Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2016, 3(1):51-54

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Physics of Rainfall

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Abstract The formation of rainfall has been studied empirically and theoretically within the compass of physics accompanied by a meteorological background. The study shows the energy transformations from molecular potential energy at ground level after the possession of heat from the sun to kinetic energy at the atmosphere after evaporation and the retransformation from kinetic in the troposphere to potential energy at the clouds when it condenses after losing its temperature (completely) and simultaneously kinetic energy (since K.E=2/3 KT) and gains absolutely potential energy through height (mgh). Also it was observed that the clouds experience freefall like other heavenly bodies and are suspended in the atmosphere through weightlessness, but they break into rain when the weightlessness is overcome by avalanche and fall under gravity. This eventuates in rainfall, but it is observed that the temperatures of the water droplets are higher than that of the clouds due to friction between the water molecules and the air and the increase in temperature of the troposphere with decrease in height. The molecules then fall back to the earth surface, losing their kinetic energy after a few motions around and totally regain their molecular potential energy when they become stationary and the process may be repeated on and on.

Keywords Rainfall, Energy transformation, Air friction, Weightlessness, Free fall, Evaporation, Condensation and Cloud.

Introduction

An important theory on rain formation put forward by a Swedish meteorologist Bergeron in 1933 and strongly supported by Findeisen in 1938 asserts that rainfall was, in effect, melted ice or snowflakes. The conflict with the theory lies in the fact that rain was also observed from clouds that did not extend up to freezing level. In some tropical countries like India and Nigeria a few observations have been made of rain from clouds, whose roofs were far below freezing levels [1].

Air comprises water vapour. The quantity of water in a giving mass of dry air is measured in grams of water per kilogram of dry air (g/kg). This is known as the mixing ratio. The quantity of moisture or water vapour in air is commonly called its relative humidity. Relative humidity is the percentage of the total water vapour the air can absorb at a particular temperature air. How much water vapour a measure of air can contain before it becomes saturated and transforms into a cloud is dependent upon its temperature [2]. Cooler air can hold lesser water vapour than warmer air before becoming saturated. Hence, one method to saturate a measure of air fast is to cool it [2]. Dew point is the temperature to which a measure of air must be cooled in order to become saturated. The various means by which water vapour is added to the air are: daytime heating eventuating in evaporation of water from the surface of oceans and seas, smaller water bodies or wet lands; wind convergence into areas of upward motion; precipitation or virga falling from above; transpiration from plants; lifting air over mountains and cool or dry air moving over warmer water [2]. Water molecules start to condense on condensation nuclei such as ice, dust and salt in other to form clouds. Clouds are a group of visible tiny water and ice particles suspended above the earth's surface [2].

Rain is droplets of water that have condensed from water vapour in the atmosphere and then precipitated – that is, fall under gravity owing to its weight. Rain is one of the main constituents of the water cycle [2-3]. It is responsible for depositing most of the fresh water on the earth. The chief maker of rain is moisture moving along three-dimensional zones of moisture and temperature contrasts known as weather fonts. There four major mechanisms for cooling the air to dew point: adiabatic cooling (rising and expansion of air due convection, large-scale atmospheric motions, or a physical barrier such as a mountain); Conductive cooling (air coming in contact with a colder surface, usually by being blown from one surface to another, for example from a liquid surface to colder land); Radiational cooling (emission of infrared radiation, either by the air or by surface underneath) and Evaporation cooling (addition of moisture to the air through evaporation, which forces the air temperature to cool to its web-bulb temperature, or until it reaches saturation).

Coalescence results when water droplets combine to create larger water droplets [2-3]. The water droplets remain stationary, typically due to air resistance. Often, larger water droplets are produced from the collision of small droplets during air turbulence. Coalescence continues as these larger water droplets descend, so that the drops become heavy enough to overcome air resistance and fall as rain. Generally, coalescence happens most often in clouds above freezing. It is known as the warm rain process [2].

The seas and oceans are the main source of rain; nonetheless rivers and lakes also contribute to it. The sun's heat evaporates the water. The water remains in the atmosphere as an invisible vapour until it condenses, first into clouds and then into raindrops. Condensation happens when the air is cooled [4].

Rainfall is measured using a rain gauge and rainfall amounts can be estimated by weather radar [2]. In this rare research work in physics, empirical with theoretical study is made on the energy transformation in the process of rain fall.

