Unit 4 –Motion

Objectives

1. Define and explain Newton’s three laws
2. Describe examples of inertia
3. Describe the relationship between force, mass and acceleration as described in Newton’s 2nd Law
4. Identify Action/Reaction forces as described in Newton’s 3rd Law
5. Calculate the force of an object given the mass and acceleration
6. Calculate and graph the speed and velocity of an object given the mass and the acceleration of that object
7. Calculate and graph the speed and velocity of an Object given the displacement and time of measurement for that object
8. Identify common forces including friction and gravity
9. Explore ways to reduce friction
10. Relate falling objects to gravitational force
11. Give examples of 6 types of simple machines and describe their functions
12. Show/explain how simple machines can be used to form complex machines
13. Describe the mechanical advantage and efficiency and the forces that affect efficiency
14. Determine the amount of work and the forces affecting the work (w=fxd)

Vocabulary

1. Inertia
2. Force
3. Net force
4. Unbalanced Force
5. Balanced Force
6. Mass
7. Acceleration
8. Deceleration
9. Distance
10. Motion
11. Displacement
12. Speed
13. Velocity
14. Friction
15. Gravity
16. Free Fall
17. Air Resistance
18. Terminal Velocity
19. Momentum
20. Newton
21. Mass
22. Power
23. Work
24. Load
25. Effort
26. Energy
27. Potential Energy
28. Kinetic Energy

Notes

**Motion** - The act or process of changing position or place.

*How do we measure motion?*

**Distance** : How far you have gone - the length between any points two points along the path of an object. Symbol is **d**

**Speed** : distance (how far you have gone) traveled in a given amount of time ***t***

***S - How fast something is moving***

**S = d / t**

**Displacement** : How far you have gone in a certain direction; distance with direction; how far you are from your starting point; symbol is **d** or **x**; the change in position of an object The straight line distance from start to finish.

**Velocity:** displacement (how far you have gone in a certain direction) per time interval;

symbol is *v* **v = d/t**

tells both speed and direction ex. meters/hour north

How do we measure changes in velocity?

**Acceleration**: The rate at which the velocity of an object is *changing*. Anything traveling at a constant speed will have no acceleration.

Formula

Average Acceleration(a) = final velocity (vf) - initial velocity (vi)

time (t) to go from vi to vf

a = vf - vi

t

remember - units of acceleration are units of velocity per time for ex. (Meters/hour)/second.

**Negative Acceleration (deceleration):** sometimes called deceleration - when velocity is decreasing, it is still changing, so this is still considered

acceleration. Because the final velocity vf will be less than the initial velocity vi, your answer will be negative.

**Graphing Motion**

1. Velocity - Speed in a specific direction A car is moving at a constant velocity to the right of 10km/hr. Plot the velocity of the car on the graph below if the car traveled 100 km in10 hours.

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(time in hours) (time in hours)

Now, the same car has slowed to a constant velocity of 5km/hr. Plot the velocity of the car over the next 10 hours.

By comparing the two graphs we can see that the steeper the line on a position vs. time graph, the higher the velocity.

Now, graph the velocity on a position vs. time graph below that is moving a constant velocity of 10 km/hour for 5 hours and then stops.

2. **Acceleration graphed** -When a car has a changing velocity it is considered to be accelerating. Because of this change the distance traveled each second is not a constant value.

Graph a car that is moving as follows:

Time in Seconds Distance in Meters

1 s 5 m

2 s 15 m

3 s 30 m

4 s 50 m

5 s 75 m

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(time in seconds)

How does the line of the acceleration graph look different than the line of the velocity graph?

**Forces-**  a scientist named Isaac Newton discovered that motion is a result of the forces exerted upon matter

**The Three Laws of Motion by Sir Isaac Newton**

-Explain all aspects of motion.

**Newton's First Law** - Describes motion produced by balanced forces. Defines Force.

An object at rest will remain at rest, and an object in motion will remain at a constant velocity unless unbalanced forces act on it. Thus…

**Force:** any influence that will cause an object at rest to move and an object in motion to change its speed and or direction of motion, or both.

