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ExpEYES Experiment

OBJECTIVE

- To observe Induced EMF in a coil due to a moving magnet using ExpEYES-17.
- To Observe Photo transistor behavior using ExpEYES-17.
- Design and study Multi vibrator circuit using IC555.

THEORY AND WORKING FORMULA

Photo transistor

Photo-transistors are operated in their active regime. The light enters the base region where it causes hole electron pairs to be generated. This generation mainly occurs in the reverse biased base-collector junction. The hole-electron pairs move under the influence of the electric field and provide the base current, causing electrons to be injected into the emitter. As a result the photo diode current is multiplied by the current gain β of the transistor. One of the drawbacks of the photo transistor is that is particularly slow and its high frequency response is very poor. Photo-diodes are much faster electronic components and are used where speed is essential despite their inferior sensitivity.

Magnetic induction

When a magnet is dropped through a coil an emf is induced in the coil. The induced emf can be viewed using a standard instrument ExpEYES-17.if the center of the coil will be considered as the origin, the induced emf shows two peaks near the origin. The peaks depend on the size, length, strength and velocity of magnet. The external force like air resistance and gravity affect the velocity of the magnet so the two peaks are not equal height. Emf generated in the coil id described by the given equation

$$emf = \frac{3\mu_o m}{2\pi} NA \left(-z_o + \frac{gt^2}{2}\right)^2 \left[R^2 + \left(-z_o + \frac{gt^2}{2}\right)^2\right]^{-5/2} gt$$

where, N = No of turns in the coil=3000, A = Area of the coil, z_o = Height above which the magnet is falling, μ_o = Permeability of free space, m = Magnetic moment of the magnet, R = Radius of the cylindrical magnet

Multi vibrator

Multi-vibrator circuits refer to the special type of electronic circuits used for generating pulse signals. These pulse signals can be rectangular or square wave signals. They generally produce output in two states: high or low. Astable multivibrator has no stable states but switches continuously between two states this action produces a train of square wave pulses at a fixed frequency. The duty cycle of an multi-vibrator refers to the ratio of the on time to the total time.

APPARATUS

- ExpEYES-17 and its software
- IC555
- photo transistor,LED
- breadboard,resistor,capacitor,connecting wires
- magnet,coil

OBSERVATION

Photo transistor

When the LED is *ON*, photo-transistor conducts and the voltage drops across the collector. When the LED is *OFF* the photo-transistor goes into cut off mode and the collector shows almost the supply voltage. The rise and fall times of the photo-transistor seem to be different.

