The Cornu Effect

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Abstract

TODO: REWRITE

In this experiment the bulk properties of perspex were investigated, specifically determining values for Young's Modulus and Poisson's ratio, found to be TODO: and TODO: respectively. The two values were determined by measurements on the interference pattern formed by the reflection of monochromatic light from the top of the perspex beam and from the bottom of a glass plate placed on top of the perspex beam, while the perspex beam, placed centrally on two knife edges a short distance apart, had weights suspended from either end.

Introduction and Theory

TODO: REWRITE The aim of this experiment was to determine, using a method of interference (Newton's Rings), Young's Modulus and Poisson's ratio for perspex.

Young's Modulus

Suppose we have a block of some material, with a force applied to the ends of the block. In that case, the *stress* is defined as the force per unit area on the block. This force results in a deformation of the material, which is quantified by the *strain*, which is defined as the change per unit length of the block, i.e. the ratio of the change in length to the original length.

This leads us to the definition of *Young's Modulus*, which is defined for some material to be the ratio of stress to strain,

$$Y = \frac{\text{stress}}{\text{strain}}$$

which can, in crude terms, be seen to describe the stiffness of the material, i.e. a high value of Young's Modulus corresponds to a stiff material, e.g. steel, while a low value corresponds to an elastic one, e.g. rubber.

Suppose we have some masses bending a beam, as per

Poisson's Ratio

Poisson's ratio is defined as the ratio of lateral strain to longitudinal strain,

$$\sigma = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

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Newton's Rings

Newton's rings are the interference patterns

Experimental Method

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0.0.1 Experimental setup

The experiment was setup as in Figure 1. This blah blah

I-V Characteristic of p-n Junction Diode

The I-V characteristic of the diode was measured using the circuit in Fig. **??**. The resistances used ranged from 68Ω to 111.1KΩ Readings of current and

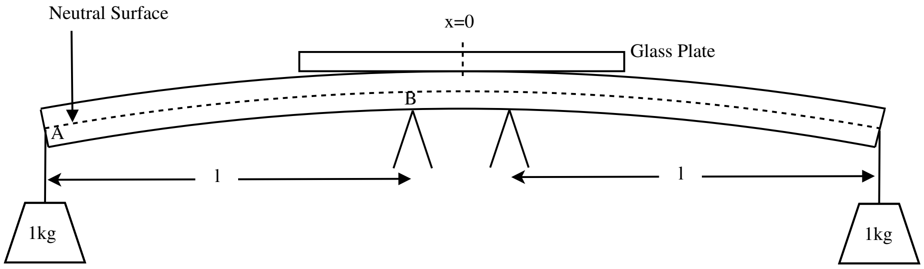

Figure 1: Experimental setup for Cornu Method experiment

voltage for a range of resistances were taken quickly to ensure that the diode temperature deviated as little as possible from room temperature. These results are plotted in Figure TODO A reading was also taken with the diode reversed and the voltmeter disconnected, and no current was detected across the diode. A plot of ln(I) against V was made for the purposes of determining e/KT, the basis of which is the formula $Ln(I) = Ln(I_0) + (eV/kT)$

Half-wave rectifier

The circuit shown in Fig.2 was connected.

The resistance was set to $10k\Omega$ and the oscilloscope was connected to the terminals X and E. With this circuit we found the diode conducted for half of each cycle of the A.C. mains, with the waveform on the oscilloscope corresponding closely to the original sinusoidal wave. The peak voltage V_0 was measured using the oscilloscope, and compared to the R.M.S. voltage of the A.C. supply.

A $4\mu F$ capacitor was then attached across the resistance box R. This had the effect of smoothing the current across the resistor. The ripple voltage, i.e. the peak to peak variation of the smoothed voltage was measured for different values of R between $20k\Omega$ and $100k\Omega$ was measured, and plotted against 1/R.