2 Types of forces -

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| --- | --- |
| 1. Contact - (between 2 things) | 2. Non Contact (no - touching between them) |
| Applied Force - pushing, pulling, hitting | Gravitational |
| Frictional | Electrical |
| Air resistance | Magnetic |
| Normal - ex. desk exerts a force against a book sitting on it, book exerts a force o desk |  |
| Tensional (rope, string, etc. when pulled apart) |  |
| Spring (compressed or stretched spring) |  |

**The law of inertia: tendency of matter to resist changes in it state of motion**

**Inertia and Mass** - mass of a body at rest determines its inertia. Greater its mass, greater its resistance to being set in motion.

ex. Soccer ball vs. a solid lead ball of the same size. If you kick a soccer ball and the lead ball with the same force, then the soccer ball will be set in motion much easier.

**Balanced and Unbalanced Forces**

Forces occur in pairs and can be either balanced or unbalanced. **Balanced forces** do not cause a change in motion. They are equal in size and opposite in direction.

Unlike balanced forces, **unbalanced forces** always cause a change in motion. They are not equal and opposite. They can be unequal in size and in direction.

Examples:

**1. Two people pushing on an object with the same force from opposite directions, then the two forces cancel out. In this case, there is no net force, so there is no change in the velocity of the object.**

**2. As another example, what would happen if we were to put some people in the bed of a truck and have them push on it? Obviously, we would find that the truck would stay still because the truck is pushing back on the people with the same force. Thus, there is no net outside force acting on the truck and its velocity doesn't change.**

**3. What about examples where there is a change in the velocity? We have all experienced riding in a car when it brakes suddenly. If we are not braced against something, we are pitched forward. This is because originally the car and we are moving at the same velocity. When the car breaks, its velocity is lowered, but our inertia causes our velocity to remain the same. Thus, from our perspective, we move forward in the car until the seat belt catches us and decelerates us to the same speed as the car.**

**Newton's Second Law** - describes motion produced by unbalanced forces.

The acceleration of an object is directly proportional to the unbalanced force acting on the object and inversely proportional to the mass of the object.

Newton’s 2nd Law points out three things about the acceleration of an object when an unbalanced force acts on it:

1. The bigger the unbalanced force acting on the object the bigger the acceleration of the object.

2. The more mass the object has the more inclined it is to resist any change in its motion.

For example, if you apply the same unbalanced force to a mass of 1000 kg and a mass of 1 kg, the acceleration (change in motion) of the 1000 kg mass will be much less than that of the 1 kg mass.

3. An object is accelerated in the same direction as its motion.

What this means - the greater the force -> the greater the object’s change in motion, or acceleration. It also means, the greater the mass of the object, the less a given force will change its motion.

Here is the 2nd Law mathematically:

Acceleration = Force a = F Mass m

Now we have an equation for force as well:

force = mass X acceleration or F = ma

The Newton - unit of force - equal to the amount of force required to accelerate a mass of one kilogram at a rate of one meter per second per second. 1N = 1 kg x 1m/**s2**.

On Earth's surface, a mass of 1 kg exerts a force of approximately 9.8 N

**Steps for Solving Force Equations**

**Problem: How much force must be applied to a toy car that has a mass of .25kg to achieve an acceleration of 2.4m/s2?**

**Step 1: Write down the formula needed to solve the problem.**

**f = ma**

**Step 2: Place the known measurements into the formula.**

**Known : The mass of the car is .25kg and the acceleration of the car is 2.4m/s2.**

**f = (.25kg) (2.4m/s2)**

**Step 3: Solve**

**f = .6N**

**A force of .6N must be applied to the toy car.**

**Make sure that all of your numbers in the equation have a SI unit and make sure you label your answer with the correct SI unit for force (N).**

**Show all work set up in the equation. Don't forget to label all numbers!**

**PROBLEMS:**

**1. If a 4500 kg car is traveling westward with an acceleration of 35.2 m/ s2, what is the force acting on it?**

**2. I am a roller skater with a mass of 72kg. If I am accelerating toward a wall at 3.7m/ s2, what will be the amount of force at which I hit the wall?**

**3. A dockworker needs to stop a box of goods that is rolling across a manual conveyer belt. The box has a mass of 8.35kg and is accelerating at .75m/ s2. How much force will he need to apply to the box in order to stop it?**

**4. How much force must be applied to move a 55kg ice skater to an acceleration of 12.5m/ s2?**

**Newton's Third Law** - explains why forces act in pairs.

For every action force there is an equal (in size) and opposite (in direction) reaction force.

