

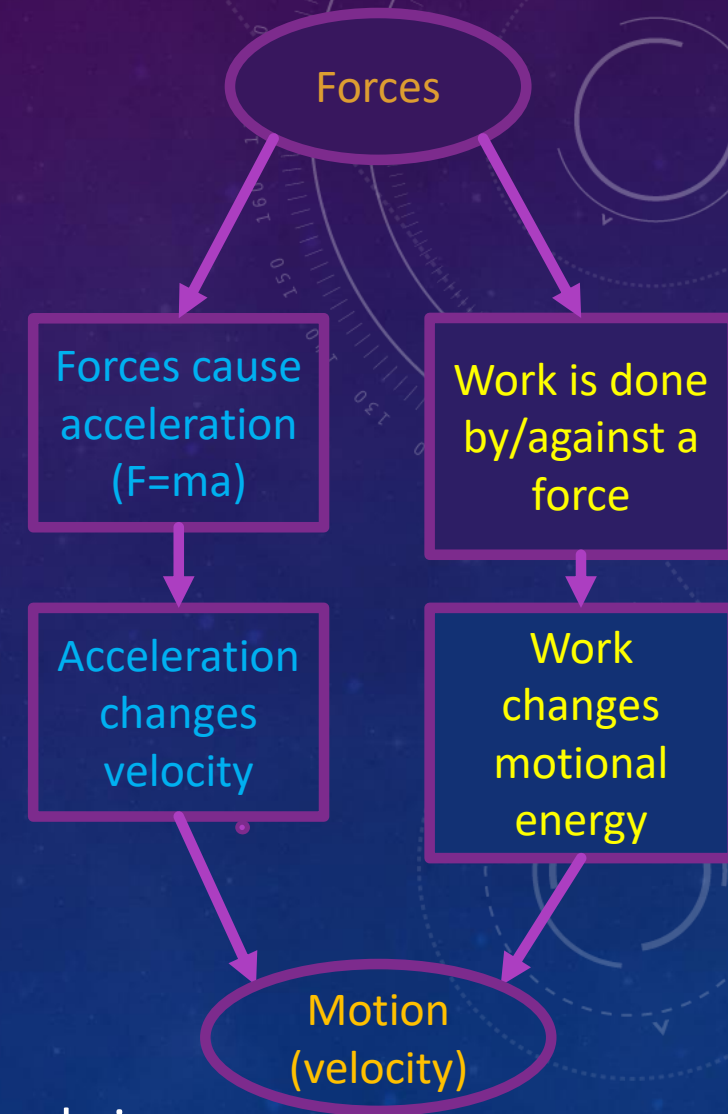


# WORK AND ENERGY

PES 1000 – PHYSICS IN EVERYDAY LIFE

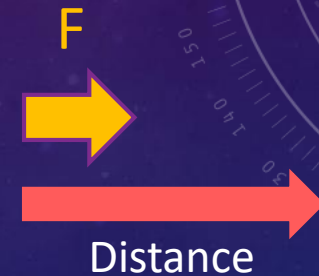
# WORK, ENERGY, AND MOTION

- We know from experience that **forces** can create motion, represented by **velocity**
- Newton's Laws explain motion in the following way:
  - **Forces** cause **acceleration** (Newton's second law)
  - **Acceleration** changes **velocity**
- Another useful approach to explain motion uses the concepts of **work** and **energy**
  - In this approach, **forces** do **work**
  - **Work** can change the amount of motional **energy** of an object
  - The motional **energy** is related to its **velocity**
- The **work and energy** method can be derived from **Newton's Laws** and vice versa
- Some situations may be easier to understand using the **work and energy** method



