RELATIVITY

1. Special Relativity
2. Time Dilation
3. Doppler Effect
4. Length Contraction
5. Twin Paradox
6. Electricity and Magnetism
7. Relativistic Momentum
8. Mass and Energy
9. Energy and Momentum
10. General Relativity

RELATIVITY

In 1905, Einstein showed how measurements of time and space are affected by motion between an observer and what is being observed.

Relativity **connects** space and time, matter and energy, electricity and magnetism – links that are crucial to our understanding of the physical universe.

SPECIAL RELATIVITY

In elementary physics, no special point is made about how we measure length, time interval, and mass.

- It doesn't matter who measures.
- everybody ought to get the same result.

How can we measure the length of a plane when we are on board?

How can we measure the length of a plane when it is in flight and we are on the ground?

Will the answer be the same?

SPECIAL RELATIVITY

Will the answer be the same?
NO!

Measurement from the ground find that the plane is shorter than the measurement from inside the plane.

To understand why the two measurement are different, we need to analyze the process of measurement when **motion is involved**.

FRAMES OF REFERENCE

What does motion mean?

It means that the position of something is changing relative to something else.

A **frame of reference** is part of the description of motion.

An **inertial frame of reference** is a frame in which Newton's first law of motion holds.

FRAMES OF REFERENCE

In an **inertial frame of reference** an object at rest remains at rest and an object in motion continues to move at constant velocity (constant speed and direction) if no net force acts on it.

Any frame of reference that moves at constant velocity relative to an inertial frame of reference is itself an inertial frame.

FRAMES OF REFERENCE

What does all this mean?

- ALL INERTIAL FRAMES ARE EQUALLY VALID

- ALL CONSTANT-VELOCITY MOTION IS RELATIVE

- THERE IS NO UNIVERSAL FRAME OF REFERENCE THAT CAN BE USED EVERYWHERE.

- NO ABSOLUTE MOTION

FRAMES OF REFERENCE

How can we deal with the consequences of the lack of a universal frame of reference?

The theory of relativity was proposed.

- **Special relativity** involves inertial frames of reference.
- **General relativity** describes the relationship between gravity and the geometrical structure of space and time.

POSTULATES OF SPECIAL RELATIVITY

1. The Principle of Relativity Postulate

The laws of physics are the same for observers in all inertial frames. No one frame is preferred over and other.

2. The speed of Light Postulate

The speed of light in free space has the same value c in all inertial reference frames.

$c = 2.998 \times 10^8$ m/s

POSTULATES OF SPECIAL RELATIVITY

Let us consider some hypothetical experiments…

- Three cars moving.
- Light, a rocket and you.

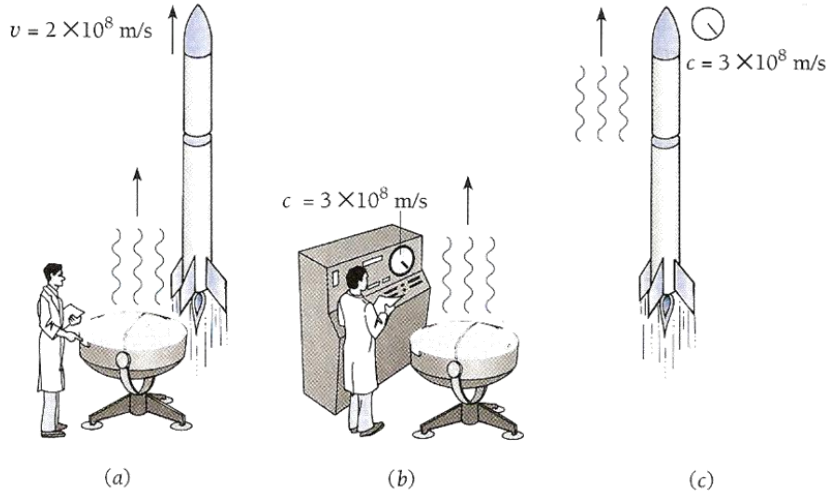

Figure 1.1 The speed of light is the same to all observers.

POSTULATES OF SPECIAL RELATIVITY

How can we account for this result without violating the principle of relativity?

• measurement of space and time are not absolute but depend on the relative motion between an observer and what is being observed.
• Your clock and meter stick to me is different to you due to relative motion but the speed of light is the same for both of us.

TIME INTERVALS AND LENGTHS ARE RELATIVE QUANTITIES, BUT THE SPEED OF LIGHT IN FREE SPACE IS THE SAME FOR ALL OBSERVERS.

NEWTONIAN VS. RELATIVITY

• A conflict between Newtonian mechanics and Maxwell's theory of electromagnetism.

- the equations differ in the way they relate measurements made in one inertial frame with those made in a different inertial frame.

• Einstein showed that Maxwell's theory was consistent with special relativity whereas Newtonian mechanics is not.

• Einstein modified Newtonian mechanics and brought these branches of physics into accord.

• Relativistic and Newtonian mechanics agree for relative speeds much lower than the speed of light.

• At high speeds Newtonian mechanics must be replaced by the relativistic version.

SPECIAL RELATIVITY

REMEMBER…

ALL MOTION IS RELATIVE; THE SPEED OF LIGHT IN FREE SPACE IS THE SAME FOR ALL OBSERVERS