QUEENS COLLEGE OF ARTS AND SCIENCE FOR WOMEN
PUNALKULAM, NEAR THANJAVU, PUDUKKOTTAI

DEPARTMENT OF PHYSICS

SUBJECT: MECHANICS

SUBJECT CODE: 16SCCPH2

AUTHOR: RAJESWARI

UNIT- 3 & 5

Newton`s law of gravitation

Isaac Newton compared the acceleration of the moon to the acceleration of objects on earth. Believing that gravitational forces were responsible for each, Newton was able to draw an important conclusion about the dependence of gravity upon distance. This comparison led him to conclude that the force of gravitational attraction between the Earth and other objects is inversely proportional to the distance separating the earth's center from the object's center. But distance is not the only variable affecting the magnitude of a gravitational force. Consider Newton's famous equation

$$F_{net} = m \bullet a$$

Newton knew that the force that caused the apple's acceleration (gravity) must be dependent upon the mass of the apple. And since the force acting to cause the apple's downward acceleration also causes the earth's upward acceleration (Newton's third law), that force must also depend upon the mass of the earth. So for Newton, the force of gravity acting between the earth and any other object is directly proportional to the mass of the earth, directly proportional to the mass of the object, and inversely proportional to the square of the distance that separates the centers of the earth and the object.

The UNIVERSAL Gravitation Equation

Newton's law of universal gravitation extends gravity beyond earth. Newton's law of universal gravitation is about the **universality** of gravity. Newton's place in the *Gravity Hall of Fame* is not due to his discovery of gravity, but rather due to his discovery that gravitation is universal. **ALL** objects attract each other with a force of gravitational attraction. Gravity is universal. This force of gravitational attraction is directly dependent upon the masses of both objects and inversely proportional to the square of the distance that separates their centers. Newton's conclusion about the magnitude of gravitational forces is summarized symbolically as

$$F_{grav} \propto \frac{m_1 * m_2}{d^2}$$

where F_{grav} represents the force of gravity between two objects

$\propto$ means "proportional to"

m_1 represents the mass of object 1

m_2 represents the mass of object 2

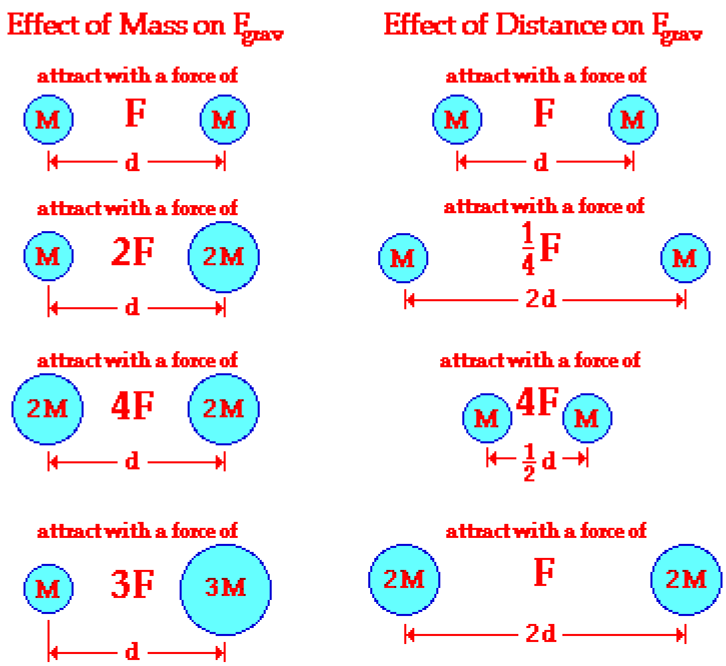
d represents the distance separating the objects' centers

Since the gravitational force is directly proportional to the mass of both interacting objects, more massive objects will attract each other with a greater gravitational force. So as the mass of either object increases, the force of gravitational attraction between them also increases. If the mass of one of the objects is doubled, then the force of gravity between them is doubled. If the mass of one of the objects is tripled, then the force of gravity between them is tripled. If the mass of both of the objects is doubled, then the force of gravity between them is quadrupled; and so on.

Since gravitational force is inversely proportional to the square of the separation distance between the two interacting objects, more separation distance will result in weaker gravitational forces. So as two objects are separated from each other, the force of gravitational attraction between them also decreases. If the separation distance between two objects is doubled (increased by a factor of 2), then the force of gravitational attraction is decreased by a factor of 4 (2 raised to the second power). If the separation distance between any two objects is tripled (increased by a factor of 3), then the force of gravitational attraction is decreased by a factor of 9 (3 raised to the second power).

Thinking Proportionally About Newton's Equation

The proportionalities expressed by Newton's universal law of gravitation are represented graphically by the following illustration. Observe how the force of gravity is directly proportional to the product of the two masses and inversely proportional to the square of the distance of separation.



