Measurement of Time Period of A Simple Pendulum using an Electronic Circuit

Bhuvnesh, Phurailatpam Hemantakumar
Department of Physics, Hindu College, University of Delhi

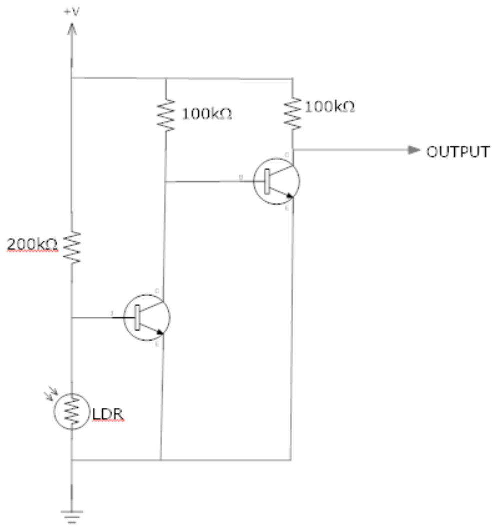
Abstract:- **This project was taken up in the hope of building an electronic circuit which enables us to measure the time period of a simple pendulum accurately, taking into account the parallax, human reflex and random errors.**

Measuring the time period of a simple pendulum by counting the number of oscillations and noting down the time using a stop watch is one of the simplest experiments one can perform to find the value of 'g', i.e. acceleration due to gravity. This experiment has restricted accuracy due the above mentioned errors. But the problem can be overcome to certain extent by employing an electronic circuit which reads the pendulum's movement, as well as count the time interval between oscillations. In this project an attempt is made to detect the pendulum using a laser detector with which a circuit consisting of timers and counters is employed to measure the number of oscillations and time of the journey simultaneously. The required result is allowed to display using 7447 IC and SSD (seven segment display).

The concepts involved in designing this project is well familiar with and read by any college student pursuing Bsc. Physics Hons.

DESCRIPTION OF THE COMPONENTS

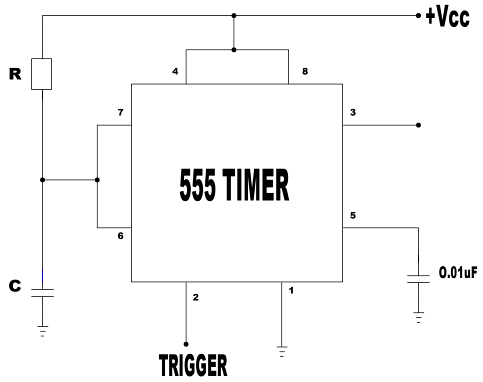
LASER DETECTOR



LDR (light depending resistor) is an electrical component which changes its resistance according to how much light intensity falls on it.

A laser from a source is allow to fall on it continuously which keep the resistance of the LDR low. As the oscillating pendulum cuts the laser, the resistance of LDR goes high. This change in the LDR resistance is read with a circuit using two transistor. The transistor on the right is used as a switch and the output is derived from its collector terminal.

555 TIMER (AS MONOSTABLE MULTIVIBRATOR AND ASTABLE MULTIVIBRATOR)

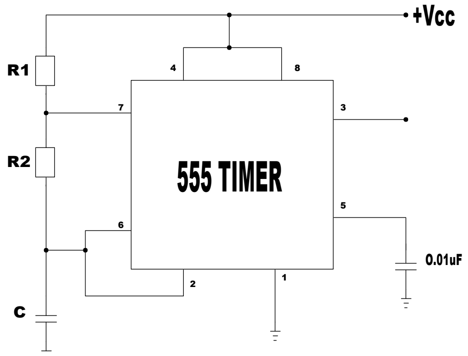


Monostable multivibrator:

It has a stable and a quasistable state. A pulse at the trigger switches the output to quasistable state and stay for predetermined length of time. Then it switches back to the stable state and wait for the next pulse.

It is used to get a digital output wave with sharp edges.

