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Experimental Validation to Prove Potential Energy can be Created and Destroyed

Birudev Hajare[1], Sandip Bhokse[2], Mahesh Borkar [3], Laxman Bagal[4], Arvind Maske [5], Tushar Mergu[6]

[1, 2, 3, 4, 5, 6]HIT, Pune, Maharashtra, India

Abstract: ***The term 'force' whenever coined reminds us of Newton and his Laws of Motion. Before Newton there were likes of Galileo and Kepler amongst others who had done noticeable work in this regard. Force and its types had been at the helm of focus given by the scientific community during and before the 17th century. Force can be described as the power required to overcome the resistance provided by a body or a material. The formulas derived by Newton to get a clear sense about gravity described both the celestial motions and the terrestrial motions of the falling objects. Our current understanding of gravity which is a force of attraction present between two masses separated by a distance, is primarily because of Newton. In this paper we are focusing on gravitational force, how it works and whether or not any energy is required, or spent, for the force of gravity to attract mass towards the surface of the earth. An experimental analysis has also been done to help us understand gravitational force and to prove the conclusion we are at is correct in all sense.***

1. Introduction

The high point of the Scientific Revolution was Isaac Newton's discovery of the law of universal gravitation: All objects attract each other with a force directly proportional to the product of their masses and inversely proportional to the square of their separation. The concept of universal gravitation revealed the physical significance of Johannes Kepler's three laws of planetary motion, solved the problem of the origin of the tides and accounted for Galileo Galilei's curious and unexplained observation that the descent of a free-falling object is independent of its weight [1]. Newton had achieved Kepler's goal of developing a physics based on causes.

The momentous discovery of universal gravitation, which became the paradigm of successful science, was not the result of an isolated flash of genius, it was the culmination of a series of exercises in problem solving. The discovery of universal gravity brings out a fundamental characteristic of all great breakthroughs in science from the simplest innovations to the most dramatic revolutions: the creation of something new by the transformation of existing notions.

2. Gravity

Gravity is the force which causes bodies to fall toward the earth. Its intensity may be measured by the velocity attained by a falling body at the end of a second. Newton's first law of motion states namely, "Everybody continues in its state of rest or uniform motion in a straight line unless compelled to alter that state by impressed force". This is because of the inertia of the body which is proportional to the mass of the body [2].

Taking in consideration a more general sense, the gravitational force can be obtained from the Newton's inverse square law that states: The gravitational attraction force between two point masses is directly proportional to the product of their masses and inversely proportional to the square of distance between them.

$$F = GMm/r^2 \quad (1)$$

Assuming constant gravitational attraction, Newton's law of universal gravitation simplifies to F = mg, where m is the mass of the body and g is gravitational acceleration having a constant vector with an average magnitude of 9.81 m/s^2 on Earth. This resulting force is the object's weight. The value of G is approximately equal to $6.67x10^{-1}Nm^2/kg^2$, and it is the universal gravitational constant [3].

It can be clearly seen from the above equation that the force is only due to gravity and the masses of the two bodies and nothing else. Therefore when work done is due to this force it does not require any external energy for the work to be done. This similarly can be explained with an example, in which a wooden block placed at the bottom of a beaker filled with water comes to the top and floats. A detailed analysis of this example is given in the next section.

3. Buoyancy Force

The upward force exerted by a fluid on a submerged object is called as buoyancy force. In a fluid column the pressure at all points at horizontal level is same. It increases with increase in depth as a result of weight of liquid column. When any object submerged in a fluid, bottom of the object is deeper than top of the object. Therefore, pressure at the bottom of the object submerged in fluid is greater than top of the object. The pressure difference results in buoyancy force.

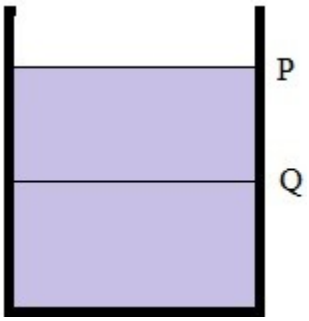

Figure 1: Beaker with water

Let, P and Q be two points in a fluid column separated by vertical distance h. Pressure at point P is P1 and at point Q is P2. Pressure difference

Upward force exerted by the water on bottom of the wooden block is given by,

$$F_{up} = P_{bottom}A \quad (6)$$

Similarly, downward force exerted by the water on top of wooden block is given by,

$$F_{down} = P_{top}A \quad (7)$$

We know hydrostatic gauge pressure is given by,

$$P_{gauge} = \rho gh \quad (8)$$

Therefore, the pressure on the bottom of the wooden block is

$$P_{bottom} = \rho ghbottom \quad (9)$$

and the pressure on the top of the wooden block is

$$F_{buoyant} = (\rho ghbottom)A(\rho ghtop)A \quad (10)$$

$$P\,2 - P\,1 = \rho gh \quad (2)$$

where, ρ = density of fluid
g = acceleration due to gravity

In the absence of gravity (g = 0), P1= P2 and pressure inside liquid at every point is same. It shows that pressure variation in fluid caused due to gravity.