Forces always come in pairs - known as "**action-reaction force pairs**."

Who is pushing on who and in what direction.

Ex. A baseball bat and a baseball.

The baseball forces the bat to the left; the bat forces the ball to the right. Together, these two forces exerted upon two different objects form the action-reaction force pair.

Baseball and glove

1. Baseball pushes glove leftwards.

2.

Bowling Ball and Pin

1. Bowling ball pushes pin leftwards.

2.

Balloon and air

1. Enclosed air particles push balloon wall outwards.

2.

**Newton’s Law of Universal Gravitation**

[**Isaac Newton**](http://great-scientists.suite101.com/article.cfm/sir_isaac_newton_scientist) - 1642-1727

realized that the same forces and the same laws of physics apply everywhere in the universe

**Force of Gravity**

A gravitational force acts between any two objects in the universe

- between you and Earth

- between you and the Sun

- between you and all the other planets

- between you and the people sitting next to you

Why do we fall down towards Earth rather than towards the Sun, another planet, or the people next to us?

The force of gravity between us and Earth is larger than the force from any of these other objects.

The force of gravity between two objects depends on the **masses** of the two objects and the distance between the centers of the two objects.

**Falling Objects**

**Free Fall, Projectile Motion and Orbital Motion**

**A free-falling object**- falling under the sole influence of gravity.

There are two important motion characteristics which are true of free-falling objects:

1. Free-falling objects do not encounter air resistance.

2. All free-falling objects (on Earth) accelerate downwards at a rate of 9.8 m/s/s

**Energy -** Matter and energy are the two fundamental concepts of physical science.

Energy is the ability to do work.

Work is moving an object against an opposing force

- Formula for work = force × distance

- SI unit of work or energy: the joule (J)

*Two basic forms of energy*

- Potential energy: energy of position - stored energy – When an object is lifted against gravity Affected by mass and height of an object As Mass increases - potential energy increase As Height increases - potential energy increases

- Kinetic energy: energy of motion - moving energy

Affected by mass and speed of an object As Mass increases - kinetic energy increases As Speed increases - kinetic energy increases

**Forms of Energy**

Energy is found in different forms including light, heat, chemical, and motion. There are many forms of energy, but they can all be put into two categories: potential and kinetic.

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| **Potential Energy** | **Kinetic Energy** |
| **Chemical Energy** is energy stored in the bonds of atoms and molecules. Ex. petroleum, natural gas, and coal  **Mechanical Energy** is energy stored in objects by tension. Ex. Compressed springs and stretched rubber bands.  **Nuclear Energy** is energy stored in the nucleus of an atom — the energy that holds the nucleus together. **fission** - process where Nuclear power plants split the nuclei of uranium atoms  **fusion** - sun combines the nuclei of hydrogen atoms in this process  **Gravitational Energy** is energy stored in an object's height. The higher and heavier the object, the more gravitational energy is stored. Ex. When you ride a bicycle down a steep hill and pick up speed, the gravitational energy is being converted to motion energy. Hydropower is another example of gravitational energy, where the dam "piles" up water from a river into a reservoir.  **Electrical Energy** is what is stored in a battery.  Can be used to power a cell phone or start a car. Electrical energy is delivered by tiny charged particles called electrons, typically moving through a wire. | **Radiant Energy** is electromagnetic energy that travels in transverse waves. Ex. visible light, x-rays, gamma rays and radio waves, sunshine  **Thermal Energy**is the vibration and movement of the atoms and molecules within substances.  **Motion Energy** is energy stored in the movement of objects. The faster they move, the more energy is stored. Ex. Wind, car crash - when the car comes to a total stop and releases all its motion energy at once in an uncontrolled instant.  **Sound** is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate — the energy is transferred through the substance in a wave. Typically, the energy in sound is far less than other forms of energy. |

WORK and MACHINES

Work - occurs when a force moves an object over a distance; it is the amount of energy transferred by a force to a moving object

Work is equal to a *Force x a distance* W = fd

Force is measured in Newtons and distance is measured in meters. Thus the unit of work is the N - m. We give these combined units a new name called the Joule

**Power** - the rate of doing work. To find power take the Force (N) X the Distance (m) and divide it by the time (s) it takes to do the work. The units for power are N-m/s. We give this a new name called the watt.