Another means of representing the proportionalities is to express the relationships in the form of an equation using a constant of proportionality. This equation is shown below.

$$F_{grav} = \frac{G \cdot m_1 \cdot m_2}{d^2}$$

where G represents the universal gravitation constant

$(G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2)$

The constant of proportionality (G) in the above equation is known as the **universal gravitation constant**. The precise value of G was determined experimentally by Henry Cavendish in the century after Newton's death.

The value of G is found to be

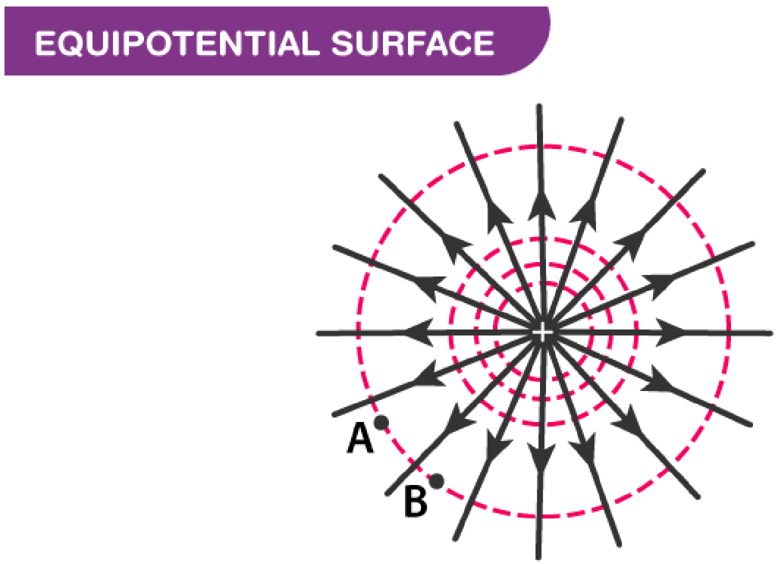
$$G = 6.673 \times 10^{-11}\ N\ m^2/kg^2$$

Equipotential Surface

The surface which is the locus of all points which are at the same potential is known as the equipotential surface. No work is required to move a charge from one point to another on the equipotential surface. In other words, any surface with the same electric potential at every point is termed as an equipotential surface.

Equipotential Points:

If the points in an electric field are all at the same electric potential, then they are known as the equipotential points. If these points are connected by a line or a curve, it is known as an equipotential line. If such points lie on a surface, it is called an **equipotential surface**. Further, if these points are distributed throughout a space or a volume, it is known as an **equipotential volume**.



Work Done in Equipotential Surface

The work done in moving a charge between two points in an equipotential surface is zero. If a point charge is moved from point V_A to V_B, in an equipotential surface, then the work done in moving the charge is given by

$$W = q_0(V_A - V_B)$$

As $V_A - V_B$ is equal to zero, the total work done is $W = 0$.

Gravity and Escape Velocity

Gravity is the force that gives most of the large objects in the Universe their structure. It holds the Earth together and in its orbit around the Sun. It holds the Sun together and in its orbit around the Milky Way. It even holds the Universe itself together.

Gravity also causes many astronomical phenomena such as tides. As perhaps the most important force for large objects, we need to understand its basic properties.

- Every object exerts a gravitational force of attraction on every other object.

- The gravitational force between two objects depends on their **masses**, being **larger** for larger masses.
- The gravitational force between two objects depends on their **separation**, being **weaker** the farther apart the objects are.

Newton discovered the mathematical expression for the force of gravity and showed it has the following form.

Force of gravity = constant x Mm/r^2, Where M and m are the masses and r is their separation. The constant is called the Universal gravitational constant and its value depends on the units used.

If the masses are in kilograms (kg) and the distance is measured in meters, and the force in metric units called Newton's, then G $=6.67 \times 10^{-11}$ newton-m^2-kg^{-2}.

The Newton is a unit of force and is defined so that a force of 1 Newton produces an acceleration of 1 meter per $second^2$ on a mass of 1 kilogram.

A little fiddling then shows that the Newton can also be expressed in more fundamental units so that the units of the Newton = kilogram-meter-sec^{-2}=kg-m-sec^{-2}.

Thus the units of G can be expressed as $meters^3$-kg^{-1}-sec^{-2}.

The critical ideas to understand are simple.

- More mass gives more force
- More separation gives less force.

Notice that doubling the distance doesn't reduce the force by a factor of 2. It reduces it by the **square** of the distance, or in this case, a factor of 4.

For example, suppose the Earth were 3 times farther from the Sun than it is now. How would the gravitational force between them change? Answer: It would be $3^2 = 9$ times weaker.

Barometer Overview

The barometer measures the ambient air pressure around the camera in hectopascals (hPa). As the ambient air pressure decreases with the altitude, the barometer can be used to measure the altitude variations of the camera.