# DEFINITIONS

- Work – A scalar quantity
  - A **force** being exerted through a **distance**
  - A transfer of **energy** from one form to another
- Energy – A scalar quantity
  - The ability to do **work**
  - There are three general categories of energy:
    - Energy of position or configuration of a system (**Potential Energy**)
    - Energy of motion (**Kinetic Energy**)
    - Radiant energy – energy in light and other forms of radiation
- Units: **Energy** and **work** (a transfer of energy) have the same units
  - Joules (J) – a derived unit.  $1 \text{ J} = 1 \text{ N} \cdot \text{m}$  (U.S. customary unit is pound-feet (lb-ft))



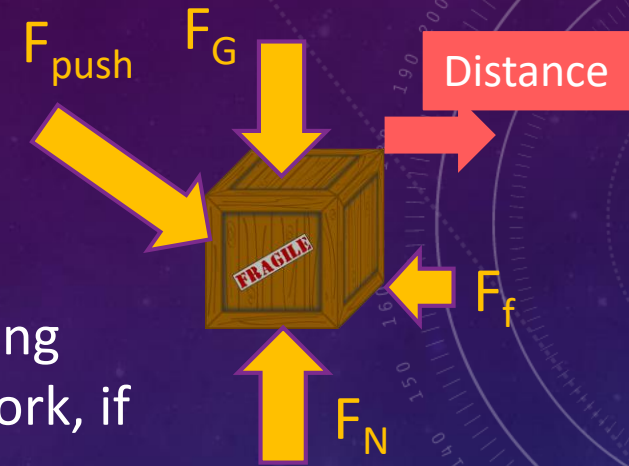
# HOW TO DETERMINE THE WORK DONE BY A FORCE

- Work is done when a force moves through a distance. If an object doesn't move, the forces on it are doing no work
- To do work, the force must move in the direction it is pointing. If part of the force points in a different direction, that part of the force does no work. Only the part of the force that points in the direction of motion does work.
- If the force points along the direction of motion, then work is done by the force. This is considered a positive number.
- If the force points opposite the direction of motion, then work is done against the force. This is considered a negative number.
- The value for work is then:
  - Work = (force in direction of motion) \* (distance travelled by the force) or  $W = F * d$



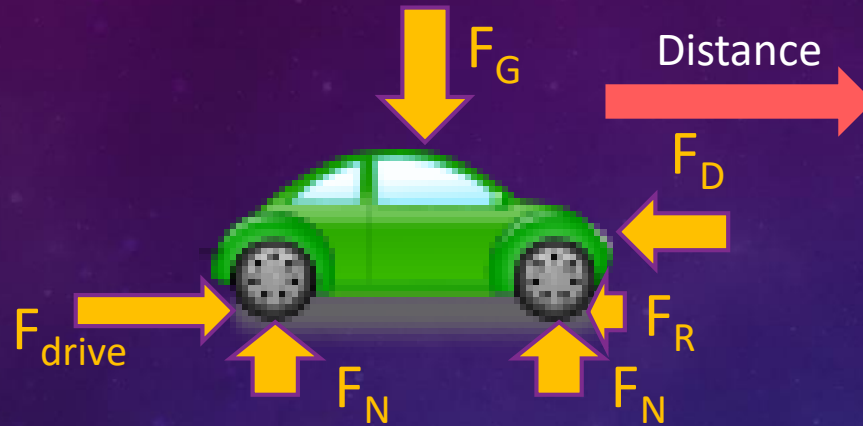
# WORK: AN EXAMPLE

- It is useful to sketch a picture of an object and the forces acting on it. Then step through each force and ask yourself what work, if any, it does.
- The **net work** is the (arithmetic) sum of the work done by all of the **forces**
  - Example: A worker pushes a box along the floor. He pushes down and to the right, as shown.
    - The sideways part of his force does **positive work**.
    - The downward part of his force does **no work**. (The box does not move down at all.)
    - The friction does **negative work**. It is work done against the motion of the box.
    - The gravitational force and the normal force do **no work**. They are vertical. The box moves horizontally.
- **Drag** and **friction** are **dissipative forces**. They always oppose motion and require work to overcome them.

