Forces

Ch 12 ☺))))

Newton's 1st and 2nd Laws

12.1

Key Ideas

- What makes an object speed up, slow down, or change directions?
- What determines how much an object speeds up or slows down?

Newton’s Laws

- The British scientist Sir Isaac Newton (1642–1727) was able to state rules that describe the effects of forces on the motion of objects.
- These rules are known as Newton's law's of motion.

Newton’s 1st Law

- *What makes an object speed up, slow down, or change directions?*
- Newton's first law of motion states that an object moving at a constant velocity keeps moving at that velocity unless an unbalanced net force acts on it.
- If an object is at rest, it stays at rest unless an unbalanced net force acts on it.
- This law is sometimes called the law of inertia.

Newton’s 1st Law

- Inertia is the tendency of an object to resist a change in motion unless an outside force acts on the object
  - It wants to keep moving or NOT move
    - Ex. catch
- Objects only change their motion when a net force acts on them
  - i.e. at car stops because a force acts on it

What happens in a head-on collision?

- The law of inertia can explain what happens in a car crash.
- When a car traveling about 50 km/h collides head-on with something solid, the car crumples, slows down, and stops within approximately 0.1 s.

What happens in a head-on collision?

- Any passenger not wearing a safety belt continues to move forward at the same speed the car was traveling.
- Within about 0.02 s (1/50 of a second) after the car stops, unbelted passengers slam into the dashboard, steering wheel, windshield, or the backs of the front seats.
- Movie

Seat Belts

- The force needed to slow a person from 50 km/h to zero in 0.1 s is equal to 14 times the force that gravity exerts on the person.
- The belt loosens a little as it restrains the person, increasing the time it takes to slow the person down.
- This reduces the force exerted on the person.
- The safety belt also prevents the person from being thrown out of the car.

Seat Belts

- Air bags also reduce injuries in car crashes by providing a cushion that reduces the force on the car's occupants.
- When impact occurs, a chemical reaction occurs in the air bag that produces nitrogen gas.
- The air bag expands rapidly and then deflates just as quickly as the nitrogen gas escapes out of tiny holes in the bag.

Newton's 2nd law

- *What determines how much an object speeds up or slows down?*
- Newton's second law of motion describes how the forces exerted on an object, its mass, and its acceleration are related

Force and Acceleration

- What's different about throwing a ball horizontally as hard as you can and tossing it gently?
- When you throw hard, you exert a much greater force on the ball.

Force and Acceleration

- The hard-thrown ball has a greater change in velocity, and the change occurs over a shorter period of time.
- Recall that acceleration is the change in velocity divided by the time it takes for the change to occur.
- So, a hard-thrown ball has a greater acceleration than a gently thrown ball.

Mass and Acceleration

- If you throw a bowling ball and a baseball as hard as you can, why don't they have the same speed?
- The difference is due to their masses.

Mass and Acceleration

- If it takes the same amount of time to throw both of them, the softball would have less acceleration.
- The acceleration of an object depends on its mass as well as the force exerted on it.
- So, force, mass, and acceleration are related.

Newton's 2nd Law

- **Newton's second law of motion** states that the acceleration of an object is in the same direction as the net force on the object, and that the acceleration can be calculated from the following equation:

Equation Manipulation!!

$acceleration = \frac{Net\ Force}{mass}$ $a = \frac{F_{net}}{m}$

Manipulate the equation to solve for mass and for force.

$m = \frac{F_{net}}{a}$ $F_{net} = ma$

Force is measured in Newtons (N)
1 N = 1 kg * m/s^2

Practice

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- 1-4

Assignment

- EOSQ (2-5)
- 12.1 CR
- MS – Newton's 2nd Law

Gravity

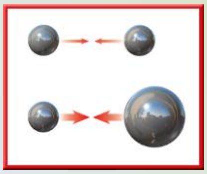
12.2

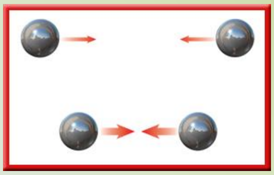
Key Ideas

- How are weight and mass related?
- Why do objects fall to the ground when dropped?
- What is the relationship between free-fall acceleration and mass?
- Why does a projectile follow a curved path?

Gravity

- **Gravity** is an attractive force between any two objects that depends on the masses of the objects and the distance between them.





Gravity – A Basic Force

- Gravity is one of the four basic forces.
- The other basic forces are the electromagnetic force, the strong nuclear force, and the weak nuclear force.

The Law of Gravitational Force

- Isaac Newton formulated the law of universal gravitation, which he published in 1687.
- This law can be written as the following equation.
- $G = 6.67 \times 10^{-11}\ N(m/kg)^2$

$$F = G(universal\ constant)\frac{Mass1\ x\ mass2}{distance^2}$$

$$F = G\frac{m_1\ x\ m_2}{d^2} =$$

The Law of Gravitational Force

- In this equation *G* is a constant called the universal gravitational constant, and *d* is the distance between the two masses, *m*1 and *m*2.
- The law of universal gravitation enables the force of gravity to be calculated between any two objects if their masses and the distance between them is known.