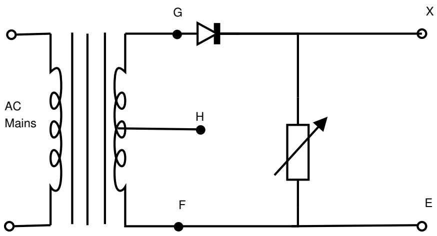

Figure 2: Half-wave rectifier circuit

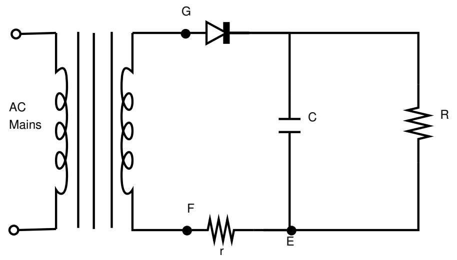

Figure 3: Circuit to measure half-wave current

It was confirmed that the maximum value of the voltage across C remained constantly at V_0.

Finally the circuit was connected as in 3, i.e. a small resistor was connected between F and E. The voltage across it was measured in the oscilloscope. The peak current i_p across this was measured, as was the fraction of the cycle for which it flowed. The charge flowing through the rectifier was then compared to the charge flowing through R per cycle.

Full-wave rectifier

The circuit was set up as in 4. This is a full wave rectifier. The waveform for this circuit was measured and compared with that of the half-wave rectifier. Using the oscilloscope, the fractional ripple voltage $\Delta V/V$ with C connected was measured. The maximum reverse voltages across the rectifiers were measured too.

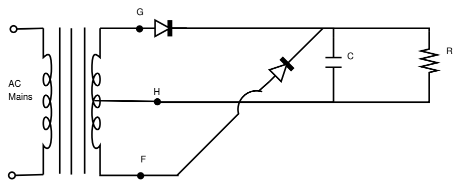

Figure 4: Full-wave rectifier circuit

Results and Analysis

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Using dimensional analysis we can derive the units of e/kT, the argument proceeds thus:

$$\begin{aligned} k = \text{Boltzmann's constant} &= \frac{[J]}{[K]} \\ e = \text{Elementary charge} &= [C] \\ T = \text{Absolute temperature} &= [K] \\ \text{therefore,} & \\ \frac{e}{kT} = \frac{[C][K]}{[K][J]} &= \frac{[C]}{[J]} \end{aligned}$$

Or in words, k has units of energy per temperature, e has units of Coulombs, therefore e/kT has units of Coulombs per Joule, or V^{-1}.

The I-V characteristic of the semiconductor diode is shown below in Figure 5.

