Foundation of Electromagnetic Waves

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Abstract: Electromagnetic waves can travel through any type of mediums like solid-liquid-gaseous materials, air and space. Electromagnetic waves are obtained from the beam of electrons passing through electric and magnetic fields acting perpendicular to each other. It is moving in the air with the speed of light and having frequency low range (3 Hz) to very high range (10^{24} Hz). It comprises with electromagnetic spectrum under different frequencies in increasing range such as radio waves, microwaves, infrared radiation, visible light waves, ultraviolet radiation, X-rays, gamma rays etc. Maxwell proposed mathematical formulas regarding electric and magnetic field for the propagation of electromagnetic waves. General conception of electromagnetic waves is that they consist of photons which are massless and chargeless particle. In this paper, it is invented that electromagnetic waves are bunch of free electrons moving with the velocity of light having very huge (infinity) mass penetrating all type of materials, air and space.

Index Terms: Electromagnetic waves, Frequency spectrum, Photons, Free electrons, Electron's rest mass, Electron's mass moving at the speed of light, Attraction time duration of paper pieces by the positive static electricity charged glass rod, Attraction time duration of paper pieces by the negative static electricity charged ebonite or plastic rod.

I. INTRODUCTION

There is no sound in space, because there are no molecules in space to transmit (carry) the sound waves. Electromagnetic waves are not like sound waves, since they do not need molecules to travel. It is observed that electromagnetic waves can travel through air, solid objects and space. Astronauts on space-walks use radio waves to communicate. Radio waves are a type of electromagnetic waves.

Electromagnetic waves are framed when an electric field couples with a magnetic field. Magnetic and electric fields of an electromagnetic wave are perpendicular to each other and to the direction of the electromagnetic wave. Radio waves, television waves, microwaves, X-Rays, visible light waves are all examples of electromagnetic waves [1]-[6]. They only differ from each other in wavelength or frequency. Wavelength is the distance between one wave crest to the next and the frequency is the number of wavelengths repeated in a second.

The smaller the wavelength (higher the frequency), the higher the energy, e.g., a brick wall blocks visible light wavelengths, but more energetic X-rays (having higher frequency and smaller wavelength) can pass through the brick walls. It is said that electromagnetic waves are "blocked" by certain materials like water, buildings, lead etc., i.e., wavelengths of energy are "absorbed" by objects. The atmosphere also absorbs some wavelengths of electromagnetic waves while to pass through. Production of electromagnetic waves by the electric and the magnetic fields are shown in Fig. 1.

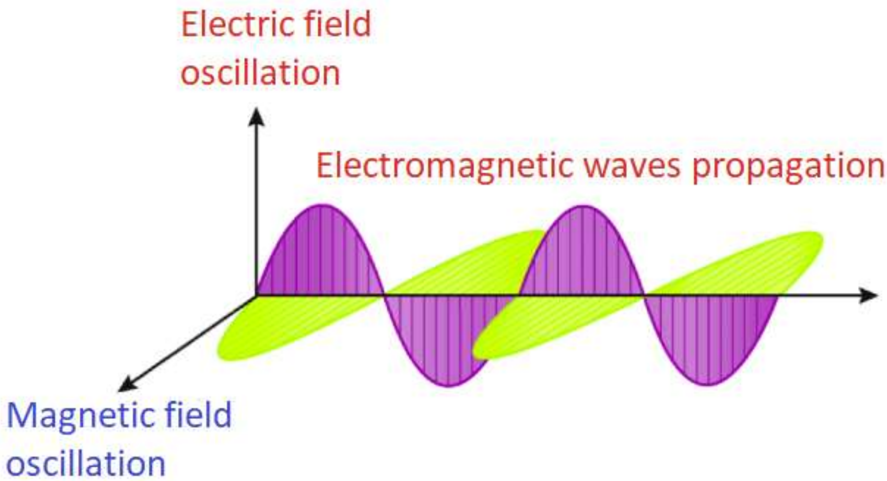

Fig. 1. Production of Electromagnetic Waves by the Electric and the Magnetic field oscillations.