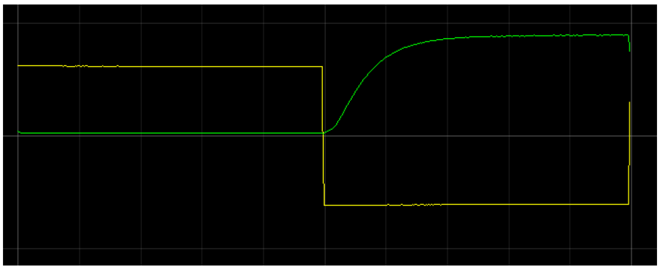

FIG. 1: *Voltage* vs. $T(ms)$ at frequency= $500Hz$

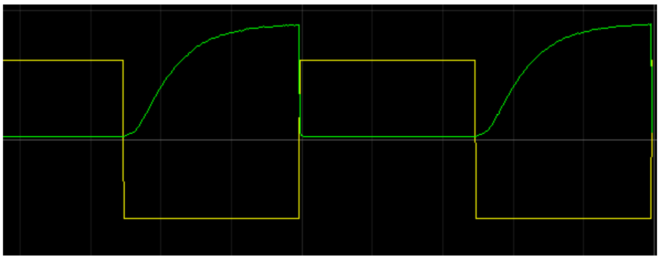

FIG. 2: *Voltage* vs. $T(ms)$ at frequency= $1000Hz$

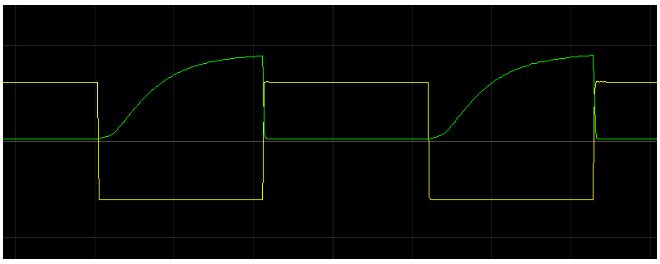

FIG. 3: *Voltage* vs. $T(ms)$ at frequency= $1200Hz$

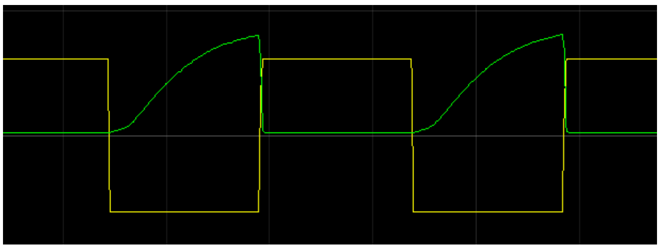

FIG. 4: *Voltage* vs. $T(ms)$ at frequency= $1700Hz$

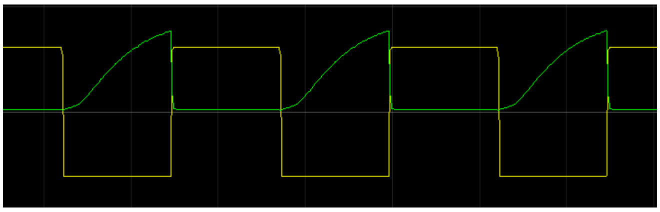

FIG. 5: *Voltage* vs. $T(ms)$ at frequency= $2000Hz$

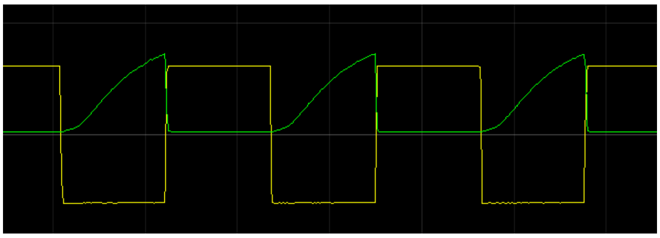

FIG. 6: *Voltage* vs. $T(ms)$ at frequency= $2200Hz$

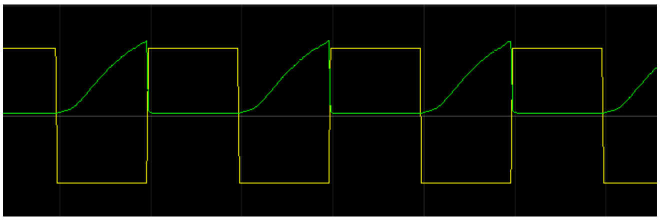

FIG. 7: *Voltage* vs. $T(ms)$ at frequency= $2500Hz$

Electromagnetic induction in the coil

The induced emf due to a moving magnet inside the coil was observed using expeyes. The figure attached below represent the data that was taken during the experiment.

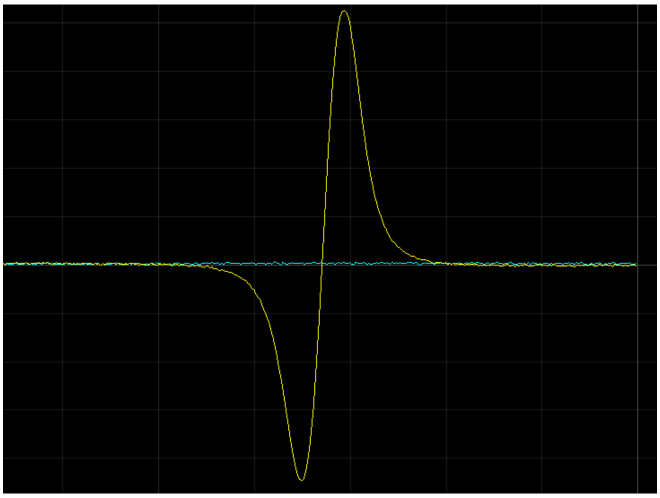

FIG. 8: *Voltage* vs. $T(ms)$ at frequency= $2000Hz$

FIG. 9: *Voltage* vs. $T(ms)$ at frequency= $2000Hz$

Multi Vibrator

Multi vibrator circuit with different duty cycles are observed using expeyes.The following plots represents the outputs of vibrators with different duty cycles

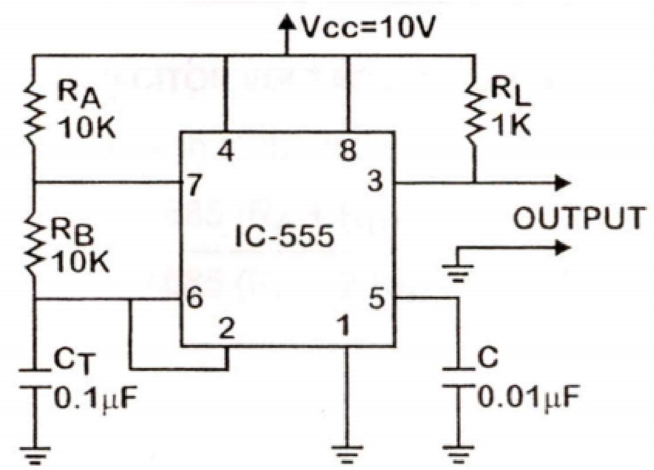

FIG. 10: *Voltage* vs. $T(ms)$ at frequency= $2000Hz$

DATA ANALYSIS

ERROR ANALYSIS

Aluminum

Given relative error in S equal to $\frac{\delta S}{S} = 0.02$
Error in slope of the graph $\delta(V/I) = 2.122 \times 10^{-6}\Omega$