Figure 1: Monostable Multivibrator

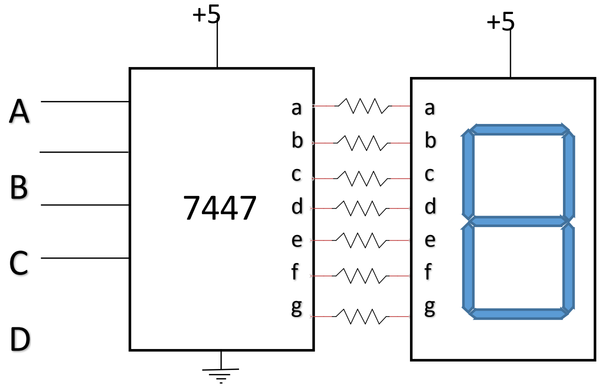


Astable multivibrator:

Neither the digital state is stable. Therefore the output switches back and forth between the two unstable state and it is periodic, rectangular waveform.

This is used for timing the journey of the oscillating pendulum.

Figure 2: Astable Multivibrator



Seven segment display (common anode):

Digital output from counter is received by 7447 IC and is converted to numerical form needed by SSD. The SSD display the numerical output corresponding to the digital output given by the counter.

Figure 3: Seven Segment Display with 7447 IC

ICs (74160 and 74373):

74160 is a decade counter which can make digital count from 0000 to 1001, and repeats itself after each cycle. Every count is triggered through the clock pin.

74373 is an IC with 20 pins. It is internally D-flip flops which can be control with the enable pin provided. It also acts as a buffer to derive SSD display.

