

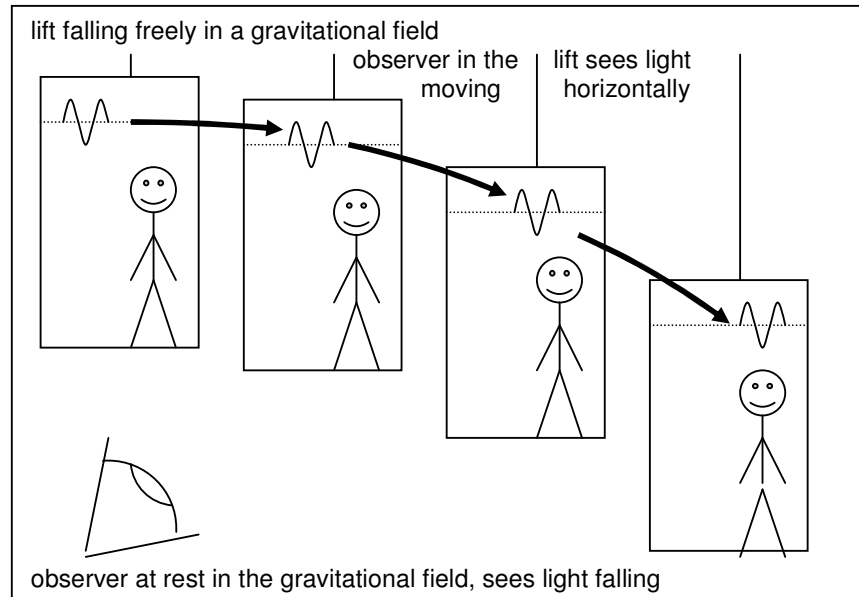
Key points

- the laws of physics are the same in an accelerated frame of reference and one at rest in a gravitational field.
- the laws of physics are the same in a free falling frame of reference in a gravitational field and in an inertial frame of reference.
- this is known as Einstein's Principle of Equivalence.

The curving of space-time by mass.

The effect of gravity on light

- consider the free falling lift in a gravitational field.
- if a person in the lift shone a light horizontally, then they would observe that the light beam travelled in a straight line, i.e. horizontally across the lift.
- this must be the case, as the same would be seen in a lift far from any gravitational field.
- however, an observer who was at rest in the gravitational field would see the light beam fall with the falling lift and it would appear to be a curved path.



- the direction taken by a ray of light can no longer be said to be straight, when it passes through a gravitational field.
- instead of travelling straight, it falls in the field and follows what is called a **geodesic**. It is a curve. It is as if space is curved.
- a geodesic is the shortest path in space-time.
- the usual model is to consider a heavy ball placed on a stretched elastic sheet. The mass distorts the rubber sheet.
- a marble rolled near the heavy mass will have its course deflected by the curve of the rubber sheet.
- this potential well model has been used in the gravitational section of the mechanics course already.
- not only does a ray of light change its motion in the space near a mass, but also time slows down for it. It changes its motion in time.
- time is curved as well. We are familiar with dealing with space in three dimensions, x, y and z.
- time can be treated as another dimension and can be given units of length if we define the length in terms of the distance travelled by light in that time.
- one second represents a distance of 300 000km.
- a projectile fired horizontally moves in a curved path on an x-y graph. If the vertical displacement y is plotted against time, x, a curve is also obtained.
- the path on a y-t plot would also be curved. Because time can be represented as a distance, it is often called **space-time**.
- there is a similar analogy with mass and energy, in that one can be converted to the other.

space time graphs

- considering motion in one dimension a space time graph can be drawn.
- the vertical axis is time and the horizontal axis is distance.
- suppose a craft travelling at 0.5c visits the nearest star 4 light years away
- to an observer on earth, the craft will take 8yrs to reach the star.
- when the craft reaches the star it sends a radio signal back to earth.