All the electromagnetic waves travel at a speed of 3×10^8 meters/second which is the speed of light. All the electromagnetic waves travel with the speed of light in medium or free space, they don't need any material medium to travel as required by other mechanical waves like sound wave, water wave and electrical wave.

When electromagnetic waves travel through space, it does not lose energy to a medium. When they strike matter, they may be reflected or refracted or diffracted or absorbed by the matter and converted to other forms of energy like heat, electricity etc.

II. ELECTROMAGNETIC WAVES CHARACTERISTICS

An electromagnetic wave is produced when an electrically charged particle vibrates. A vibrating charged particle causes the electric field surrounding it to vibrate as well. A vibrating electric field, in turn, creates perpendicularly a vibrating magnetic field. Again a vibrating magnetic field is applied on the charged particle which also creates perpendicularly a vibrating electric field. These two types of vibrating fields (electric and magnetic fields) acting perpendicularly (at right angles) combine to create an electromagnetic wave which travels perpendicular to the both fields. Therefore, an electromagnetic wave is a transverse wave. They are deflected neither by the electric field nor by the magnetic field. However, they are capable of showing interference or diffraction [1]-[6].

Electromagnetic waves are split into a range of frequencies (wavelengths), this is known as the electromagnetic spectrum in increasing frequency like radio waves, microwaves, infrared radiation, visible light waves, ultraviolet radiation, X-rays, gamma rays, shown in Table 1.

Table 1 Electromagnetic Spectrum

Name of the Spectrum	Wavelength	Frequency
Radio waves	100 Mm – 1 m	3 Hz – 300 MHz
Microwaves	1 m – 1 mm	300 MHz – 300 GHz
Infrared Radiation	1 mm – 750 nm	300 GHz – 400 THz
Visible Light	750 nm – 400 nm	400 THz – 800 THz
Ultraviolet Radiation	400 nm – 1 nm	10^{15} Hz – 10^{17} Hz
X-Rays	1 nm – 1 pm	10^{17} Hz – 10^{20} Hz
Gamma Rays	1 pm – 0.0001 pm	10^{20} Hz – 10^{24} Hz

This is clearly explained by Max Planck and Albert Einstein's Modern Quantum Theory such as electromagnetic waves consist of photon particles (as they assumed) and the energy (E) possessed by the waves or photon particles are calculated [1]-[3]. Photon is a massless and chargeless elementary particle having particle and wave properties both as per their assumptions. If the energy of each photon is E;

Then, $E = hf$ ....(1)

where h is called Planck's Constant, $h = 6.626 \times 10^{-34}$ joule–second; f or ν is the linear frequency of the electromagnetic waves. If velocity of electromagnetic waves is c and λ be the wavelength,

we know, $f\lambda = c$, then $f = c/\lambda$,

Therefore, $E = hf = hc/\lambda$ ....(2)

Velocity of electromagnetic waves, c is equal to the velocity of light,

Hence, $c = 2.9979 \times 10^{8}$ meters/second or 1,86,000 miles/second.

Therefore, it is seen that if frequency of the electromagnetic waves is high, it will possess more energy, and thus it will penetrate the atoms, i.e., living and non-living body with more energy or power. It is already proved by Albert Einstein in Photoelectric Effect (earned Nobel Prize in 1921 for this) that when high frequency electromagnetic waves consisting of photon particles fall any atoms (metallic or non-metallic), the photons will release electrons from the atoms, called photoelectrons, cause current generation or current flow through the circuit.

Actually, the assumption of electromagnetic waves as photons like massless and chargeless particle is not correct; if a photon is massless, then its energy (potential and kinetic both) becomes zero, i.e., the photon cannot strike with certain energy. Therefore, the photons are nothing except free electrons which have very less mass in rest (stationary) condition, i.e., 9×10^{-31} kg and infinity mass in free stage when moving with the speed of light. Hence, electromagnetic waves are free electrons having very huge (infinity) mass comparing to its volume (radius of an electron, $r = 2.82 \times 10^{-15}$ m), and negative charge moving with the speed of light.