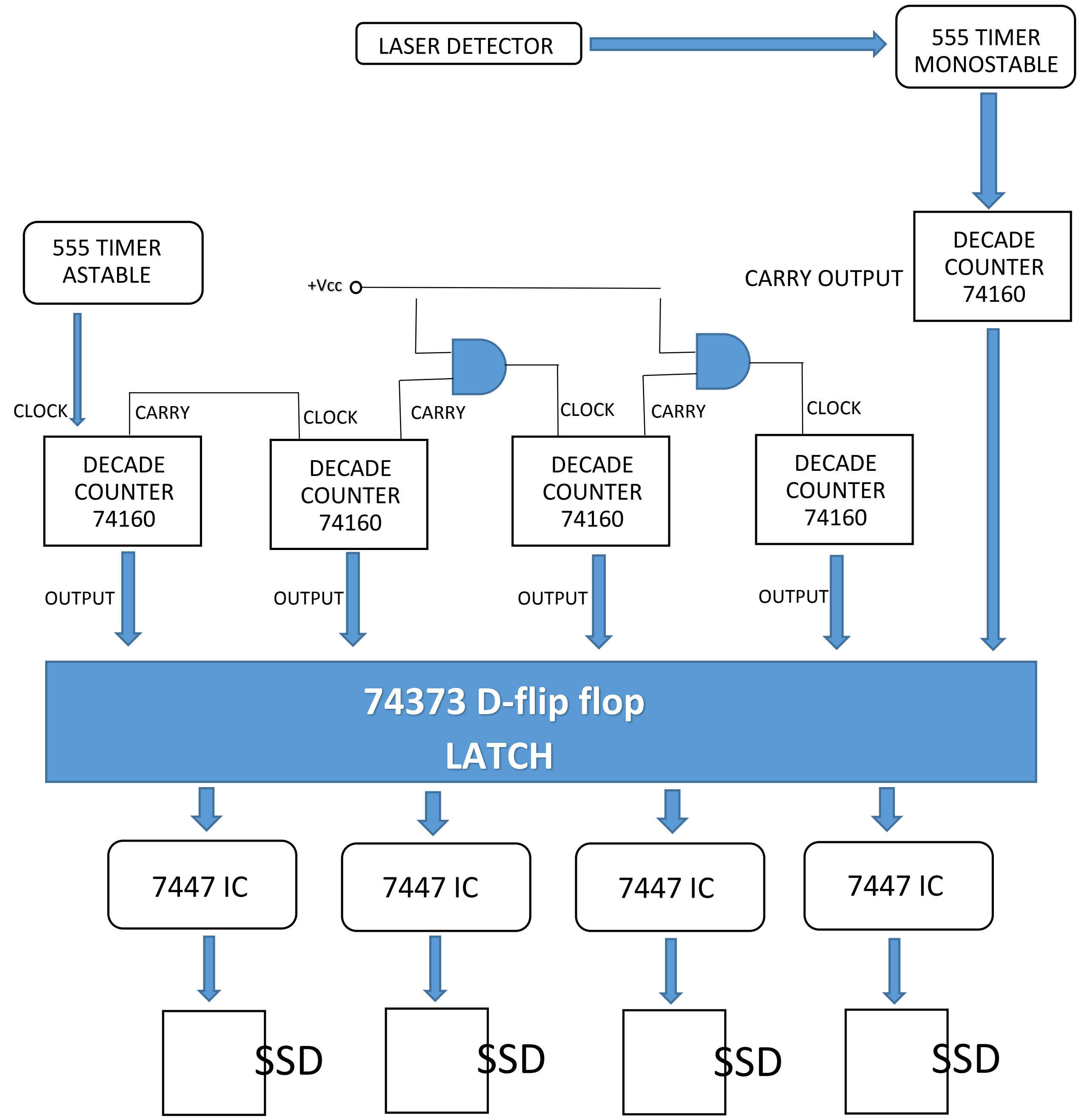


Figure 4: Schematic diagram of the circuit used

EXPERIMENT

The pendulum is allowed to oscillate between the laser source and the detector. When at rest the laser, the bob of the pendulum and the LDR are made collinear. As the pendulum oscillates it cuts the laser which makes the detector to send a pulse and trigger the 555 timer (monostable). The timer output's time period is set to be higher than the time the detector is obstructed while crossing the laser and lower than the time it takes to return to the mean position, i.e. when the timer is triggered again. The timer is then connected to a decade counter (74160 IC), which increase its count as the laser is cut, i.e. for every half oscillation. The carry output of 74160 IC goes to each enable pin of 74373 ICs which later will help in latching the output of the series counters.

The 555 timer (astable) is made to oscillate with a known frequency, by adjusting the value of capacitor and resistor used (87.5878Hz, for this experiment). It is then interface with a series of decade counters. These counters start counting as soon as there is an output from the 555 timer (astable) and the process continues. But the experiment dictates the requirement of time interval in certain number of oscillations. In order to achieve this 74373 ICs are employed to latch the counters' output.

Each 74373 IC is control through enable pin by the carry output from the counter connected to 555 timer (monostable). This counter counts from 0000 to 1001 and then starts from 0000 with a high carry output. As long as it is high, it enables the 74373 ICs and the output of the series counters is made available to be displayed by SSDs. When the former counter changes 0000 to 1000, its carry output goes low, thus disenabling the 74373 ICs. As a consequence the output display in SSD is latch till 74373 ICs are enable again.

Numbers displayed on SSDs are noted after every five oscillations for a particular pendulum length. Such ten readings are taken for nine different pendulum lengths and graph is plotted for each set, between the SSDs readings and number of oscillation. A line is drawn that fits the data points and the slope of this line will give the number of count made by the astable 555 timer per oscillation. The required time period of the pendulum can be obtained by multiplying the value of the slope with the least count of the astable 555 timer.

Comparison between the experimental results and theoretical values are made by plotting a graph between 'time period (T)' and 'length of the pendulum (*l*)'. Further comparison can be achieved by plotting graph between '*l* ' and 'T^2'.

The formula $T=2\pi\sqrt{l/g}$ is used to find the value of 'g'.

OBSERVATIONS

Least count of the astable 555 timer = 0.011417 s

Theoretical value of 'g'= 981cm/s^2

g =acceleration due to gravity

$T= 2\pi\sqrt{l/g}$ $\quad$ $l = (g/4\pi^2)T^2$

l = length of the pendulum

T = time period of the pendulum

Following are the graphs and tables to find the time period of the given length:

1. Pendulum length= 100 cm

Graph 1

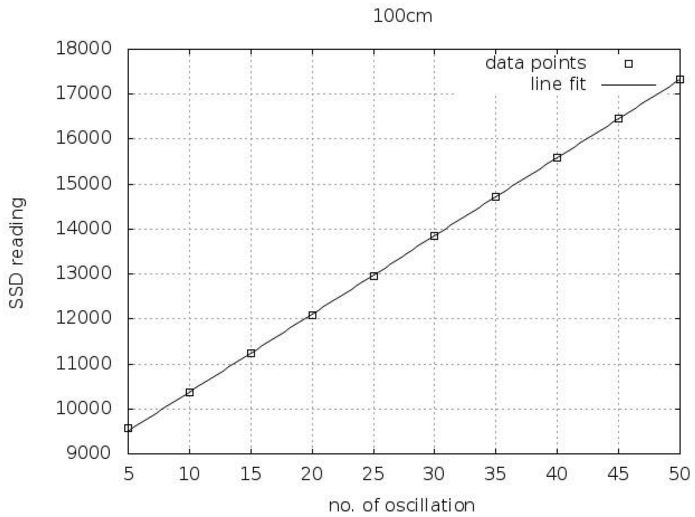


Table 1

NO. OF OSCILLATIONS	SSDs READINGS
5	9568
10	10357
15	11227
20	12095
25	12965
30	13839
35	14715
40	15588
45	16464
50	17339