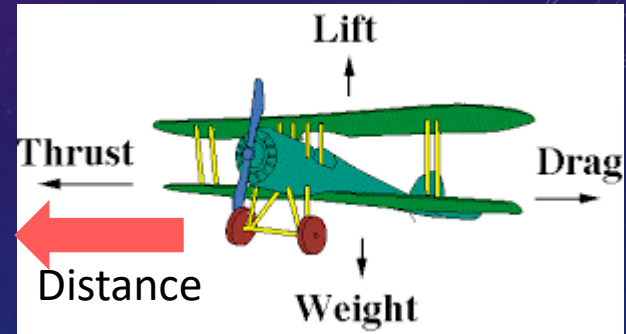


# PRACTICE: WHICH FORCES DO WORK?

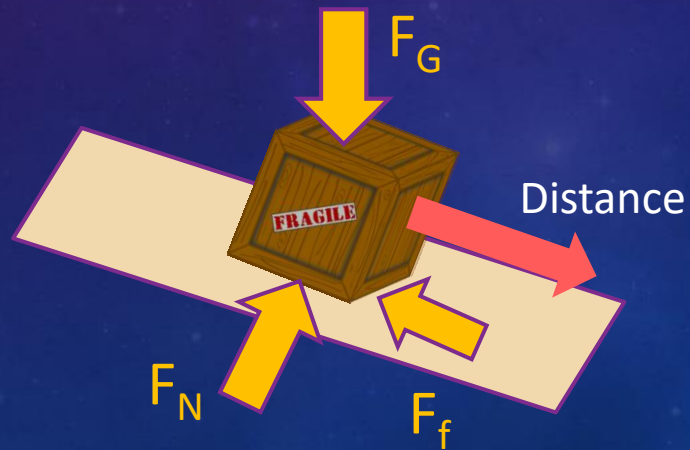
- Car



- Airplane



- Box on a plane



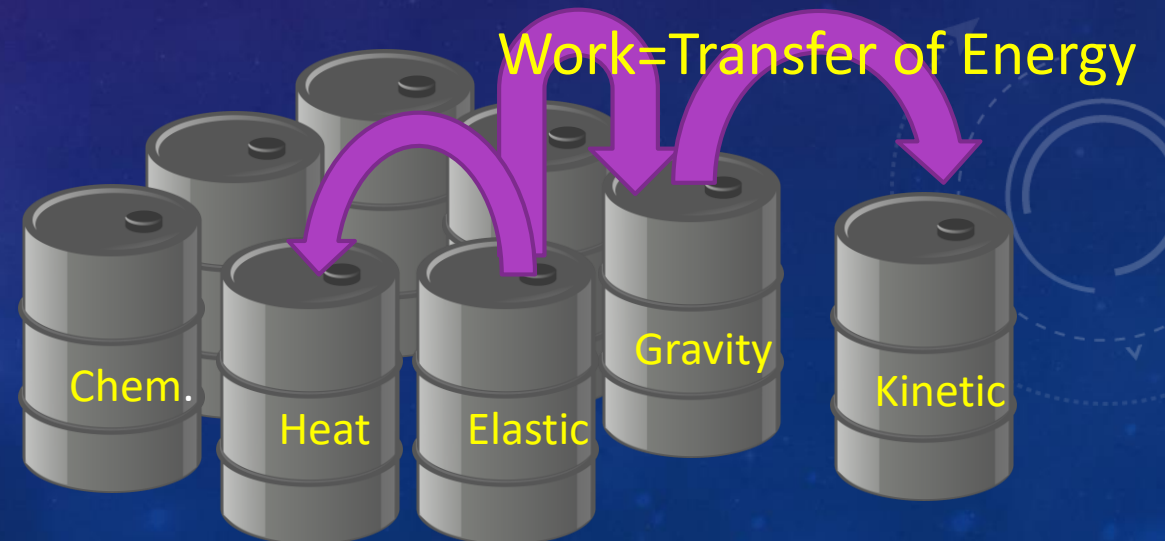
# TYPES AND FORMS OF ENERGY

- Energy takes many, many forms. Here is a partial list:

Form	Description	Type	
Gravitational	Depends on an object's position in a gravity field	Potential	
Kinetic	Energy of motion which depends on its speed and mass	Kinetic	
Chemical	Depends on the configuration of a substance's molecules	Potential	
Heat	Depends on the internal vibration of a substance's molecules	Kinetic	
Light	Light waves and other electro-magnetic radiation carry energy	Radiant	
Nuclear	Splitting or fusing the nuclei of atoms involves great energies	Potential	
Elastic	Solid bodies store energy when they are deformed	Potential	
Sound	Sound waves carry energy	Kinetic	
Electrical	Electric charges can store energy based on their configuration	Potential	
(and more)			

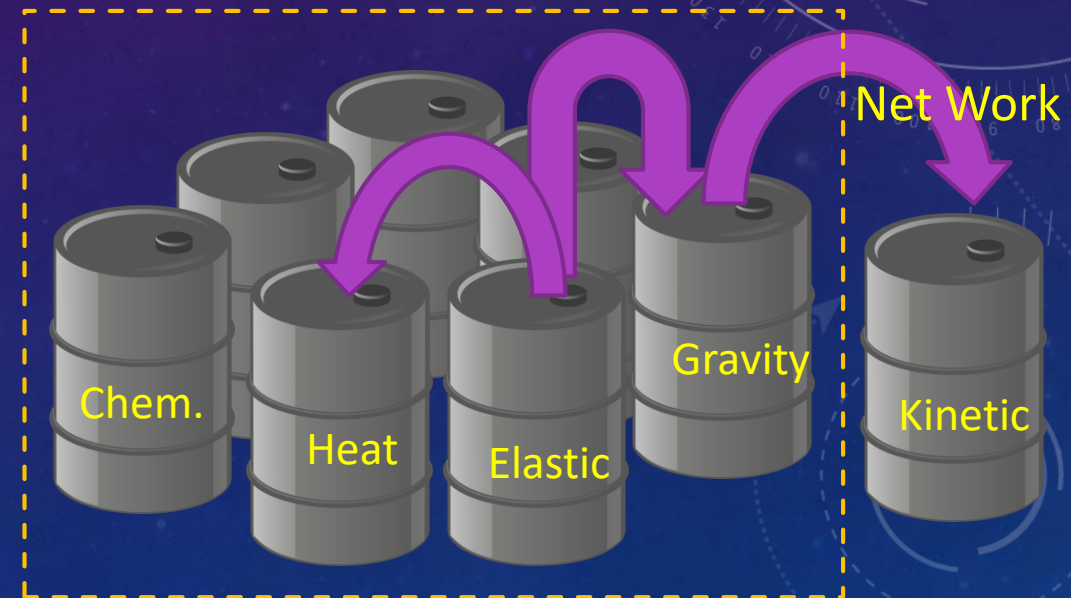
# BARREL ANALOGY

- It is useful to visualize the physics behind work and energy using **barrels** holding different forms of **energy**.
- **Energy** can flow from one barrel to another. This is **work** changing the form of the energy.
- If every form of energy is accounted for with a barrel, there is no work 'leaking' out of the system
- One of the barrels is for **Kinetic Energy**. This is related to the motion of an object. Any energy that is transferred to or from here affects its motion.
- Kinetic Energy =  $\frac{1}{2} \text{mass} * (\text{speed})^2$ 
  - $KE = \frac{1}{2} * m * v^2$