Whenever electromagnetic waves exist in a medium with matter, their wavelength is decreased. Wavelengths of electromagnetic radiation, whatever medium they are traveling through, are usually quoted in terms of the vacuum wavelength, although this is not always explicitly stated.

III. ELECTROMAGNETIC WAVES THEORY

With the publication of "A Dynamical theory of the Electromagnetic Field" in 1865, James Clerk Maxwell (Scotland, U.K.) demonstrated that electric and magnetic field travels through space as waves moving at the speed of light. Maxwell's equations encompass the major laws of electricity and magnetism [1]-[6].

The four Maxwell equations are on electromagnetic theory corresponding that D is the electric flux density coulombs/sq. meter, ρ (rho) is the electric charge density coulombs/cubic meter, B is the magnetic flux density weber/sq. meter, E is the electric field intensity volt/meter, H is the magnetic field intensity amperes/meter, J is the electric current density ampere/sq. meter, and they are expressed below:

(i) div $D = \rho$ (ii) div $B = 0$ (iii) curl $E = -\frac{\partial B}{\partial t}$ (iv) curl $H = \frac{\partial D}{\partial t} + J$

The compact way of writing these equations in the meter-kilogram-second (mks) system is in terms of the vector analysis operators divergence (div) and curl, i.e., in partial differential equations form. The equations describe how the electric field can create a magnetic field and vice-versa. Here Maxwell established relations between the electric field intensity (E) and the magnetic flux density (B); the magnetic field intensity (H) and the electric flux density (D).

IV. PRODUCTION OF ELECTROMAGNETIC WAVES

Electromagnetic waves travel through empty space or through insulating materials, but they cannot travel through conducting materials, although they can travel along their surfaces. When alternating current flows through a wire (i.e., electric charges are accelerated), it produces lesser amount of electromagnetic waves. The frequency of the electromagnetic waves created by this way equals to the frequency of the alternating current.

The inverse effect also happens, if an electromagnetic wave strikes a wire (i.e., receiving antenna), it induces an alternating current of the same frequency in the wire. This is how the receiving antennas of a radio or television sets work [4]-[6]. Thus, an antenna is most efficient when its length is of the order of the wavelength of the electromagnetic waves emitted or received. For TV transmission, electromagnetic waves having wavelengths of the order of one meter, which is also the size of a typical TV antenna.

Therefore, electromagnetic radiation is produced whenever a charged particle, such as an electron changes its velocity, i.e., whenever it is accelerated or retarded (decelerated).

The generation of electromagnetic radiation into two categories is below:

(i) Systems or processes that produce radiation covering a broad continuous spectrum of frequencies, e.g., the Sun with its continuous spectrum.

(ii) Those that emit (and absorb) radiation of discrete frequencies that are characteristics of particular systems, e.g., a radio transmitter or receiver tuned to one frequency.

Because any change in motion is an acceleration or deceleration, circulating currents of electrons produce electromagnetic radiation. When these circulating electrons move at relativistic speeds (i.e., approaching the speed of light), then the brightness of the radiation increases enormously. This radiation was first observed at the General Electric Company in 1947 in an electron synchrotron which is a type of particle accelerator that forces relativistic electrons into circular orbits by using powerful magnetic fields.

Electromagnetic waves consist of wavelengths range from 10^{-18} m to 100 km which corresponds to frequencies from 3×10^{26} Hz to 3×10^{3} Hz. All the energy from the Sun that reaches the earth arrives as solar radiation, part of a large collection of energy called the electromagnetic radiation spectrum. Solar radiations are composed with electromagnetic radiation like visible light, ultraviolet light, infrared radiation, radio waves, X-rays and gamma rays. Radiation is one way to transfer heat energy. Every object or matter is continually radiating electromagnetic waves unless its temperature is at absolute zero.

