# Introduction to Physics

## Motion & Energy

### Lecture 4

# Part I: the study of matter and energy, forces and motion (ideas central to all of the sciences)

Classical physics: Mechanics

Modern physics: Quantum mechanics

# **Mechanics**: the study of motion

- The branch of science that linked astronomy to earth based studies
- Foundation of the scientific method: thought process of conducting modern science

# The Scientific Method and the formation of theories

*1.* **Observations** of an aspect of the universe are made.

*2 A* ***hypothesis is created*** : a description that is consistent with what was observed.

*3.* Use the hypothesis to pose a **prediction**.

*4.* **Test** the prediction with experimentation or further observations and modify the hypothesis in the light of your results.

*5.* **Repeat steps 3 and 4** until there are no discrepancies between theory and experiment and/or observation.

When consistency is obtained the hypothesis becomes a ***theory*** and provides a clear and logical set of propositions which explain a class of phenomena. A **theory** is broad and is the framework within which observations are explained and predictions are made.

# **Quantum Mechanics**: The study of atoms, their parts & other particles

- Quanta (quantum): discrete (whole piece), small amount

- Such studies today rely on instrumentation in order to observe patterns of things beyond human perception.

*(We will return to this topic at a later date)*

# The scientific method brought unity to observations of the natural world

Artisans:

Studied earthly systems & their variables (changes in surrounding conditions like temperature)

- Biotic & abiotic systems:
  - alive & nonliving
    - Metals,
    - Solids, Liquids, gases

Astronomers:

Studied celestial bodies

- Sun
- Planets
- Constellations

# Isaac Newton : considered father of modern science

- 1642-1727,  Lived in England, was finishing his studies during the bubonic plague: he had time (18 months) for contemplation (~1666)
- Theorized connections between astronomy and systems on earth
  - Laws of Motion

# One set of laws describes all motion: Laws of Motion

- 1st law , Inertia : the tendency of an object to remain in uniform motion until acted upon by a force
- 2nd law defines Force = Mass x Acceleration

  $F = M(a)$

  (It doesn't tell you what the force is, but that there is one, and how to calculate it)
- 3rd law, For every force there is an equal and opposite force

# Types of Motion

- Uniform motion :  constant direction and speed
  - Objects at rest falls into this category as well
- Acceleration : change in direction or speed ( an increase or a decrease)
  - Objects slowing down, speeding up or changing direction falls into this category

# Force

- Defined as what is intervening to change the speed and path of objects in uniform motion (there are all sorts of forces)
- Mass in motion has a Force that you can perceive and calculate equal to the Mass times its acceleration

  (allows us to recognize when a force is acting)

# The third law: not so intuitive…
## for every force there is an equal & opposite

- Forces come in pairs, but act on different items
- Consider sitting on a wooden or metal chair for a few hours, you will feel it pushing back up on you with the same force that you exert on it. (otherwise it would fall apart or you would leave an impression on it)
- Imagine wearing roller skates and pushing against a wall, or firing a weapon. The force of the wall or recoil pushing back causes you to roll backwards.

# Gravity: the attractive force between masses

Gravity is one of the 4 MAJOR categories of force in the universe, the others being:

- Electromagnetism
- Strong force
- Weak force

# Mass vs. Weight

- Mass is the quantity of substance in a volume
- Weight is mass multiplied by the force of the gravity. Mass does not change, weight will if you go to the moon.
  - The moon's gravitational force on your mass would be less than the earth's on your mass. So, what we call your weight would differ.
- Any two masses have an attractive force between them called gravitational force.

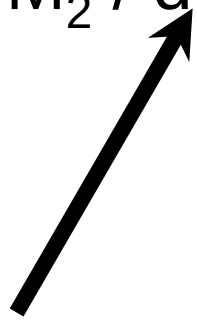
# Newton's law of Universal Gravitational Force ( $F_G$ )

- Gravitational force of attraction $F = G( M_1 \times M_2 / d^2)$
- Where G is the gravitational constant and

  $M_1$= mass of object 1

  $M_2$= mass of object 2

  d = distance between them; see that it is squared



- Look at the dynamic: Notice that as the distance between two object increases, the less force created, because you divide by a larger number.

