-lb. elephant from one end of the space shuttle to the other.
Is there a force involved to move the elephant? What is it?

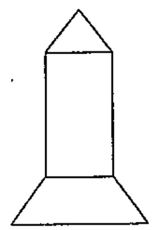
4. You are moving a very heavy cart (on wheels) full of computers. What force(s) do you have to work against to move the cart?

5. You are moving a very heavy wheelbarrow load full of gravel. What force(s) do you have to work against to move the wheelbarrow?

PHY 111 Thrust force on a rocket

Rockets are propelled upward by expelling gases downward. How does this work?

A rocket is initially at rest and has a mass of 5000 kg. There is an upward thrust force of 200,000 N on the rocket.



a) Draw force diagram for the rocket.

b) Find the net force and acceleration of the rocket.

c) What is the speed of the rocket after 20 seconds of thrust?

d) How high is the rocket after 20 seconds of thrust?

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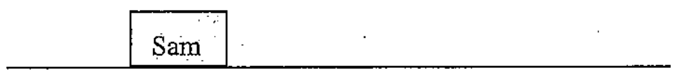
PHY 111 **Skiing with a Jet Pack (Coefficient of friction)**

Sam likes to go skiing using a jet pack to propel himself forward. With his jet pack on full force, he can accelerate himself across the snow such that (starting from rest) he covers **d** meters in **t** seconds. The coefficient of friction between the skis and the snow is **μ**. Sam's mass is 80 kg.

d = **t** = **μ** =

a) Draw a motion diagram for the sled. Include the acceleration arrow.

b) Complete the force diagram for Sam. Draw both horizontal and vertical forces. If one force is larger than another, be sure it is evident in your diagram. Also show the direction of the net force using a double arrow. (The sled is moving toward the right.)

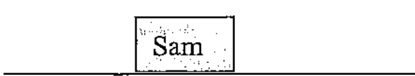


c) Find Sam's acceleration.

d) Find the thrust force of the jet pack.

As soon as Sam reaches his top speed in **t** sec, he turns off the jet pack and slides to a stop.

e) Draw the force diagram for Sam after the jet pack is turned off.



f) What is Sam's top speed?

g) What is the distance that he slides after the pack is turned off?

PHY 111 **Apparent weight**

In some situations, like moving vehicles, amusement park rides, elevators, or a space shuttle, a person will feel like his weight is different than his true weight. This is called *apparent weight.*

In the following situations, draw a force diagram on the person.

1. A 50-kg person stands on a bathroom scale on a floor at rest. What is the reading of the scale in newtons? (This is the same as asking what is the normal force of the floor on the person.

2. A 50-kg person stands on a scale in a rocket that is accelerating upward at 40 m/sec^2. What is the upward force of the scale on the person? This is the apparent weight of the person.

3. A 50-kg person stands on a scale in an elevator that is accelerating downward at 3 m/sec^2. What is the upward force of the scale on the person? What is the apparent weight of the person? What is the true weight of the person?

4. A 50-kg person is in a free-fall chamber which is allowed to free fall for a few seconds before slowing down. What is the upward force of the scale on the person? What is the apparent weight of the person? What is the true weight of the person?

In what other kinds of free-fall situations can a person have an apparent weight of zero?