Molecules or atoms emit radiation when high energy electrons in a high atomic level (higher shell or orbit) fall down to lower energy levels (lower orbit). The energy lost is emitted as electromagnetic waves radiation, e.g., light, infrared, radio waves etc. When energy is absorbed by an atom, it causes the electrons to “jump” up to higher energy levels (higher orbit or shell). Therefore, all atoms (objects) absorb and emit radiation, i.e., electromagnetic waves. When the absorption of energy balances the emission of energy, the temperature of the atoms stays constant. If the absorption of energy is greater than the emission of energy, the temperature of an object rises. If the absorption of energy is less than the emission of energy, the temperature of an object falls.

Electromagnetic radiation is made when an atom absorbs energy. The absorbed energy causes one or more electrons to change their locale within the atom. When the electron returns to its original position, an electromagnetic wave is produced. Depending on the kind of atom and the amount of energy, this electromagnetic radiation can take the form of heat, light, ultraviolet, or other electromagnetic waves.

There are several ways of causing atoms to absorb energy. One way is to excite the atoms with electrical energy. We do this in neon signs (tubes). The electricity we put through the neon tubes will excite or add energy to the neon atoms. These electrons in these atoms are then in a high energy state. The electrons don’t like to be in the high energy state and will fall back down into the low energy state giving off radiation which we see as light.

In electromagnetic waves, energy is transferred through vibrations of electric and magnetic fields. Quantum physics explains that electrons kick up virtual photons (i.e., free electrons), which travel at the speed of light and hit other particles, exchanging energy and momentum. Here virtual photons are free electrons only.

The German physicist Heinrich Hertz was the first to generate and detect certain types of electromagnetic waves in the laboratory in 1887.

An electron in an atom can absorb energy from light or electromagnetic waves (photons) or heat (phonons) only if there is a transition between energy levels that matches the energy carried by the photon or phonon. Photons with correct wavelength can cause an electron to jump from the lower to the higher energy level (shell) by absorbing energy from the incident electromagnetic waves. Electron will not stay at a higher energy level for longer period, it drops from higher to lower energy level emitting a new photon (i.e., free electron) as spontaneous emission, $E_2 - E_1 = \Delta = hv$, which is shown in Fig. 2.

Here h is called Planck’s Constant, $h = 6.626 \times 10^{-34}$ joule–second; v is the linear frequency of the electromagnetic waves.