How much force is there between a 45 g object and a 68 kg object if they are 0.2 m apart?

- Numeric

What would happen to force of gravity if you doubled one of the masses?

A. Nothing
B. Double
C. Triple
D. Quadruple
E. ½
F. 1/3
G. ¼

How do we find the answer to the previous question? Put in "1's"!!

- If all variables are 1, the answer is 1

$$F = G\frac{m_1\ x\ m_2}{d^2} = \qquad F = G\frac{1\ x\ 1}{1^2} = 1$$

- If we change one of the masses to 2 (doubled) what happens

$$F = G\frac{2\ x\ 1}{1^2} = 2$$

- The answer doubles!!

What happens to the force if we double the distance between the objects?

A. Nothing
B. Double
C. Triple
D. Quadruple
E. ½
F. 1/3
G. ¼

How we got the answer.

$$F = G\frac{m_1\ x\ m_2}{d^2} =$$

$$F = G\frac{1\ x\ 1}{2^2} = \frac{1}{4}$$

The Range of Gravity

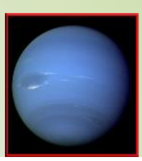
- No matter how far apart two objects are, the gravitational force between them never completely goes to zero.
- Because the gravitational force between two objects never disappears, gravity is called a long-range force.

The Range of Gravity

- In the 1840s the most distant planet known was Uranus.
- The motion of Uranus calculated from the law of universal gravitation disagreed slightly with its observed motion.
- Some astronomers suggested that there must be an undiscovered planet affecting the motion of Uranus.

The Range of Gravity

- Using the law of universal gravitation and Newton’s laws of motion, two astronomers independently calculated the orbit of this planet.
- As a result of these calculations, the planet Neptune was found in 1846.



Earth's Gravitational Acceleration

- When all forces except gravity acting on a falling object can be ignored, the object is said to be in free fall.
- Close to Earth's surface, the acceleration of a falling object in free fall is about 9.8 m/s^2.
- This acceleration is given the symbol *g* and is sometimes called the acceleration of gravity.

Earth's Gravitational Acceleration

- By Newton's second law of motion, the force of Earth's gravity on a falling object is the object's mass times the acceleration of gravity.

$$Force\ (N) = mass(kg)\ x\ acceleration\ (m/s^2)$$

$$F = ma$$

- Force is measured in Newton's (N),mass in kg and acceleration in m/s^2.

Weight

- The gravitational force exerted on an object is called the object's **weight**.
- Because the weight of an object on Earth is equal to the force of Earth's gravity on the object, weight can be calculated from this equation:

$$Force\ (N) = mass(kg)\ x\ gravity\ (m/s^2)$$

$$F = mg$$

Weight and Mass

- Weight and mass are not the same.
- Weight is a force and mass is a measure of the amount of matter an object contains.
- Weight and mass are related. Weight increases as mass increases.

Weight and Mass

- The weight of an object usually is the gravitational force between the object and Earth.
- The weight of an object can change, depending on the gravitational force on the object.

Weight and Mass

- The table shows how various weights on Earth would be different on the Moon and some of the planets.

Weight Comparison Table

Weight on Earth (N)	Weight on Other Bodies in the Solar System (N)				
	Moon	Venus	Mars	Jupiter	Saturn
75	12	68	28	190	87
100	17	90	38	254	116
150	25	135	57	381	174
500	84	450	190	1,270	580
700	119	630	266	1,778	812
2,000	333	1,800	760	5,080	2,320

Weightlessness and Free Fall

- You've probably seen pictures of astronauts and equipment floating inside the space shuttle.
- They are said to be experiencing the sensation of weightlessness.

Weightlessness and Free Fall

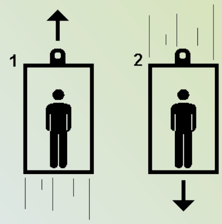
- However, for a typical mission, the shuttle orbits Earth at an altitude of about 400 km.
- According to the law of universal gravitation, at 400-km altitude the force of Earth's gravity is about 90 percent as strong as it is at Earth's surface.
- So an astronaut with a mass of 80 kg still would weigh about 700 N in orbit, compared with a weight of about 780 N at Earth's surface.

Floating in Space

- So what does it mean to say that something is weightless in orbit?
- When you stand on a scale you are at rest and the net force on you is zero.
- The scale supports you and balances your weight by exerting an upward force.

Riding in a elevator

- What would happen to the # on the scale when the elevator…



Floating in Space

- A space shuttle in orbit is in free fall, but it is falling around Earth, rather than straight downward.
- Everything in the orbiting space shuttle is falling around Earth at the same rate, in the same way you and the scale were falling in the elevator.
- Objects in the shuttle seem to be floating because they are all falling with the same acceleration.