Slope=173.608

Time period= 1.982 s

g=1000.49 m/s^2

2. Pendulum length= 90 cm

Graph 2

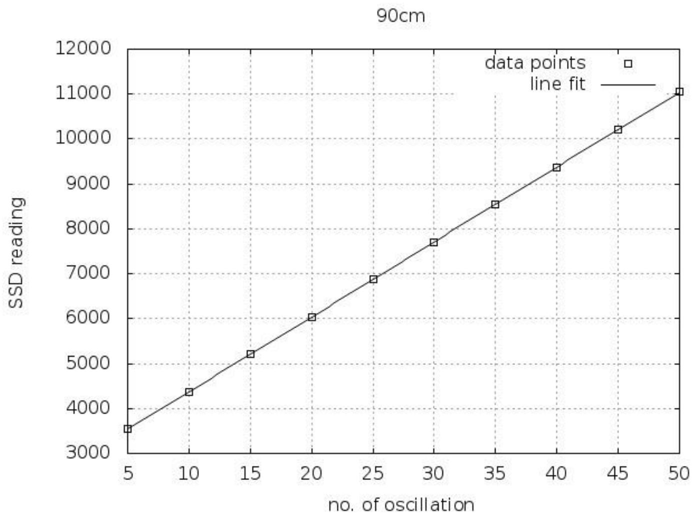


Table 2

Slope= 166.696

Time period= 1.903 s

g=981.12 cm/s^2

NO. OF OSCILLATIONS	SSDs READINGS
5	3544
10	4375
15	5206
20	6040
25	6874
30	7706
35	8540
40	9375
45	10209
50	11045

3. Pendulum length = 80 cm

Graph 3

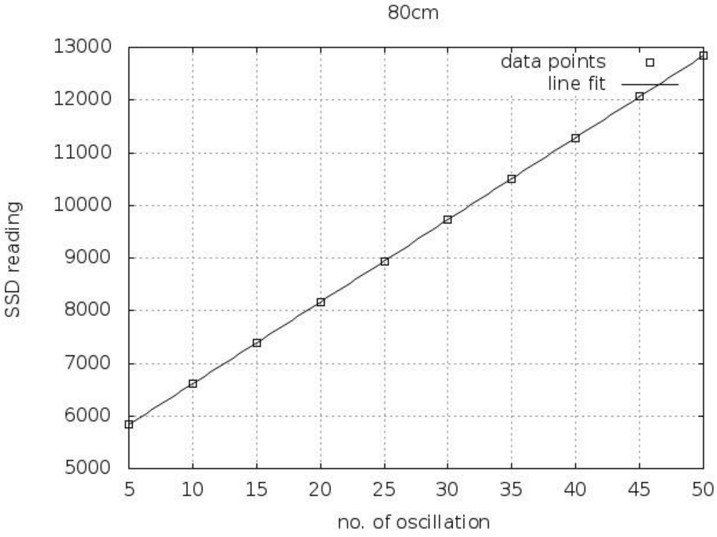


Table 3

NO. OF OSCILLATIONS	SSDs READINGS
5	5840
10	6615
15	7390
20	8166
25	8943
30	9722
35	10503
40	11283
45	12065
50	12847

Slope=155.719

Time period= 1.778

g=999.04 cm/s^2

4. Pendulum length= 70 cm

Graph 4

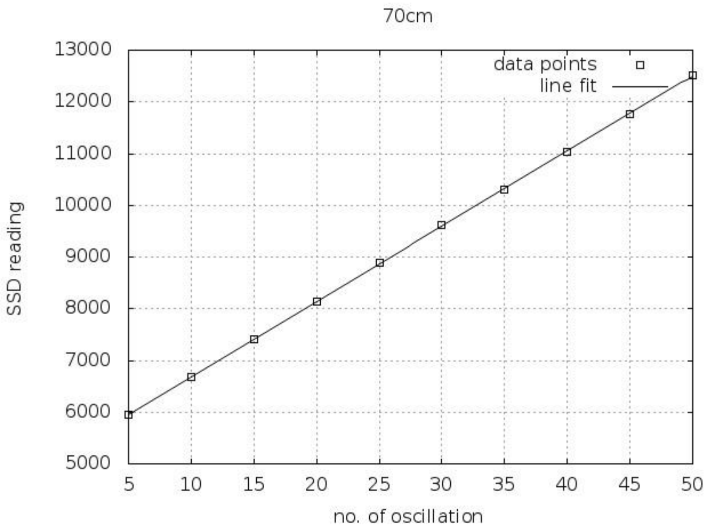


Table 4

Slope=

NO. OF OSCILLATIONS	SSDs READINGS
5	5941
10	6675
15	7410
20	8145
25	8882
30	9623
35	10296
40	11035