# PRINCIPLE OF WORK AND ENERGY

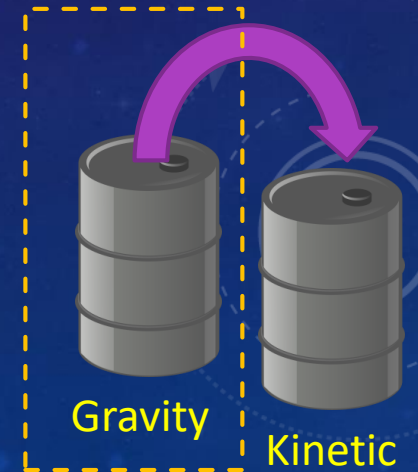
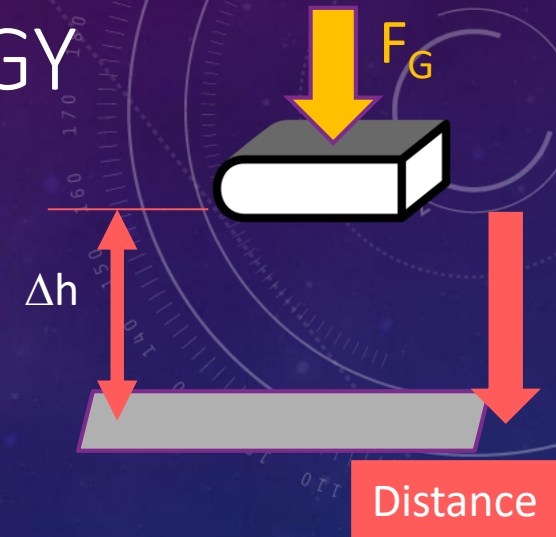
- One method of looking at motion is the Principle of Work and Energy. It states:  
**The net work affecting an object changes its kinetic energy**
- In equation form,  $\text{Work}_{\text{net}} = \Delta \text{K.E.}$  ( $\Delta$  means “change in”)
- In words, you add up all the **positive work** done by **forces on an object** and **negative work** done **against forces by the object**. The total is equal to the **change in kinetic energy** of the object.
- In the barrel analogy, any work that flows into the **Kinetic Energy** barrel changes its motion



# APPLYING THE PRINCIPLE OF WORK AND ENERGY

Let's apply the **Principle of Work and Energy** to an example:

- We drop a book from a certain height above the floor.
  - Between when we have released it and right before it reaches the ground, only **gravity** and **drag** affect it.
  - **Drag force** is very small, so we can ignore it.
  - This means that the **work done by gravity** is entirely converted into **kinetic energy** as it approaches the floor.

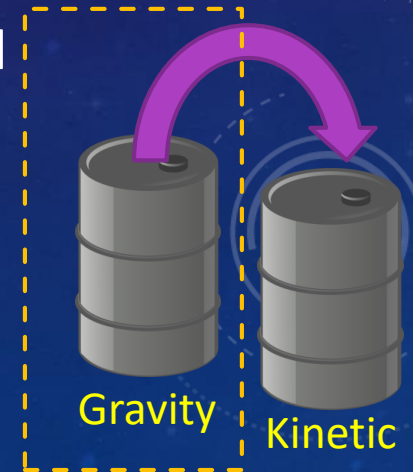
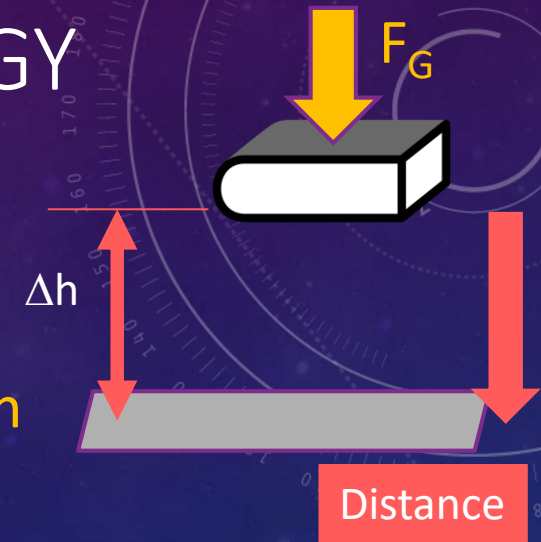