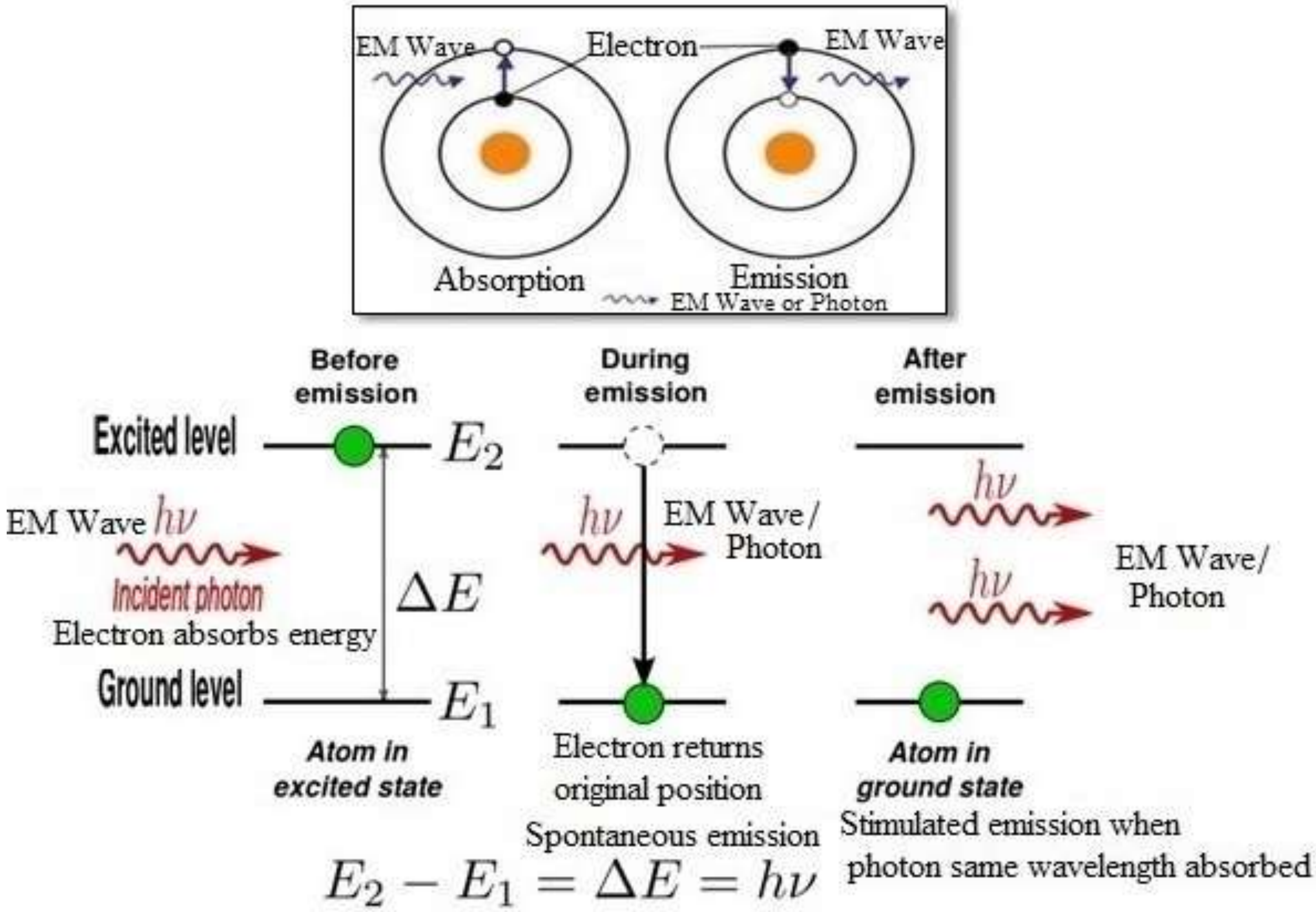

Fig. 2. Electromagnetic waves absorption and emission by an atom or electron.

This phenomenon is a direct physical manifestation of the Heisenberg Uncertainty principle. The emitted photon or electromagnetic wave has random direction, but its wavelength matches the absorption wavelength of the transition. When an electron is excited from one state to that at a higher energy level with energy difference ΔE, it will not stay that way forever. Eventually, a photon will be spontaneously created from the vacuum (actually electron is thrown) having energy ΔE. Conserving energy, the electron transitions to a lower energy level which is not occupied, is with transitions to different levels having different time constants. This process is called “spontaneous emission”. Spontaneous emission is a quantum-mechanical effect and a direct physical manifestation of the Heisenberg uncertainty principle in which proposed that the electrons are always changing orbits or positions in an atom. The emitted photon has random direction, but its wavelength matches the absorption wavelength of the transition. This is the mechanism of fluorescence and thermal emission.

A photon with the correct wavelength to be absorbed by a transition can also cause an electron to drop from the higher to the lower level, emitting a new photon. The emitted photon exactly matches the original photon in wavelength, phase, and direction. This process is called “stimulated emission”.

Electromagnetic waves are generated by several electronic instruments. A Gunn diode, also known as a transferred electron device (TED), is a form of diode, a two-terminal semiconductor electronic component, with negative resistance, used in high-frequency electronics. Electromagnetic waves are generated by Gunn diode, although the Gunn diode is only made by n-type semiconductor doping in different concentrations. In Gunn diode, electrons inside the different n-type layers are oscillated due to positive and negative resistance occurring according to the voltage applied between the terminals of the diode. Therefore, some electrons are skipped out from the semiconductor material of the Gunn diode in air with the same frequency of oscillation which is identified as electromagnetic waves.