Free-fall Acceleration

- You experience Free-fall acceleration when the only force acting on you is gravity
  - This can only happen if there is NO air resistance
- Air resistance can balance out your falling acceleration
  - Terminal velocity is the fastest an object can fall
    - The air resistance = the force of gravity

Because the gravitational force between two objects never disappears, gravity is called a…

A. Forever Force
B. Long-Range Force
C. Net Force
D. Super Force
E. Distance Force
F. None of the above

The acceleration due to gravity on Earth's surface is…

A. 98 m/s^2
B. 9.8 m/s^2
C. 8.9 m/s^2
D. 89 m/s^2
E. 9.8 km/s^2
F. 8.9 km/s^2
G. 89 km/s^2
H. 98 km/s^2

Which of the following are true?

A. Weight and mass are the same.
B. Weight and mass are not related.
C. Weight decreases as mass decreases.
D. The mass of an object can change, depending on the gravitational force on the object.
E. More than one of the above
F. None of the above

Astronauts are weightless when they are in space.

A. True
B. False

Which of the following examples is/are an example of something that is weightless.

A. Astronaut floating in space
B. You in a falling elevator (the cable broke)
C. A ball falling from the top of a building
D. None of the above
E. More than one of the above

Projectile Motion

- If you've tossed a ball to someone, you've probably noticed that thrown objects don't always travel in straight lines. They curve downward.
- Earth's gravity causes projectiles to follow a curved path.

Horizontal and Vertical Motion

- When you throw a ball, the force exerted by your hand pushes the ball forward.
- This force gives the ball horizontal motion.
- No force accelerates it forward, so its horizontal velocity is constant, if you ignore air resistance.

Horizontal and Vertical Motion

- However, when you let go of the ball, gravity can pull it downward, giving it vertical motion.
- The ball has constant horizontal velocity but increasing vertical velocity.

Horizontal and Vertical Motion

- Gravity exerts an unbalanced force on the ball, changing the direction of its path from only forward to forward and downward.
- The result of these two motions is that the ball appears to travel in a curve.

Horizontal and Vertical Motion

- If you were to throw a ball as hard as you could from shoulder height in a perfectly horizontal direction, would it take longer to reach the ground than if you dropped a ball from the same height?

Click image to view movie

Assignment

- EOSQ (1-2)
- 12.2 CR

Newton's 3rd Law

12.3

Newton's 3^{rd} Law

- **Newton's third law of motion** describes action-reaction pairs this way. When one object exerts a force on a second object, the second one exerts a force on the first that is equal in strength and opposite in direction.

Action Reaction Forces

- When a force is applied in nature, a reaction force occurs at the same time.
- When you jump on a trampoline, for example, you exert a downward force on the trampoline.
- Simultaneously, the trampoline exerts an equal force upward, sending you high into the air.

Action Reaction Forces DON'T Cancel Out

- According to the third law of motion, action and reaction forces act on different objects.
- Thus, even though the forces are equal, they are **not balanced** because they act on different objects.

Action Reaction Forces DON'T Cancel Out

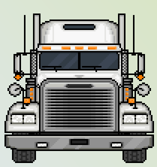
- For example, a swimmer "acts" on the water, the "reaction" of the water pushes the swimmer forward.
- Thus, a net force, or unbalanced force, acts on the swimmer so a change in his or her motion occurs.

Momentum

- A moving object has a property called momentum that is related to how much force is needed to change its motion.
- The **momentum** of an object is the product of its mass and velocity.

Momentum

- Compare momentums of…

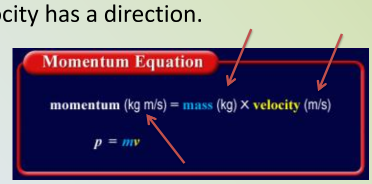


Momentum

- Force is related to changes in momentum
  - Ex. Caching an egg
    - Moving hands vs. NOT moving hands

Momentum

- Momentum is given the symbol *p* and can be calculated with the following equation:
- The unit for momentum is kg · m/s. Notice that momentum has a direction because velocity has a direction.



Practice

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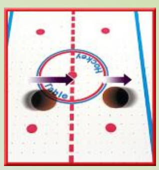
The Law of Conservation of Momentum

- The momentum of an object doesn't change unless its mass, velocity, or both change.
- Momentum, however, can be transferred from one object to another.
- The law of conservation of momentum states that if a group of objects exerts forces only on each other, their total momentum doesn't change.

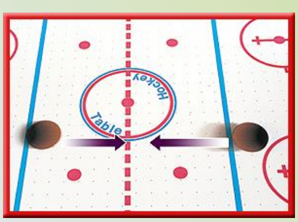
The Law of Conservation of Momentum

- The results of a collision depend on the momentum of each object.
- When the first puck hits the second puck from behind, it gives the second puck momentum in the same direction.



When Objects Collide

- If the pucks are speeding toward each other with the same speed, the total momentum is zero.



Momentum depends on…

A. Acceleration
B. Mass
C. Velocity
D. A & B
E. B & C
F. A & C
G. All of the above
H. None of the above

What is the momentum of an object that has a velocity of 4.5 m/s north and a mass of 4.5 grams?

- Numeric

Assignment

- EOSQ (4,7)
- 12.3 CR
- MS – Momentum (work day on Monday)
  - 1,2,3,5,6,7,9,10,14,16