45	11771
50	12504

145.525

Time period= 1.661 s

g=1001.65 cm/s^2

5. Pendulum length= 60 cm

Graph 5

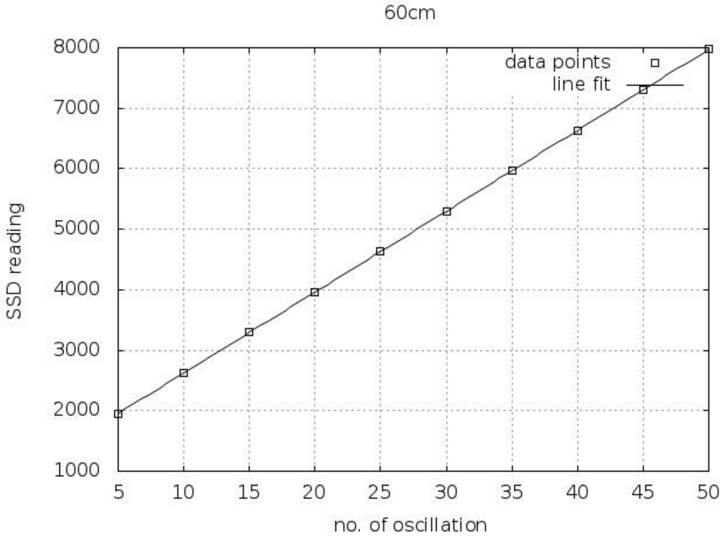


Table 5

NO. OF OSCILLATIONS	SSDs READINGS
5	1955
10	2623
15	3292
20	3961
25	4629
30	5298
35	5966
40	6635
45	7303
50	7971

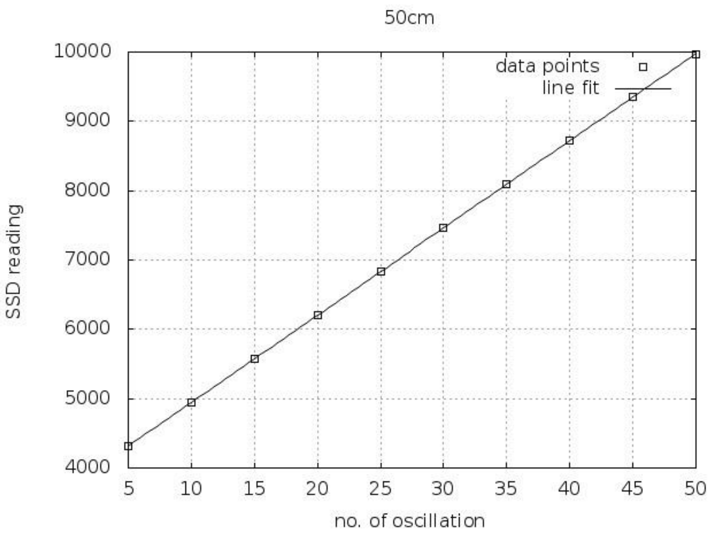
Slope=133.701

Time period=1.526 s

g=1017.18 cm/s^2

6. Pendulum length= 50 cm

Graph 6



Slope= 125.771

Time period= 1.436 s

Table 6

NO. OF OSCILLATIONS	SSDs READINGS
5	4310
10	4943
15	5577
20	6211
25	6841
30	7468
35	8094
40	8720
45	9346
50	9971

g=957.24 cm/s^2

7. Pendulum length= 40 cm

Graph 7

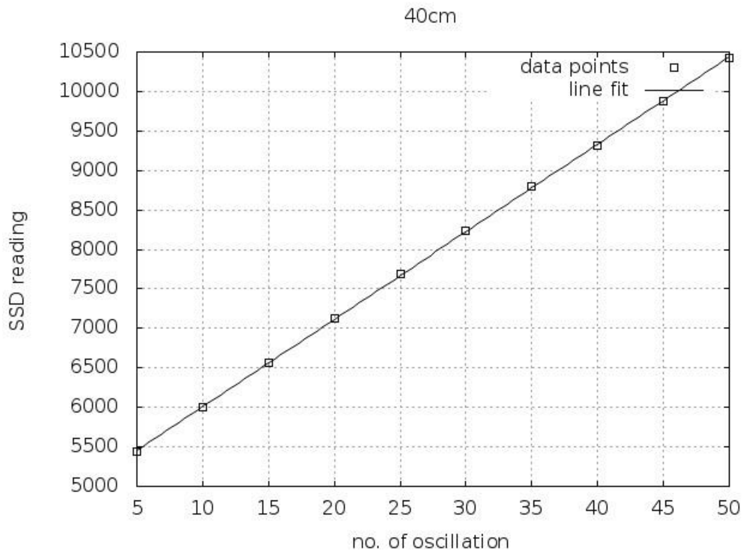


Table 7

NO. OF OSCILLATIONS	SSDs READINGS
5	5443
10	6003
15	6563
20	7123
25	7682
30	8242
35	8803
40	9311