Then electromagnetic waves are generated by Klystron and Magnetron instrument. Here, electrons beam from the cathode is oscillated by applying high electric field and high magnetic field [at right angles (perpendicularly) to the electric field], as a result some electrons are transmitted with the frequency of oscillation as electromagnetic waves.

Therefore, we can conclude that electromagnetic waves are only special type of free electrons with the speed of light which comes out from an atom or electron beam by application of high electric field and perpendicularly high magnetic field. Thus these free electrons (electromagnetic waves) are not deflected (neutral) by electric or magnetic field.

It is observed that when an electric field is applied, a magnetic field will be automatically exist or evolve which is perpendicular to the electric field, and vice-versa. Therefore, when both the electric field and the magnetic field are acting simultaneously at right angles (perpendicular) to each other, the strengths of the both fields are high enough to oscillate (skip out) electrons releasing from the atoms or electron beam as electromagnetic waves perpendicularly to the both fields.

If an electron moves with a velocity v, its mass $m_1 = m_0/\sqrt{1-(\frac{v^2}{c^2})}$, where c = velocity of light, m_0 = electron's rest mass; this equation indicates the mass will increase with the increase of its velocity, in this equation the electron's mass increases 1% when velocity increases 15% of velocity of light, if $v = c$, m_1 becomes infinity [2]-[9]. Since electromagnetic waves travel with the speed of light and it consists of free electrons only which have very huge (infinity) mass, therefore these tiny electrons having radius, i.e., $r = 2.82 \times 10^{-15}$ m can penetrate any material. Thus when electromagnetic waves consisting of free electrons are moving inside any material, air and space, its mass is infinity, i.e., huge mass. Due to this characteristic, electromagnetic waves or free electrons can penetrate any type of materials.

V. CONFIRMATORY EXPERIMENT: PROOF ELECTROMAGNETIC WAVES AS FREE ELECTRONS

A solid glass rod and a piece of silk (pure silk cloth) are taken. The glass rod is slightly heated so that outermost electrons of the glass (silicon) atom receive sufficient energy to reach conduction band. Then the warm glass rod is rubbed by silk piece cloth from middle portion to one terminal (end) in one way direction. Small pieces of paper are kept on a table. After rubbing 1-2 minutes, the glass rod is brought near or touching small paper pieces, the paper pieces will be attracted by the glass rod like a magnet. This is happened, because positive static electricity (positive type static electric charge) creates or acquires on the upper layer or periphery of the glass rod. This positive static electric charge on the glass rod will remain indefinite period until it discharges by external opposite sources, i.e., negative type electric charge [7]-[9].

Case I: There are no powerful electromagnetic wave sources near the positive static electricity charged glass rod, i.e., mobile phone, microwave oven, remote control etc. are not switch on or working condition, then the positive type static electricity on the glass rod persists longer duration such as 10-15 minutes depending upon the other remote electromagnetic wave sources such as nearby mobile BTS (Base Transceiver Station or Tower), TV and radio transmission network, electromagnetic wave signals from remote mobile phones and electronic instruments etc. Gradually the positive static electric charge on the glass rod is neutralized or discharged by the remote sources of electromagnetic waves which is shown in Fig. 3.

