# Level 1 Physics Case Studies

# Relativity, Gravity and Galaxy Formation.

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2 distinct parts to course:

Lectures 1-3: Absolute vs. Relative

Newtonian Physics → Special Relativity

Special Relativity → General Relativity

General Relativity → Cosmology

Lectures 4-5: Gravitational Galaxy Formation

Sound Waves → Galaxy Formation

Microwave Background → Cosmology

## Absolute versus Relative.

Absolute versus Relative views of the World:-

Debated both by Philosophers and Physicists.

Can science contribute in this almost religious area?

Newtonian Physics → Special Relativity

Isaac Newton:

- Greatest Scientific Genius
- By age of 23, had invented calculus, made fundamental discoveries in optics and had laid foundation for Theory of Universal Gravitation.
- 1666 → “Miracle Year” in Physics.

## Newton's Laws of Mechanics.

Newtonian mechanics define a family of reference frames, inertial frames, in which laws of physics take a simple form. Inertial frame is that of a constant velocity observer.

Newton's First Law: A body continues in its state of rest or uniform motion in a straight line, except if acted on by external forces.

Newton's Second Law: The acceleration of a body is inversely proportional to its mass and directly proportional to the magnitude of the external force acting upon it and takes place in the direction of the force. ($F=ma$)

Newton's Third Law: The forces that two bodies exert upon each other are equal in magnitude and opposite in direction. (Law of action and reaction)

## Newton's Law of Gravitation

Two objects of mass $m_1$, $m_2$ attract each other with a force which is proportional to $m_1 \times m_2$ and inversely proportional to the square of the distance between them. ($F=Gm_1m_2/r^2$)

Consequences

The force which attracts a falling apple to the ground is the same that governs the motion of the Moon around the Earth.

→ Universality of Physical Laws

since:

All 3 of Kepler's Laws of Planetary Motion could be derived from Newton's Laws.

Explains why objects of different mass fall at the same rate.

Bigger the mass, the bigger the gravitational force but the smaller the acceleration due to bigger "inertia". Gravitational and inertial effects of mass cancel – Equivalence of Gravitational and Inertial Mass (see later).

Newton's "Principia" in 1686 "I now demonstrate the frame of the System of the World."

## Absolute vs Relative

Success of Newtonian Physics immediately raises a fundamental question :-

Is an absolute frame of reference needed to measure the motions of objects?

But why do only constant velocity observers see Universal Physical Laws?

Also constant velocity with respect to what?

Principle of Newtonian Relativity: Laws of Motion are the same for every constant velocity (inertial) observer.

$\Rightarrow$ An observer in a closed train compartment cannot determine train's constant velocity.

Newton: Absolute rest frame exists → constant velocity is with respect to fixed stars.

Leibniz: Disputed this view → no absolute space. Only relative positions, velocities and accelerations matter since only these can be measured.

Newton replied with his Rotating Bucket experiment → water is rotating with respect to an absolute frame - inertial and non-inertial observers see different physics.

There matters lay till debate re-opened with the philosopher Ernst Mach and Albert Einstein at end of 19$^{th}$ Century.