Forces

2. Unbalanced forces cause changes in velocity. As a basis for understanding this concept:
   a. *Students know* a force has both direction and magnitude.
   b. *Students know* when an object is subject to two or more forces at once, the result is the cumulative effect of all the forces.
   c. *Students know* when the forces on an object are balanced, the motion of the object does not change.

d. *Students know* how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.

e. *Students know* that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).

f. *Students know* the greater the mass of an object, the more force is needed to achieve the same rate of change in motion.

g. *Students know* the role of gravity in forming and maintaining the shapes of planets, stars, and the solar system.

Additional Notes

- Newton's first law of motion states that the motion of an object will not change if no unbalanced forces act on it.
- Inertia is the tendency of matter to resist a change in motion. Mass is a measure of inertia.
- Newton's second law of motion states that the acceleration of an object depends on its mass and on the force exerted on it.
- Newton's third law of motion states that whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.
- Momentum is the property of a moving object that depends on its mass and velocity.
- When two or more objects interact, momentum may be exchanged, but the total amount of momentum does not change. This is the law of conservation of momentum.
- All objects accelerate toward Earth at 9.8 m/s/s.
- Air resistance slows the acceleration of falling objects.
- An object is in free fall if gravity is the only force acting on it.
- An orbit is formed by combining forward motion and free fall.
- Objects in orbit appear to be weightless because they are in free fall.
- A centripetal force is needed to keep objects in circular motion. Gravity acts as a centripetal force to keep objects in orbit.
- Projectile motion is the curved path an object follows when thrown or propelled near the surface of Earth.
- Projectile motion has two components—horizontal and vertical. Gravity affects only the vertical motion of projectile motion.

Forces in the Same Direction

25 N → 20 N →

Net force
25 N + 20 N = 45 N
to the right

Forces in Different Directions

← 10 N 12 N →

Net force
12 N − 10 N = 2 N
to the right

Part 2: Newton's Second Law

Isaac Newton expressed the relationship between force, mass, and acceleration in his second law. This law is so important that it became the basis for much of modern physics. In fact, Newton's contribution to science was so great that the unit for force, the newton (N), was named after him. A newton is defined as the force needed to produce an acceleration of 1 m/s^2 on a 1 kg object. Therefore, 1 N = 1 kg × 1 m/s^2. The equation for Newton's second law is given below.

EQUATION: Force = mass × acceleration

$F = m \times a$

If you know two of the values in this equation, you can calculate the third by changing the equation around, as follows:

$$\text{acceleration} = \frac{\text{Force}}{\text{mass}} \quad \textit{and} \quad \text{mass} = \frac{\text{Force}}{\text{acceleration}}$$

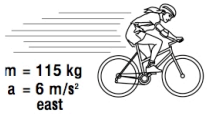
SAMPLE PROBLEM: A soccer ball accelerates at a rate of 22 m/s^2 forward when kicked by a player. The soccer ball has a mass of 0.5 kg. How much force was applied to the ball to produce this acceleration?

Force = mass × acceleration
Force = 0.5 kg × 22 m/s^2
Force = 11 kg × m/s^2
Force = **11 N**

Use the equations above to complete the following problems:

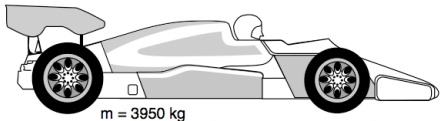
2. Calculate the force necessary to accelerate the following vehicles at the rate of acceleration shown in the illustration.

a.



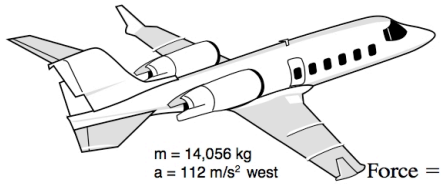
Force = _____

b.



Force = _____

c.



Force = _____

3. How much force is needed to move a 0.1 kg snowball at a rate of 15 m/s^2 upward?

_____

_____

4. A 0.02 N push accelerates a table-tennis ball along a table at 8 m/s^2 north. What is the mass of the ball?

_____

_____

5. At lift-off, an astronaut on the space shuttle experiences an acceleration of approximately 35 m/s^2 upward. What force does an 80 kg astronaut experience during this acceleration?