However, ambient air pressure is also modified by weather conditions. During sunny days the ambient pressure is higher than during rainy ones. This means that the barometer is affected by outdoor conditions and that it can’t be used to estimate the absolute altitude of the camera from the sea level. Therefore only relative altitude variations are provided by this sensor.

Fortin barometers

In the Fortin barometer, the level of mercury in the glass at the bottom of the barometer cistern is adjusted to a scale zero, known as the fiducial point, each time a reading is to be taken. The level of mercury in the column is then read against the scale, using a vernier adjustment for extra accuracy. Air is evacuated from the top of the tube of mercury and the lower end is fixed in the cistern containing the reservoir of mercury. The Fortin barometer is simple to use as it has a clear easy-to-read linear scale. These barometers can be mounted on a wall or suitable pillar.

In addition to instruments manufactured under the Russell Scientific Instruments' name, we manufacture, service and repair F Darton and WF Stanley, Griffin and George, and Gallenkamp precision mercury barometers.

Fortin barometers can be moved without risk of damage but should always be carried flat or upside down. If a Fortin barometer is to be moved after installation, the following procedure must be followed: turn the adjustment screw until the mercury fills the reservoir and the mercury in the column is about 25mm from the top of the scale. Remove the barometer from the wall, incline or tilt gently and then place in a flat position. Finally, adjust the screw further until a small air gap is left in the reservoir.

The re-hang the instrument, reverse this procedure. Please note that all precision barometers are supplied in a purpose-built fibre board case with a polystyrene cutout inner to support the instrument.

Faulty barometer

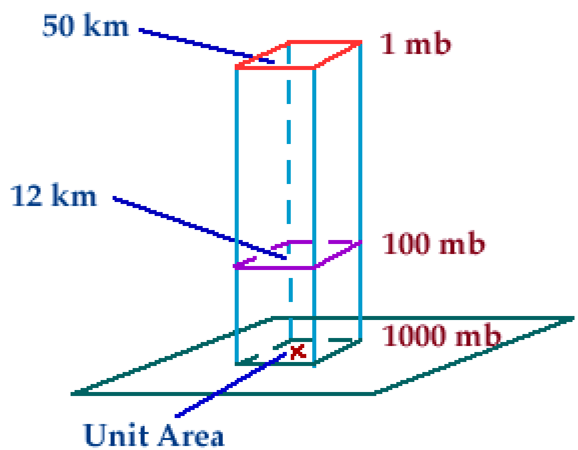
A Faulty Barometer Contains Certain Amount of Air and Saturated Water Vapour. It Reads 74.0 Cm When the Atmospheric Pressure is 76.0 Cm of Mercury and Reads 72.10 Cm When the Atmospheric Pressure

Variation of atmospheric pressure with altitude

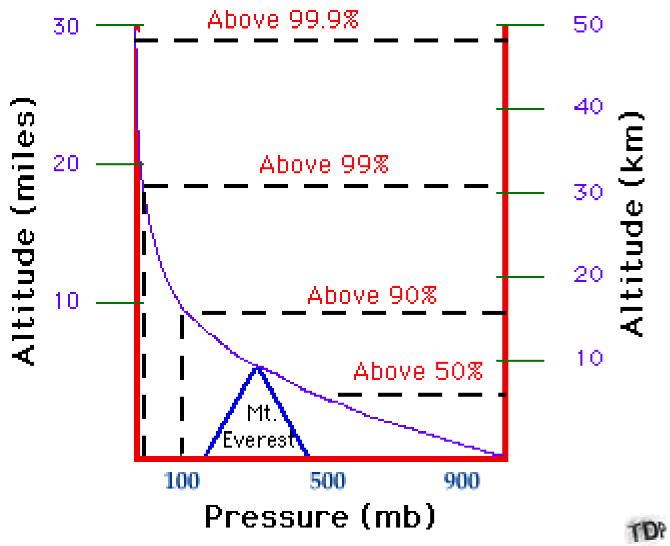
Pressure with Height

pressure decreases with increasing altitude

The pressure at any level in the atmosphere may be interpreted as the total weight of the air above a unit area at any elevation. At higher elevations, there are fewer air molecules above a given surface than a similar surface at lower levels. For example, there are fewer molecules above the 50 km surface than are found above the 12 km surface, which is why the pressure is less at 50 km.



What this implies is that atmospheric pressure decreases with increasing height. Since most of the atmosphere's molecules are held close to the earth's surface by the force of gravity, air pressure decreases rapidly at first, then more slowly at higher levels.



Since more than half of the atmosphere's molecules are located below an altitude of 5.5 km, atmospheric pressure decreases roughly 50% (to around 500 mb) within the lowest 5.5 km. Above 5.5 km, the pressure continues to decrease but at an increasingly slower rate.