P = fd or P = W t t

Energy - ability to cause change; can change the speed, direction, shape, or temperature of an object

Mechanical Advantage - the advantage created by a machine that enables people to do work while using less force

Simple machines are used to make work easier by

1. Transferring a force from one place to another

2. Changing the direction of a force

3. Increasing the magnitude of a force

4. Increasing the distance or speed of a force

5. Provide a mechanical advantage

Load - the weight being lifted by the simple machine. Also called resistance , resistance load, load force , resistance force , output force

Effort - effort is the force placed on the simple machine to move the load. Also called applied force , effort force or input force

What are simple machines?

. Simple machines are tools that make work easier

. They have few or no moving parts

. These machines use energy to work

. Do work with one movement

. Make our work easier by letting us use less mechanical effort to move an object

. Simple machines make work easier for us by allowing us to push or pull over increased distances

. You are doing the same amount of work - it just seems easier

What are Compound or Complex Machines?

. Two or more simple machines working together

. Most of the machines we use today are compound machines

6 Main Types of Simple Machines

- Divided into Two groups:

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| Inclined planes | Levers |
| Ramp | Lever |
| Wedge | Wheel & Axle |
| Screw | Pulley |

Ramp or Inclined Plane

. A flat surface that is higher on one end - slanting surface connecting a lower level to a higher level.

. You can use this machine to move an object to a lower or higher place.

. Inclined planes make the work of moving things easier - allows us to raise an object with less effort than if we lifted it directly upward.

. Trade-off : you must move things a greater distance

. The longer the distance of the ramp, the easier it is to do the work

. It will take a much longer time to do the work

. The shallower the ramp, the easier it is to move the object

. The trade-off is that you must move the object farther to lift it to the same height

Examples of Inclined Planes :

. Ramp, Slanted Road, Path up a Hill, Slide

Wedge

. A wedge is a simple machine used to push two objects apart

. A wedge is usually made up of two inclined planes

. These planes meet and form a sharp edge. This edge can split or push objects apart

. A wedge is an inclined plane which moves

. A wedge can also be used as a lifting device, by forcing it under an object

. Most wedges (but not all) are combinations of two inclined planes

. Can also be round, like the tip of a nail

. The narrower the wedge (or the sharper the point of a wedge), the easier it is drive it in and

. Trade-off : To split something apart really wide, you have to push the wedge a long distance.

. Generally it can be anything that splits, cuts, or divides another object including air and water

Examples of Wedges : Knife, Axe, Teeth, Forks, Nails

Screw

. An inclined plane that winds around itself

. a wedge at the tip

. A screw has ridges and is not smooth like a nail

. Some screws are used to lower and raise things

. They are also used to hold objects together

. A screw is like the ramp -the width of the thread is like the angle of an inclined plane

. The wider the thread of a screw, the harder it is to turn it.

. Trade-off : The distance between the threads depends on the slope of the inclined plane - the steeper the slope, the wider the thread

. Screws with less distance between the threads are easier to turn

Examples of Screws : Jar Lids, Light Bulbs, Stools, Clamps, Jacks, Wrenches, Spiral Staircase

Lever

. A lever is a board or bar that rests on a turning point

. This turning point is called the fulcrum

. An object that a lever moves is called the load

. The load is a force or object which must be overcome by the lever

. The applied force or effort or input force is the force you use to move the lever

. Lifts or moves loads

. By changing the position of the fulcrum, you can gain extra power with less effort

. The closer the object is to the fulcrum, the easier it is to move

. Most common simple machine because just about anything that has a handle on it has a lever attached

. The arm length of the lever is determined by the position of the fulcrum

. Used to transfer force

. It can be used to increase the force that is applied, or make something move in a different direction, or through a greater distance

. It can be used to lift something that is far away

. It is the same principle as the inclined plane - the greater the distance over which the force must be applied, the smaller the force required to do the work (lift the load)

. Force moves over a longer distance

. Depending on where the fulcrum is located

. A lever can multiply either the force applied or

. The distance over which the force is applied

Three types of levers:

First Class Lever

. Fulcrum in the center - between load & effort

. The lever changes the direction of force

. The fulcrum is placed close to the load , and this will let you move the load with just a small applied force (effort)

. This type of lever system gives you a mechanical advantage , which means that the force you apply gets multiplied , so you can put a large force on the load.