# APPLYING THE PRINCIPLE OF WORK AND ENERGY

- The Principle of Work and Energy says that the net work (done by gravity) is converted into Kinetic Energy, or
  - Work done by gravity is **force\*distance = weight\*distance =  $(m*g)*\Delta h$**
  - Net Work = Change in KE, therefore  **$m*g*\Delta h = \frac{1}{2} m*v^2$**
  - Notice that mass appears on both sides of the equation, so it cancels out. This means that the speed does not depend on the mass of the object, and **all objects fall at the same rate** if drag is ignored.
  - Here's a convenient formula for finding the speed of an object dropped from rest (and ignoring drag):

- $v = \sqrt{2 * g * \Delta h}$

- If the **speed is doubled**, the **kinetic energy is quadrupled**. This means that it takes **four times as much effort (work)** to go twice as fast.



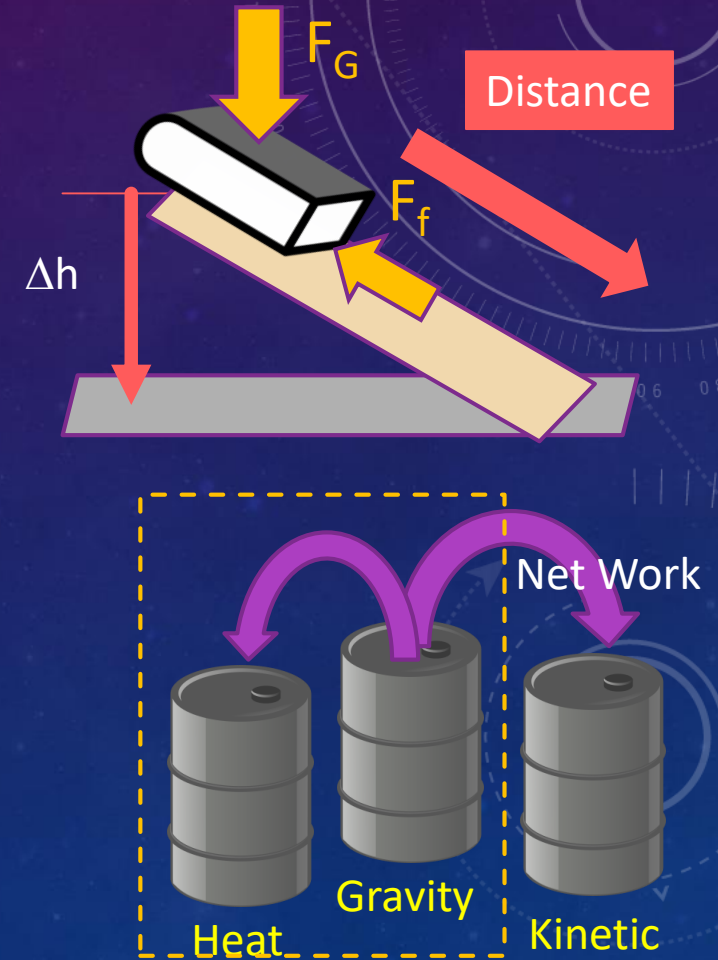
$$KE = \frac{1}{2} * m * (v)^2$$

$$4 * KE = \frac{1}{2} * m * (2v)^2$$

# APPLYING THE PRINCIPLE OF WORK AND ENERGY

Let's apply the **Principle of Work and Energy** to another example:

- The same book slides down a rough wooden slope from the same height as before.
  - We will **ignore air drag** again, but the friction is not ignorable.
  - The **gravitational force** does **work** since the book changes height.
  - It takes some of that work to overcome **friction**, which transfers energy into **thermal form**, so the book is going slower.