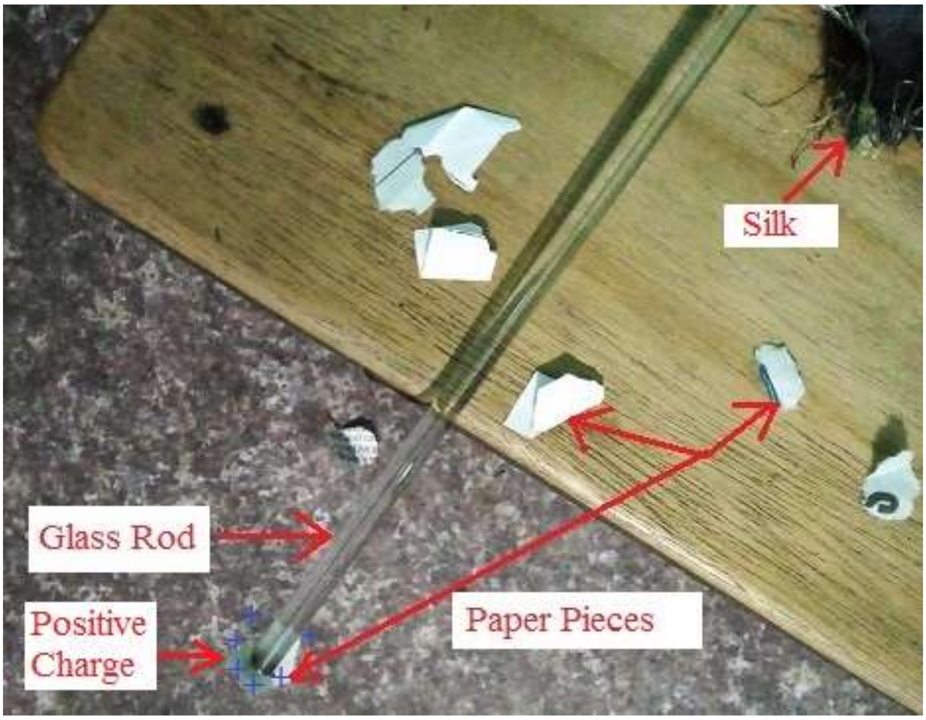

Fig. 3. Glass rod rubbed by the silk cloth attracts pieces of paper for different duration of times.

Case II: The glass rod is positively static electricity charged by rubbing silk cloth and the glass rod attracts paper pieces. Then strong electromagnetic wave sources like mobile phone or other electromagnetic waves transmitter under switch on condition is brought in front of the glass rod, the glass rod discharges positive static electricity charge immediately, i.e., within one minute, and it no longer attracts the paper pieces. Therefore, the attraction time duration of paper pieces by the positive static electricity charged glass rod is fully dependent on the amount of electromagnetic waves nearby or received by the glass rod, and this attraction time duration is inversely proportional to the amount or power of the nearby electromagnetic wave sources.

Case III: When ebonite rod or plastic rod is rubbed with wool, ebonite or plastic rod acquires negative static electricity charge and wool acquires positive static electricity charge in same amount. This negative static electricity charge on the ebonite or plastic rod attracts paper pieces also. When electromagnetic wave sources like mobile phone, remote control etc. in switch on or working condition are brought in front of the negative static electricity charged ebonite or plastic rod, they do not affect the negative static electric charge of the ebonite or plastic rod, and the ebonite or plastic rod attracts the paper pieces till discharged its negative static electric charge in same time as in normal condition.

Attraction time duration of paper pieces by the negative static electricity charged ebonite or plastic rod does not depend on the nearby electromagnetic wave sources. Hence, the electromagnetic waves cannot discharge or neutralize the negative static electric charge on the ebonite or plastic rod. Therefore, electromagnetic waves comprise with free electrons only.

VI. CONCLUSION

By the above confirmatory experiment, it is proved that electromagnetic waves are high speed (with the velocity of light) free electrons only, which are randomly moving in materials, air and space. Positive type static electricity on the glass rod periphery is immediately discharged by the electromagnetic waves due to composed by electrons only. Hence, the discharging rate of the positive static electricity on the glass rod depends on the availability of free electrons from the nearby electromagnetic waves, i.e., power of the nearby electromagnetic wave sources. On the other hand, electromagnetic waves have no effect on discharging of the negative type static electricity induced on the periphery of ebonite rod or plastic rod when rubbed with wool. Again electromagnetic waves gradually decreasing its power by propagating distance through materials and air, because free electrons are absorbed by the materials and water. Therefore, electromagnetic waves are formed by free electrons having higher frequency and huge (infinity) mass traversing with the velocity of light.

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