but,

$$F_{buoyant} = \rho gA(h_{bottom} - h_{top}) \quad (11)$$

$$h_{bottom} - h_{top} = h_{block} \quad (12)$$

$$F_{buoyant} = \rho gAh_{block} \quad (13)$$

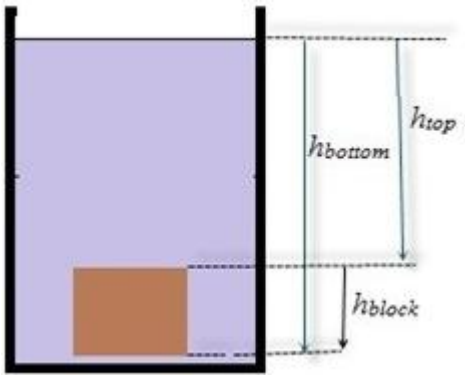

Figure 2: Representation of block in a beaker

The wooden block with surface area A of each side is fully immersed into water having density ρ at a certain depth from free surface of water. The buoyant force exerted by water on wooden block is given by [4],

$$F_{buoyant} = F_{up}F_{down} \quad (13)$$

The force exerted by a liquid at rest per unit area normal to the surface in contact with the liquid is called pressure. By definition,

$$Ah_{block} = V_f \quad (14)$$

where, V_f = Volume of the water displaced by the wooden block.

$$F_{buoyant} = \rho gV_f \quad (15)$$

As long as object is fully submerged with increase in depth pressure on top and bottom of object also increases but difference between them always constant. Hence buoyant force does not depend on overall depth of the object submerged. Above expression shows that buoyant force depend on the density of the fluid in which the object is submerged, the acceleration due to gravity g and the volume of the displaced fluid V_f .

The net force on a submerged object will be the buoyant force on the object minus the magnitude of the weight of the object.

$$F_{net} = F_{bouyant}W \quad (16)$$

$$F_{net} = F_{bouyant}mg \quad (17)$$

$$P = F/A \quad (4)$$

$$F = P\,A \quad (5)$$

$$F_{net} = (\rho_f V_f g)(\rho_o V_o g) \quad (18)$$

where, ρf = density of the fluid,
ρo = density of the object,

Vo = volume of the object submerged If object is fully submerged, two volumes are equal

Suppose $V_f = V_o = V$

$$F_{net} = V_g(\rho_f \rho_o) \quad (19)$$

Net force decides the nature of movement of object inside the fluid. Net force depends on volume of fluid displaced or volume of the object submerged, acceleration due to gravity g and difference between density of fluid and

object. If the density of the object is greater than the density of the fluid the net force will be negative which means the object will sink if released in the fluid. If density of object is less than density of fluid net force will be positive and object move in upward direction when fully submerged.

If same experiment is performed in zero gravity (g = 0) though density of wooden block is less than density of water there is no displacement of wooden block. Expression for pressure difference, buoyant force and net force include the term acceleration due to gravity. If acceleration due to gravity becomes zero there is no pressure difference and hence no buoyant force and net force. It means displacement of any object fully submerged into fluid basically depends on gravity. Now, consider wooden block of density 750 kg/m3 is submerged into the water having density 1000 kg/m^3. Let,

All the side of wooden block = 100 mm = 0.1 m
Volume of wooden block = 10-3 m3.
Area of top and bottom surface of wooden block = 0.01 m2. Pressure on top surface of wooden block is given by,

$P_{top} = \rho * gh_{top}$

As net force acting on wooden block is positive block move in upward direction. This displacement takes place without consumption of any type of energy.

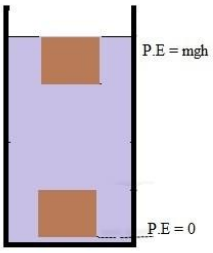

Figure 3: Representation of Potential Energy of the wooden block

If lower most position of block taken as reference point potential energy at that point considered as zero. Block reach at top position because of net force acting on it which is due to gravitational force. It will have potential energy P.E = mgh due to its height from reference position. Though the potential energy at bottom position is zero block reach to top position only due to gravitational force and it is not consumed for this displacement. It is clear that only gravitational force is required for displacement instead of any type of energy. Potential energy possessed by the block at certain height h is not the conversion of any type of energy. Hence in above experiment it clearly observed that potential energy is generated.

Consider aluminium block of same dimensions as that of wooden block held at height h. Potential energy at this position

$= 1000 * 9.81 *(150 * 10^{-3})$
$= 1471.5$ P a

Pressure on bottom of wooden block is given by (20)

become P.E= mgh due to its height. Density of aluminium block is 2710 kg/m3. The net force acting on aluminium block is given by

$P_{bottom} = \rho * gh_{bottom}$
$= 1000 * 9.81 * (250 * 10^{-3})$

$$F_{net} = V_g(\rho_f - \rho_o)$$
$$= 10^{-3} * 9.81 * (1000 - 2710) \quad (21)$$
$$= -16.77 \text{ N} \quad (24)$$
$$= 2452.5 \text{ P a}$$

Due to this pressure difference at top and bottom surface of wooden block buoyance force acting on it. The buoyance force acting on wooden block is given by equation 15.

$F_{buoyant} = \rho *_g V_f$

Since net force acting on aluminum block is negative aluminum block sink into the water due to gravitational force. In this case potential energy decreases and become zero at bottom position. Thus, we can say that potential energy is destroyed and not converted in any other type of energy.

4. Conclusion

$= 1000 * 9.81 * 10^{-3}$
$= 9.81$ N (22)

From the above discussion, we can conclude that the displacement of the block upwards and downwards is only because of gravitational force and after both the displacements Buoyant force acts upwards and weight of wooden block acts downward. The nature of displacement of wooden block inside the water is depends on net force acting on it. The net force acting on it according to equation 19.

$$F_{net} = V_g(\rho_f - \rho_o)$$

the change in energy is observed.

Even after the displacements taking place, the value of gravitational force does not change, though it is the primary reason for the displacement.

Therefore, it can be stated that the Potential Energy in block is generated and in the other case destroyed as well.
$= 10^{-3} * 9.81*(1000 - 750)$
$= 2.4525$ N (23)

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