_____

_____

6. What is the acceleration of a train with a mass of 3.2×10^9 kg that pushes itself forward with 2.4×10^{10} N of force?

_____

_____

Part 3: The Force of Gravity

Forces are not always exerted on objects by direct physical contact, such as a hand pushing a door closed. For instance, the Earth exerts the force of gravity on objects even when the objects are not directly touching the ground. The acceleration on an object due to the force of gravity is 9.8 m/s^2 downward. In other words, for every second an object is falling, its velocity increases by 9.8 m/s downward.

7. a. A 9 kg bowling ball rolls off a table and strikes the ground. If the ball is in the air for 0.5 seconds, how fast is the ball moving when it hits the ground?

_____

_____

b. Another bowling ball with one-fifth less mass rolls off the same table and strikes the ground. When this ball hits the ground, is it moving faster, slower, or the same speed as the first ball? Explain your answer.

_____

_____

Forces in Motion

USING VOCABULARY

To complete the following sentences, choose the correct term from each pair of terms listed below, and write the term in the space provided.

1. An object in motion tends to stay in motion because it has _____. (inertia or terminal velocity)
2. Falling objects stop accelerating at _____. (free fall or terminal velocity)
3. _____ is the path that a thrown object follows. (Free fall or Projectile motion)
4. A property of moving objects that depends on mass and velocity is _____. (inertia or momentum)
5. _____ only occurs when there is no air resistance. (Momentum or Free fall)

UNDERSTANDING CONCEPTS

Multiple Choice

6. A feather and a rock dropped at the same time from the same height would land at the same time when dropped by
   - **a.** Galileo in Italy.
   - **b.** Newton in England.
   - **c.** an astronaut on the moon.
   - **d.** an astronaut on the space shuttle.
7. When a soccer ball is kicked, the action and reaction forces do not cancel each other out because
   - **a.** the force of the foot on the ball is bigger than the force of the ball on the foot.
   - **b.** the forces act on two different objects.
   - **c.** the forces act at different times.
   - **d.** All of the above
8. An object is in projectile motion if
   - **a.** it is thrown with a horizontal push.
   - **b.** it is accelerated downward by gravity.
   - **c.** it does not accelerate horizontally.
   - **d.** All of the above
9. Newton's first law of motion applies
   - **a.** to moving objects.
   - **b.** to objects that are not moving.
   - **c.** to objects that are accelerating.
   - **d.** Both (a) and (b)

Name _____

FORCE AND ACCELERATION

A force is a push or a pull. To calculate force, we use the following formula.

$F = ma$ where F = force in newtons
m = mass in kg
a = acceleration in m/sec²

Example: With what force will a rubber ball hit the ground if it has a mass of 0.25 kg?

Answer: $F = (0.25\text{ kg})(9.8\text{ m/s}^2)$
$F = 2.45\text{ N}$

Solve the following problems.

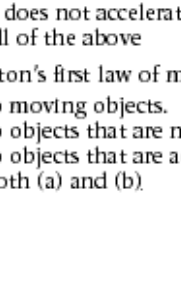
1. With what force will a car hit a tree if the car has a mass of 3,000 kg and it is accelerating at a rate of 2 m/s²?
   Answer: _____
2. A 10 kg bowling ball would require what force to accelerate it down an alleyway at a rate of 3 m/s²?
   Answer: _____
3. What is the mass of a falling rock if it hits the ground with a force of 147 newtons?
   Answer: _____
4. What is the acceleration of a softball if it has a mass of 0.50 kg and hits the catcher's glove with a force of 25 newtons?
   Answer: _____
5. What is the mass of a truck if it is accelerating at a rate of 5 m/s² and hits a parked car with a force of 14,000 newtons?
   Answer: _____

Name _____

FORCE DIAGRAMS

Find the resultant force in each of the following diagrams and draw the resultant vector. Use a ruler and a protractor where necessary. Scale: 1 cm = 10 N, where N represents newtons of force.

1.