FIG. 11: *Voltage* vs. $T(ms)$ at frequency= $2000Hz$

Relative error in slope will be

$$\frac{\delta(V/I)}{(V/I)} = \frac{2.122}{3.238} \times 10^{-2} = 0.655 \times 10^{-2}$$

So relative error in $\rho_\circ$ is given by

$$\implies \frac{\delta\rho_\circ}{\rho_\circ} = \sqrt{\left(\frac{\delta V/I}{V/I}\right)^2 + \left(\frac{\delta S}{S}\right)^2}$$
$$= \sqrt{(2 \times 10^{-2})^2 + (0.655 \times 10^{-2})^2}$$
$$= 2.105 \times 10^{-2}$$

So relative error in ρ is given by

$$\implies \frac{\delta\rho}{\rho} = \sqrt{\left(\frac{\delta\rho_\circ}{\rho_\circ}\right)^2 + \left(\frac{\delta S}{S}\right)^2}$$
$$= \sqrt{(2 \times 10^{-2})^2 + (2.105 \times 10^{-2})^2}$$
$$= 2.903 \times 10^{-2}$$

So error in resistivity $\delta\rho = 2.903 \times 10^{-2} \times 26.42 \times 10^{-9} = 0.767 \times 10^{-9}\Omega m$. So Value of resistivity of Aluminum with error value = $(26.42 \pm 0.767) \times 10^{-9}\Omega m$.

n-Silicon

Given relative error in S equal to $\frac{\delta S}{S} = 0.02$.
Relative error in thickness of silicon $\frac{\delta W}{W} = 0.02$.
Error in slope of the graph $\delta(V/I) = 1.042 \times 10^{-1}\Omega$.
Relative error in slope will be

$$\frac{\delta(V/I)}{(V/I)} = \frac{1.042}{9.484} \times 10^{-2} = 0.11 \times 10^{-2}$$

So relative error in $\rho_\circ$ is given by

$$\implies \frac{\delta\rho_\circ}{\rho_\circ} = \sqrt{\left(\frac{\delta V/I}{V/I}\right)^2 + \left(\frac{\delta S}{S}\right)^2}$$
$$= \sqrt{(2 \times 10^{-2})^2 + (0.11 \times 10^{-2})^2}$$
$$= 2.003 \times 10^{-2}$$

So relative error in ρ is given by

$$\Longrightarrow \frac{\delta\rho}{\rho} = \sqrt{\left(\frac{\delta\rho_\circ}{\rho_\circ}\right)^2 + \left(\frac{\delta S}{S}\right)^2 + \left(\frac{\delta W}{W}\right)^2}$$
$$= \sqrt{(2\times10^{-2})^2 + (2.003\times10^{-2})^2 + (2\times10^{-2})^2}$$
$$= 3.465\times10^{-2}$$

So error in resistivity $\delta\rho = 3.465\times10^{-2}\times0.214 = 0.007\Omega m$. So Value of resistivity of n-Silicon with error value = $0.214\pm0.007\Omega m$.

n-Germanium

From fitting between ρ and T we got the $\delta b = \delta(\frac{E_g}{2K_B}) = 63.68K$. So error in band gap energy δE_g is given by

$$\delta E_g = 2\times K_B\times 63.68$$
$$= 1.099\times10^{-2} eV$$

So value of Band gap energy with error value is equal to $0.669\pm0.001 eV$.

SOURCE OF ERROR

- Material (Al) used in the foil is commercial grade, while standard resistance is for pure Al.
- The thickness of Al foil is very small and there could be more error in measuring of thickness.
- The formula for ρ is valid for semi-infinite /very large surface in comparison with the probe distance.
- Variation of doping in sample.

RESULT

- Value of Resistivity of Aluminum(ρ_{Al})=$(26.42\pm0.767)\times10^{-9}\Omega m$
- Value of Resistivity of n-Silicon(ρ_{Si})=$0.214\pm0.007\Omega m$
- Value of Band gap energy for n-Germanium (E_g)=$0.669\pm0.001 eV$

CONCLUSION

According to band theory, in metals the Fermi level lies in the conduction band giving rise to free conduction electrons. However, in semiconductors the position of the Fermi level is within the band gap, about halfway between the conduction band and the valence band. This means that at absolute zero temperature, there would be no free conduction electrons, and the resistance is infinite. However, the resistance decreases as the charge carrier density in the conduction band increases. From the experiment we have obtained the value of resistivity(ρ) of Al and $n-Si$ equal to $(26.42\pm0.767)\times10^{-9}\Omega m$ and $0.214\pm0.007\Omega m$ respectively. The resistivity of $n-Ge$ decreases exponentially with the increase in T as shown in $fig4$ and obtained the value of band gap energy(E_g) equal to $0.669\pm0.001 eV$.

[1] Introduction of Solid State Physics *by C. Kittel IVth edition.*