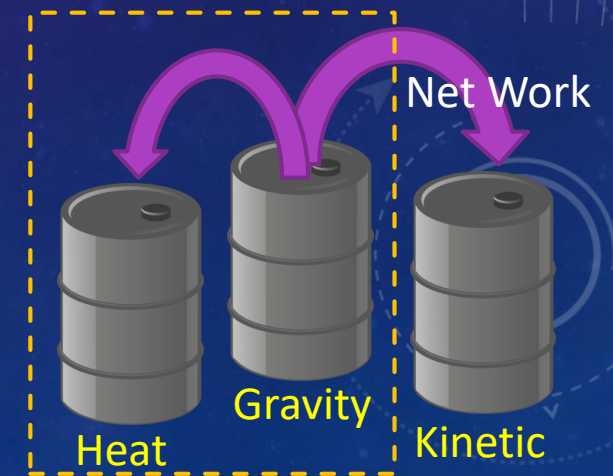
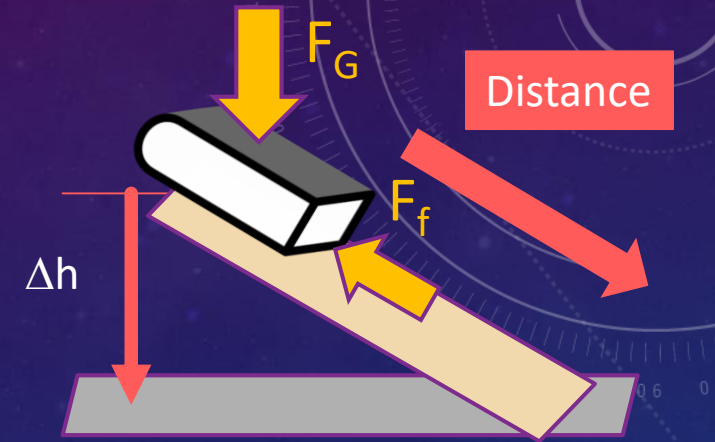


# APPLYING THE PRINCIPLE OF WORK AND ENERGY

- The Principle of Work and Energy says

$$\text{Work}_{\text{net}} = \text{Gravitational} - \text{Thermal} = \text{Kinetic Energy}$$

- The total (net) work is whatever is left of the work done by gravity after the amount to overcome friction has been subtracted.
- The book has less energy in the form of **kinetic energy**, so it is moving **slower** than if it was simply dropped