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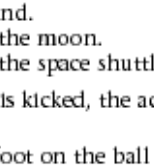
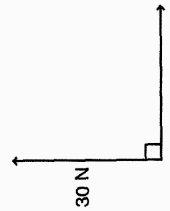
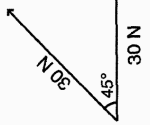


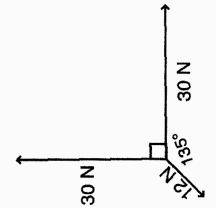
3.



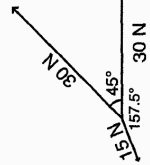
4.



5.



6.

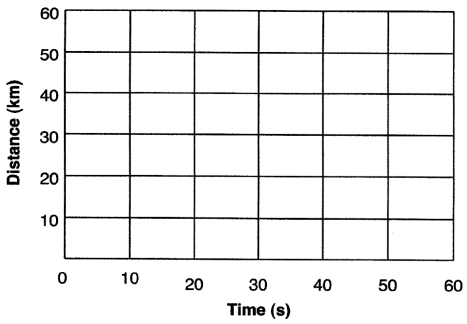


GRAPHING DISTANCE VS. TIME

Name _____

Plot the following data on the graph and answer the questions below.

Distance (km)	Time (s)
0	0
5	10
12	20
20	30
30	40
42	50
56	60



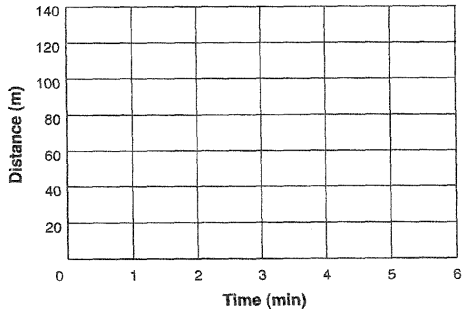
1. What is the average speed at t = 20 s? _____
2. What is the average speed at t= 30 s? _____
3. What is the acceleration between 20 s and 30 s? _____
4. What is the average speed at t = 40 s? _____
5. What is the average speed at t = 60 s? _____
6. What is the acceleration between 40 s and 60 s? _____
7. Is the object accelerating at a constant rate? _____

CALCULATING AVERAGE SPEED

Name _____

Graph the following data on the grid below and answer the questions at the bottom of the page.

Time (min)	Distance (m)
0	0
1	50
2	75
3	90
4	110
5	125



$$\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time}}$$

1. What is the average speed after two minutes? _____
2. After three minutes? _____
3. After five minutes? _____
4. What is the average speed between two and four minutes? _____
5. What is the average speed between four and five minutes? _____

DETERMINING SPEED (VELOCITY)

Name _____

Speed is a measure of how fast an object is moving or traveling. Velocity is a measure of how fast an object is traveling in a certain direction. Both speed and velocity include the distance traveled compared to the amount of time taken to cover this distance.

$$\text{speed} = \frac{\text{distance}}{\text{time}} \qquad \text{velocity} = \frac{\text{distance}}{\text{time}} \text{ in a specific direction}$$

Answer the following questions.

1. What is the velocity of a car that traveled a total of 75 kilometers north in 1.5 hours? _____
2. What is the velocity of a plane that traveled 3,000 miles from New York to California in 5.0 hours? _____
3. John took 45 minutes to bicycle to his grandmother's house, a total of four kilometers. What was his velocity in km/hr? _____
4. It took 3.5 hours for a train to travel the distance between two cities at a velocity of 120 miles/hr. How many miles lie between the two cities? _____
5. How long would it take for a car to travel a distance of 200 kilometers if it is traveling at a velocity of 55 km/hr? _____
6. A car is traveling at 100 km/hr. How many hours will it take to cover a distance of 750 km? _____
7. A plane traveled for about 2.5 hours at a velocity of 1200 km/hr. What distance did it travel? _____
8. A girl is pedaling her bicycle at a velocity of 0.10 km/min. How far will she travel in two hours? _____
9. An ant carries food at a speed of 1 cm/s. How long will it take the ant to carry a cookie crumb from the kitchen table to the ant hill, a distance of 50 m? Express your answer in seconds, minutes and hours. _____
10. The water in the Buffalo River flows at an average speed of 5 km/hr. If you and a friend decide to canoe down the river a distance of 16 kilometers, how many hours and minutes will it take? _____