# Galileo, the father of experimental science, experimented on gravity

- Showed that terrestrial gravity caused things to accelerate at the same rate, even if their masses differed
  - Used carefully run experiments with inclined planes and balls, diluting the force of gravity

*Galileo (1564-1642)*

# Energy and Motion

- Motion is linked to energy. To study energy, gravity or motion, a necessary place to start is to define the system that you are working in, figure out the variables and create controls. Then you can set up observations and test hypotheses.
  - How is energy involved? Motion must have energy linked to it.

# Thermodynamics : study of energy

- The word itself *thermodynamics* reveals the ideas of heat (thermo) and motion (dynamic); where they are, energy is found.
- Energy is defined as the ability to do work.

  W=Work = F x d (force times distance moved)

  P=Power = W/t (work divided by time)
- There are 2 laws to define energy.

# Laws of Thermodynamics

- 1. Energy is conserved, it is neither created nor destroyed.
  - It just changes form
- 2. Energy flows naturally in the direction from a higher ordered state to a less ordered state (from order to disorder) this is called entropy
  - It requires an input of energy to go in the opposite direction

# Types of Energy

- Potential energy: energy at rest; stored energy (in terms of mass, chemistry or structure)
- Kinetic energy: energy of motion (mass in motion is in a kinetic state)
- Conservation of energy can be observed when an object goes in and out of these states.

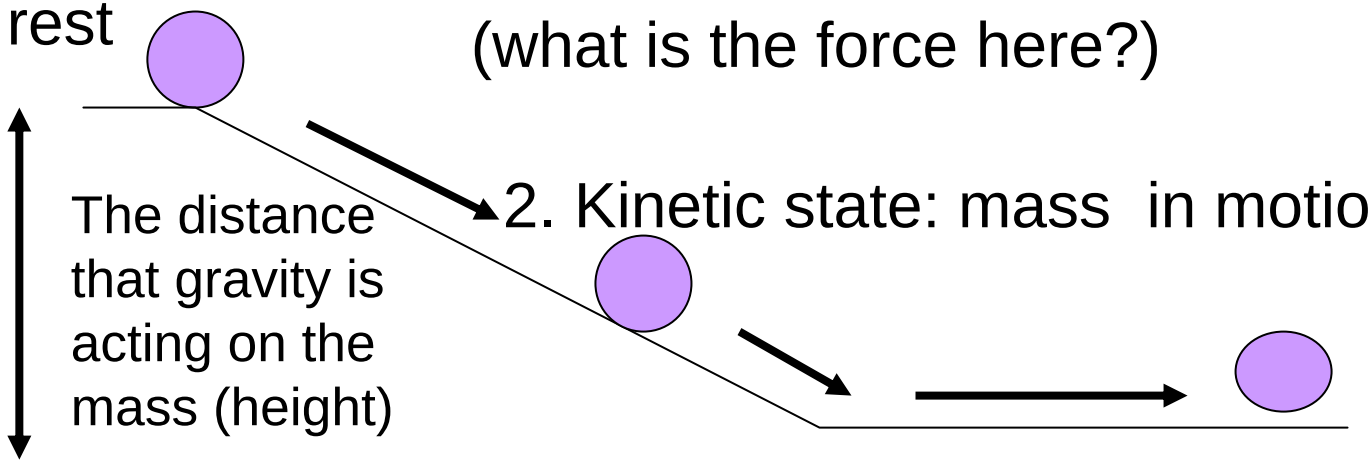
# When Energy shifts form, the quantity of energy is equal but is in another state

- Within a system the starting quantity of energy should equal the end quantity.

1a. Potential state, mass at rest

1b. Apply a force and send the ball rolling down a hill

(what is the force here?)



# Why does the ball stop rolling?

- The ball ends up back in a potential state because of entropy.

The energy dissipates, it slowly lessens because of friction.

If energy is transferred as force to an object, setting it into motion, can you predict how fast that object will move?

# Conservation of Momentum shows conservation of energy

- Two balls of identical mass and size are at rest, in a state of potential energy.


- Apply a known force to ball one and if it collides squarely with ball two, all kinetic energy flows into the second ball and sends it forward. The first stops when it hits ball two. How fast or far does ball two roll?