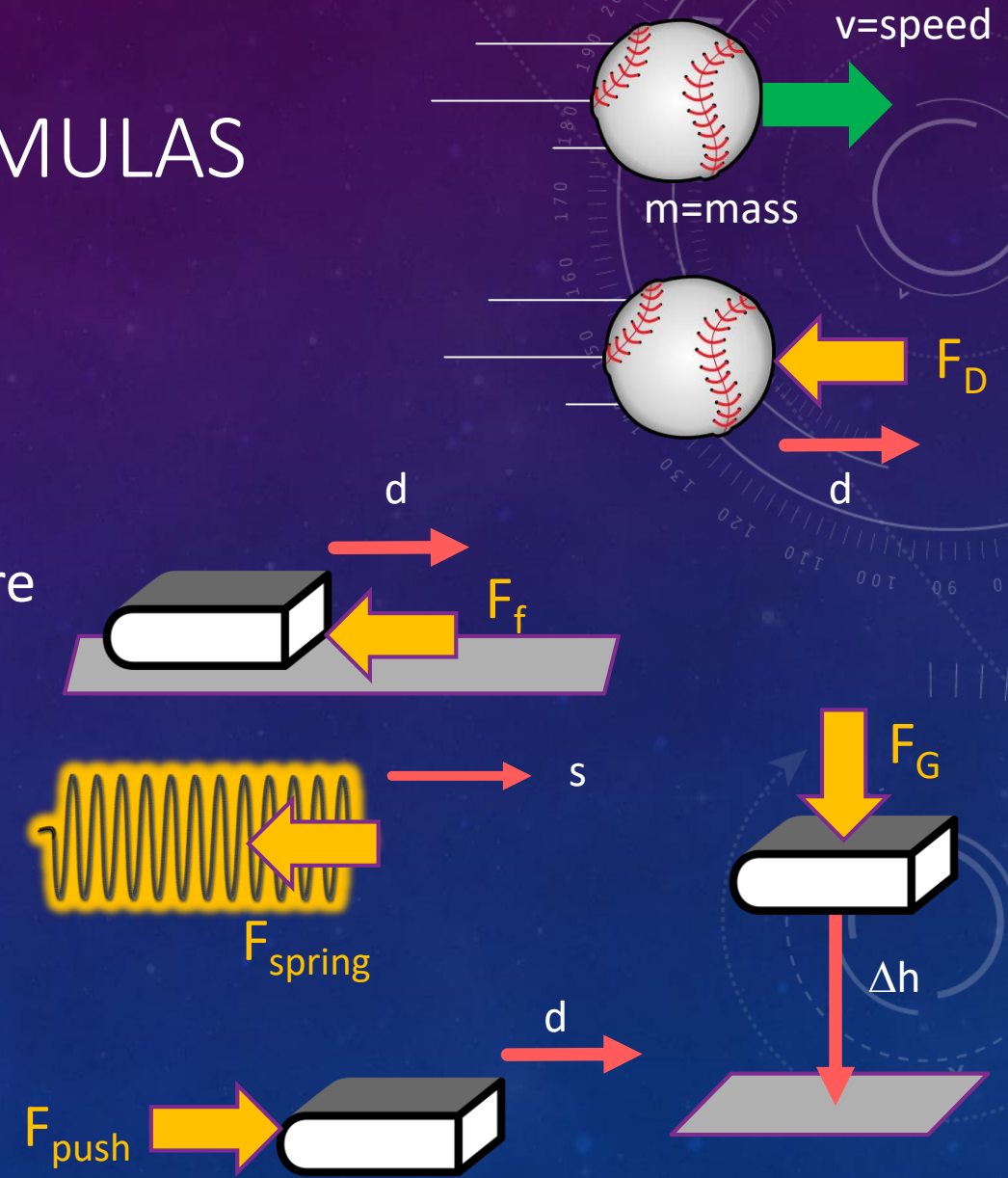
# KINETIC ENERGY AND WORK FORMULAS

Kinetic Energy – Depends on an object's mass and speed

- $KE = \frac{1}{2} m * v^2$  (Note: always zero or positive)

Here are some work formulas for some of the more common situations we'll encounter:

- Work done against drag:  $W_D = - F_D * d$
- Work done against friction:  $W_f = - F_f * d$
- Work done by or against a spring:  $W_{spr} = -\frac{1}{2} k * s^2$
- Work done by or against gravity:  $W_G = m * g * \Delta h$
- Work done by a pushing force:  $W_{push} = F_{push} * d$



# SOME OTHER ENERGY UNITS

- Energy is so important to the study of nature that we have many units other than **Joules**, the **SI unit**, to measure it, each convenient to the particular field in which it is studied
  - Batteries – **Amp-hours** (A-h) for a given voltage
  - Power delivery – **Kilowatt-hours** (Kw-h)
  - Heating and Air Conditioning – **British Thermal Units** (BTU)
  - Food and nutrition – **Kilo-calories** or **Calories** (Cal)
  - Chemistry – **calories** (cal)
  - Sub-atomic physics – **Electron-volt** (e-V)

# CONCLUSION

- The concepts of **work** and **energy** are another way of looking at how motion occurs.
- The **work** done by a **force** depends on the **distance** it moves in the direction it is pointing.
- **Energy** is the **ability to do work**.
- There are many **forms of energy**.
- The **Principle of Work and Energy** relates work done or *on* or *by* a system to its motional energy