# LECTURE #11 – SUMMARY
# SECTION III. FORCE AND ENERGY IN CLASSICAL MECHANICS

## Section III.1 Newton's Laws of Motion

kinematics – the description of motion
dynamics – deals with what causes motion and changes in motion (forces)
The relationships between force and motion are described by Newton's Laws.

### Newton's First Law of Motion

"A body in motion tends to stay in motion, or to remain at rest if it is at rest, unless it is acted upon by a net force."

$$\vec{F}_{net} = \sum_{i=1}^{N} \vec{F}_i \qquad \text{If } \vec{F}_{net} = 0\text{, then } \sum_{i=1}^{N} \vec{F}_{x_i} = 0,\quad \sum_{i=1}^{N} \vec{F}_{y_i} = 0,\quad \sum_{i=1}^{N} \vec{F}_{z_i} = 0.$$

So a lot can be happening to the object, but as long as the forces on it cancel ($\vec{F}_{net} = 0$), then the object will move with constant velocity.

This is also known as the Law of Inertia, because it is equivalent to saying that an object has inertia. Inertia describes an object's resistance to change in motion.

### Newton's Second Law of Motion

"The rate at which a body's momentum changes is equal to the net force acting on the body."

Define momentum as $\vec{P} \equiv m\vec{v}$, with $\vec{P} \parallel \vec{v}$ and SI units: kg m s$^{-1}$

Momentum is a measure of the "quantity of motion" of an object, whereas mass is a measure of the "quantity of matter" in an object and force is a measure of "push and pull" on an object.

Thus: $\vec{F}_{net} = \frac{d\vec{P}}{dt} = \frac{d(m\vec{v})}{dt} = \frac{dm}{dt}\vec{v} + m\frac{d\vec{v}}{dt}$ For constant m: $\boxed{\vec{F}_{net} = m\frac{d\vec{v}}{dt} = m\vec{a}}$

Direction: $\vec{F}_{net} \parallel \vec{a}$; Magnitude: $F_{net} = ma$; Units: kg $\times$ m / s$^2 \equiv$ N (= Newton)

Remember that net force is a vector quantity. For constant m:

$$F_{x,net} = \frac{d(mv_x)}{dt} = ma_x \qquad \vec{F}_{y,net} = \frac{d(mv_y)}{dt} = ma_y \qquad \vec{F}_{z,net} = \frac{d(mv_z)}{dt} = ma_z$$

### Newton's Third Law of Motion

"If object A exerts a force on object B, then object B exerts an oppositely directed force of equal magnitude on object A."
Also written as: "For every action, there is an equal and opposite reaction."

This tells us something profound: forces do not act ON bodies, but between them.