Mechanism of Cloud and Rain Formation

Water is carried into the atmosphere as invisible vapour when it evaporates from the earth's surface. The water vapour cools at it rises through the atmosphere (troposphere) and a point is reached when the water vapour cannot remain in this state. This occurs at an altitude defined in the meteorological lexicon as the lifting condensation level. At this level, condensation unavoidably results on small nuclei (Figure 1). They fall as drizzle or rain, when the cloud droplets become large enough, under the influence of gravity [5].

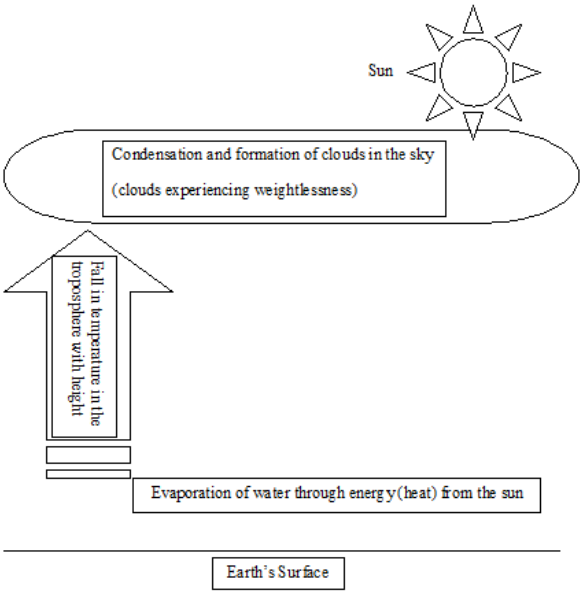

Figure 1: Evaporation and condensation of water

Energy Transformation During Rain and Free Fall

When the temperature of water molecules on the earth surface rises through heat (a form of energy from the sun) acquired from the environment, the molecules on the surface of the water bodies gradually lose their molecular potential energy (P.E) and simultaneously gain kinetic energy (K.E) gradually till it reaches its maximum (since energy can neither be destroyed nor created but can be transformed from one form to another) [1, 6]. When the molecules gain maximum K.E, they become excited and escape from the surface of the water bodies (K.E = 3/2*KT; where K = Boltzmann constant and T = Temperature).The higher the temperature of the molecules, the higher their K.E and simultaneously the velocity or rate of escape from the surface of the water bodies (since K.E = 1/2 * MV^2), see Fig. 2.

The K.E transports the excited molecules through the atmosphere. The molecules gradually lose their K.E and simultaneously acquire P.E due to decrease in temperature with height in the troposphere, see Fig. 1. If the K.E is just enough for them to reach the cloud, its P.E is about maximum at that point and the water molecules begin to condense and are suspended as water bodies in space: either as semi-solid or solid.