. The trade-off of using a lever like this is that you have to apply a force over a large distance , and the load itself will move only a short distance

. The fulcrum is between the load and where you apply the force (effort)

. This lever system has no mechanical advantage.

. Whatever force is necessary to move the load is the force you must apply

. This type of lever system takes advantage of another property of some levers: they reverse the direction of the force

. You can push in one direction, and the load moves the other way

. The fulcrum is nearer the applied force (effort)

. Much more force than the force of the load itself must be applied

. If you're lifting something, it will require much more force than would be needed if you were to just lift the load by yourself - this type lever system makes the work harder !!

. This type of lever system usually uses a motor to lift the load

. The load is far away , and it moves a long distance

. We get a small movement where we applied the force

Examples of 1 st Class Levers:

. See-saw, Scissors, Pliers

2nd Class Lever

. The load is in the center - between the fulcrum and the applied force or effort

. Causes the load to move in the same direction as the force you apply

. When the load is nearer to the fulcrum, the effort needed to lift the load will be less

. If you want to move a very large load with a small effort, you must put the load very close to the fulcrum

Examples of 2 nd Class Levers: Wheelbarrow, Nutcracker

3 rd Class Levers

. The applied force or effort is in the center - between the load and fulcrum

. This lever system does not give any mechanical advantage

. No matter where you apply the force, the force you apply must always be greater than the force of a load

. No matter how close or how far the load is from the fulcrum, the effort used to lift the load, has to be greater than the load!

. The load moves in the same direction as the force you apply

. A motor is usually used with this lever system to lift loads at a distance

. Speeds up movement

Examples of Third Class Levers: Your bent arm, Fishing rod

Wheel & Axle

. A wheel with a rod, called an axle, through its center lifts or moves loads

. The axle is a rod that goes through the wheel

. This lets the wheel turn

. The wheel & axle can be used as a tool to multiply the force you apply

. Or to multiply the distance traveled

. A lever that is able to rotate through a complete circle (360° )

. The circle turned by the wheel is much larger than the circle turned by the axle.

. The increased distance over which the force is applied as the wheel turns results in a more powerful force on the axle, which moves a shorter distance

. Trade-off-: The larger the diameter of the wheel, the less effort you need to turn it, but you have to move the wheel a greater distance to get the same work done.

Examples of Wheels and Axles: Cars, Roller skates, Door knobs, Gears

Pulleys

. Instead of an axle, the wheel could also rotate a rope or cord. This variation of the wheel and axle is the pulley

. In a pulley, a cord wraps around a wheel

. As the wheel rotates, the cord moves in either direction

. When a hook is attached to the rope you can use the wheel's rotation to raise and lower objects.

. The rope fits on the groove of the wheel

. One part of the rope is attached to the load

. When you pull on one side of the pulley, the wheel turns and the load will move

. Pulleys let you move loads up, down, or sideways

. Pulleys are good for moving objects to hard to reach places

. A pulley makes work seem easier because it changes the direction of motion to work with gravity

. A pulley saves the most effort when you have more than one pulley working together

Trade-off - as you increase the number of pulleys, you also increase the distance you have to pull the rope

. In other words, if you use two pulleys, it takes half the effort to lift something, but you have to pull the rope twice as far

. Three pulleys will result in one-third the effort - but the distance you have to pull the rope is tripled!

Types of Pulleys: Blinds, Cranes

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| **Looking for - Speed** | **Looking for - Velocity** |
| **Given** | **Given** |
| **Formula** | **Formula** |
| **Looking for - Acceleration** | **Looking for - Acceleration** |
| **Given** | **Given** |
| **Formula** | **Formula** |
| **Looking for - Force** | **Looking for - Work** |
| **Given** | **Given** |
| **Formula** | **Formula** |
| **Looking forPower** | **Looking for** |
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