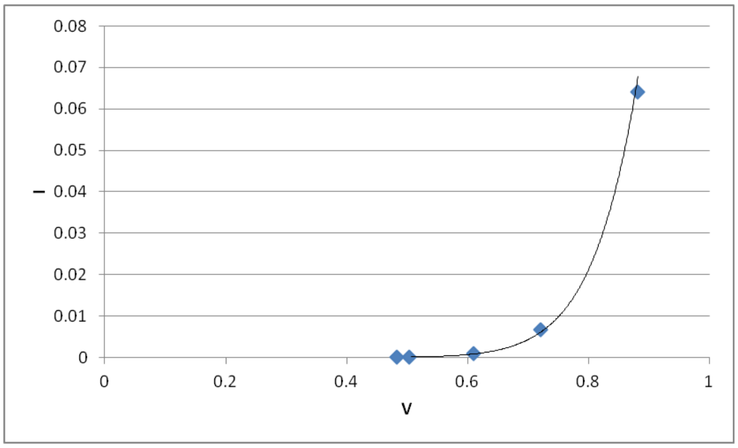

Figure 5: I-V Characteristic

The graph of ln(I) against V is shown in Fig6

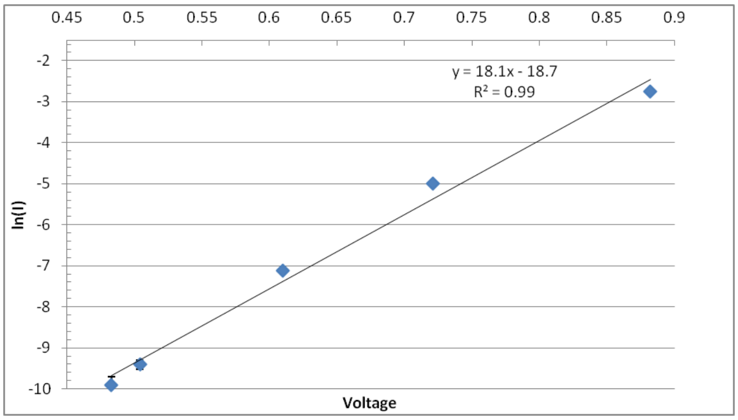

Figure 6: Plot of ln(I) against Voltage

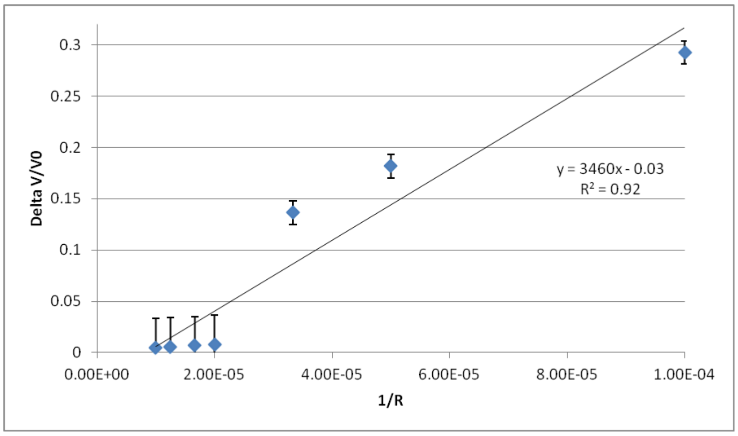

Figure 7: Plot of $\Delta V/V_0$ against Voltage

The value for e/KT which was found from the graph was $18.1 \pm 1V^{-1}$. This differs from the accepted value by a factor of approximately 2, which makes sense since the equation for the current through a silicon diode should be given as

$$I = I_0(exp(eV/\eta kT) - 1)$$

where $\eta \approxeq 2$

The voltage for the diode at room temperature was

$$V_1 = 1.123 \pm 0.01V$$

The steady state voltage was

$$V_2 = 1.089 \pm 0.01V$$

giving a difference of $34 \pm 1mV$ This corresponds to a temperature rise of $\Delta T = 15 \pm 0.5K$

Half wave rectifier

We found the peak voltage across the resistor, when set to be $10k\Omega$ to be $7.04 \pm 0.01V$. When divided by $\sqrt{2}$ this gives 4.97V which compares to the RMS voltage of 5V across the A.C. supply.

The plot of fractional ripple voltage $\Delta V/V_0$ against 1/R is shown below in Figure 7.

The peak current i_p was found to be $0.78 \pm 0.03mA$ and flowed for 0.175ms. The period of the cycle was found to be 20ms. The average current through the rectifier was found to be $5.74 \pm 0.05mA$ while the average current through the resistor was found to be $5.89 \pm 0.01mA$.

Full wave rectifier

We found the fractional ripple Voltage for a $10k\Omega$ resistance to be 0.045. The maximum reversed voltage was found to be 508 ± 4 mV.

Discussion and Conclusions

TODO: REWRITE Our results showed the expected behaviour of the p-n semiconductor diode, that its behaviour depended on its orientation in the circuit and that it could be used effectively to convert AC current into a smooth DC current. We also found that the quality of the smoothed DC current, where quality is defined as a small $\Delta V/V_0$, is proportional to the resistance of the circuit, i.e. for a higher resistance, $\Delta V/V_0$ is lower, or that $\Delta V/V_0$ is inveresly proportional to R. Some results from our graphs had large error values that could have been improved with more data points.