

## *GENERAL THEORY OF RELATIVITY*

### *PRINCIPLE OF EQUIVALENCE*

"Effects of gravitation and acceleration cannot be distinguished from, one another"

The principle of equivalence states that local observations made in an accelerated reference frame are indistinguishable from observations made in Newtonian gravitational field

Ex.

~ If two balls are dropped inside an accelerating ship, they would continue to move upwards side by side with the velocity of the ship at the moment of release and the floor would move upwards faster than the balls which will fall at the same time regardless of their masses. (Motion can be attributed to the force of gravity)

~ If the ship was not moving, at constant velocity, the balls would remain suspended in the same place hence the balls and the ship move the same amount.

### *Bending of light by gravity*

~ a ball thrown sideways (in a gravity free region) will follow a straight line path relative to an observer inside the ship and to a stationary observer outside the ship.

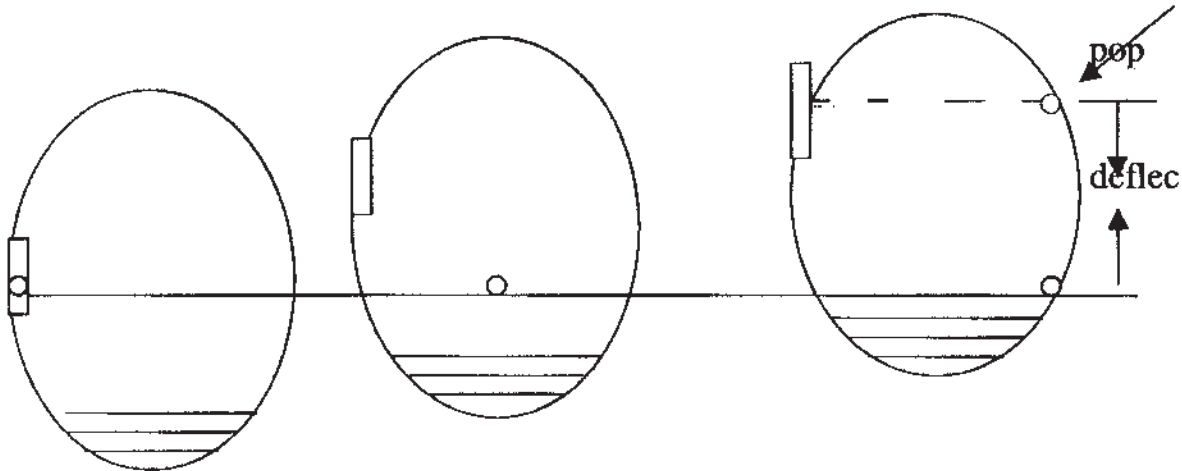
~ if the ship is accelerating the outside observer still sees a straight line path but the to the inside observer the path is curved.

This principle also applies to a beam of light,

"light is a stream of particle like photons that bend in a gravitational field as any material object"

A light ray enters the spaceship horizontally through a side window and reaches the opposite wall after a very short time

(The presence of mass results in the bending or warping of space time)



(Pop) point opposite window  
(Deflect) deflection

An outside observer sees light travel in a straight line but like the ball it strikes a point opposite the window  
To an observer inside, light bends as if is responding to a gravitational field  
This deflection in the earth is not noticeable because it is tiny compared to the vast distance light travels with its high speed.

*Gravity and time*  
*Gravitational red shift*

Gravitation causes time to slow down.  
The stronger the gravitational field the greater the slowing down of time  
Application of the principle of equivalence and time dilation to an accelerating reference frame.

Ex. Clocks A, B and C.

A and B are on the accelerating disc and C is on the ground.

A and C run on the same rate (hence A is not moving relative to the ground)

B runs slower because of its centrifugal force field

If this centrifugal force is interpreted as the force of gravitation, according to the principle of equivalence, clocks in the strong gravitational fields of force run slower than clocks in weak fields of force e.g. clock in the surface of the earth runs slower than the clock further away in the surface of the sun.

All atoms emit light specific frequencies, characteristic of the vibration rate of electrons within the atom.

Every atom is therefore a clock and slowing down of atomic vibrations indicates the slowing down of the clock.

An atom in the sun should emit light of slower frequency (slower vibration ) than light emitted by the same kind of atom on the earth.

Gravitation in the sun is stronger than on the earth, a lowering of frequency shifts the color towards red hence red is at the low frequency end of the visible spectrum. This effect is known as gravitational red shift

*References :*

*Conceptual physics (7<sup>th</sup> edition): Paul G. Hewitt*

*Cutnell Johnson physics(3<sup>rd</sup> edition) : John D Cutnell, Kenneth W. Johnson*