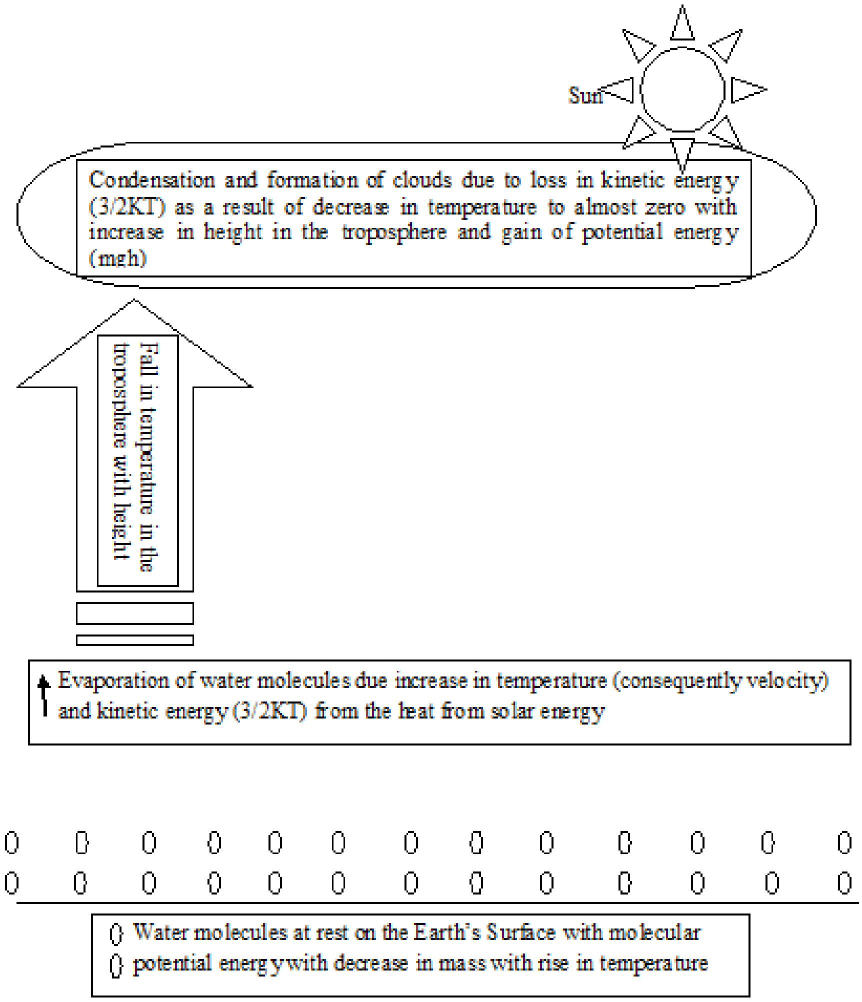

Figure 2: Mechanical energy transformation

Ordinary the condensed water molecules will pour or fall down back to the earth through gravity, but it rather remains suspended through weightlessness and experiences free fall in the atmosphere. The process continues and gradually the mass of the cloud grows heavier and heavier and with time, the weightlessness is overcome by the rising weight of condensing water molecules; eventuating in the collapse of the clouds so formed.

Soon, after the collapse of weightlessness; the condensed clouds begin to fall under the influence of gravity as rain or other forms of water particles and the whole P.E of the molecules once more are transformed to K.E with some energy lost in the form of heat due to air friction, see Fig. 3.

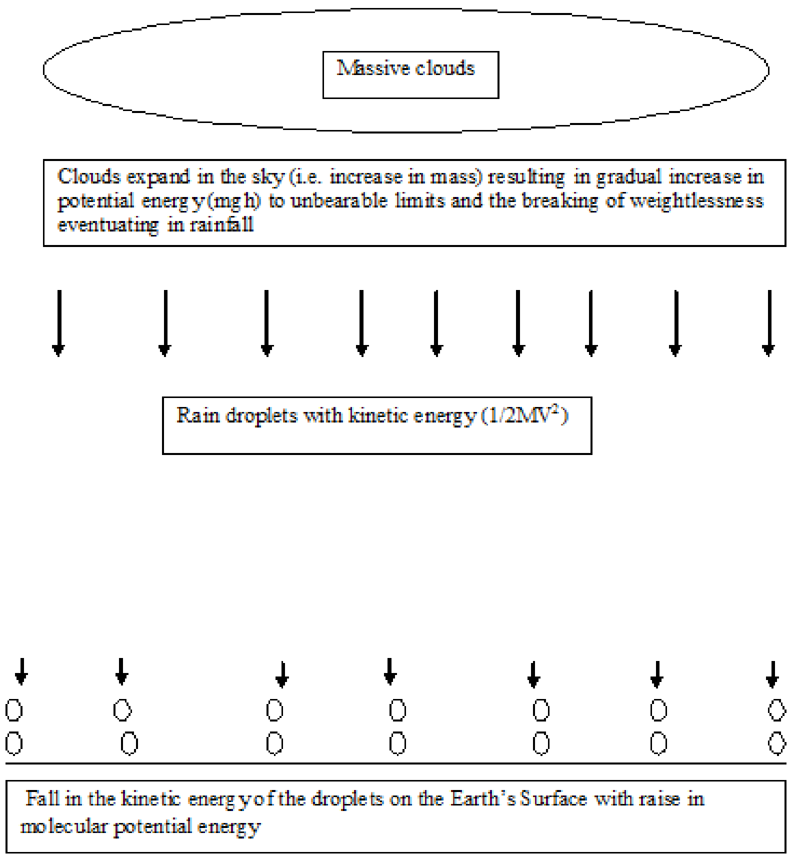

Figure 3: Break of cloud's weightlessness

The air friction and the rise in temperature in the troposphere with decreasing height are the reasons why the temperature of rain water is slightly higher than that of the clouds. The heat rises its temperature. This is the physics behind rain fall. It shows the conservation of energy in the process and its transformation from one form to another according to the laws of thermodynamics.

Conclusion

The process of rainfall is eventuated by transformation and retransformation of mechanical energies. The influence of weightlessness keeps the clouds hanging over the sky, resulting in a freefall until their growing weight is counterbalanced by gravity. In consequence, there is a breakage of huge clouds into water molecules that hit the earth as rain after travelling under gravity through the troposphere and acquiring heat via air friction and rise in troposheric temperature with height.

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