45	9870
50	10431

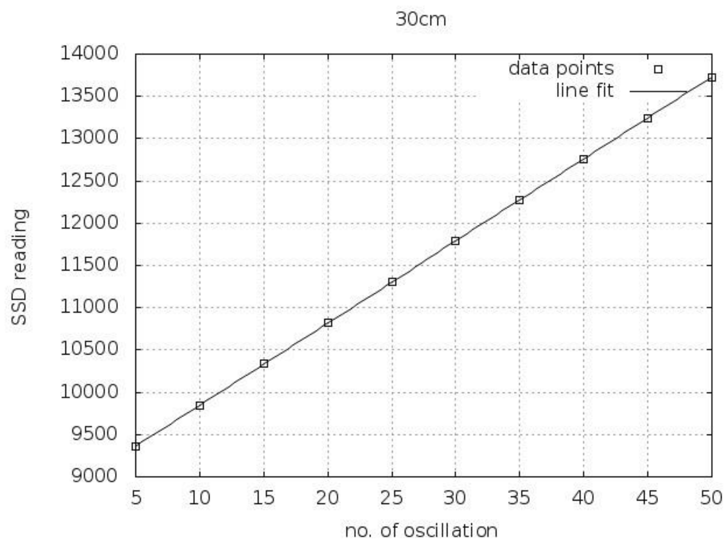
Slope= 110.668

Time period= 1.263 s

g=989.94 cm/s^2

8. Pendulum length= 30 cm

Graph 8



Slope= 97.0436

Time period= 1.108 s

g=964.72 cm/s^2

Table 8

NO. OF OSCILLATIONS	SSDs READINGS
5	9364
10	9848
15	10334
20	10819
25	11305
30	11790
35	12275
40	12761
45	13245
50	13730

9. Pendulum length= 20 cm

Graph 9

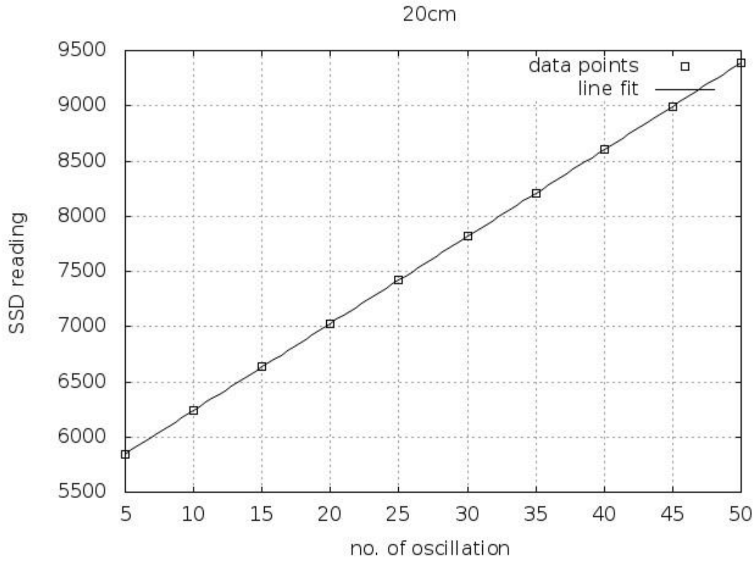


Table 9

Slope=

NO. OF OSCILLATIONS	SSDs READINGS
5	5848
10	6242
15	6635
20	7028
25	7422
30	7815
35	8208
40	8602
45	8996
50	9390

78.6958

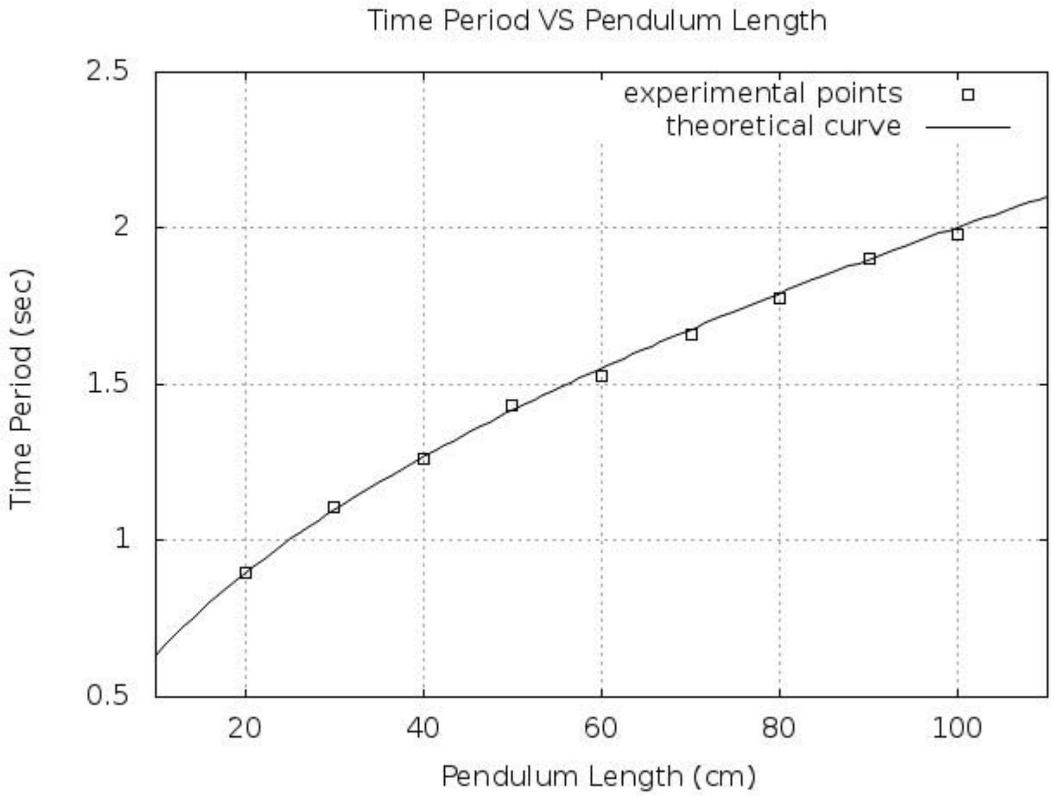
Time period= 0.896 s

g=983.49 cm/s

COMPARISON BETWEEN THE EXPERIMENTAL RESULTS AND THEORETICAL VALUE

Table 10: Time period of the pendulum in a particular length

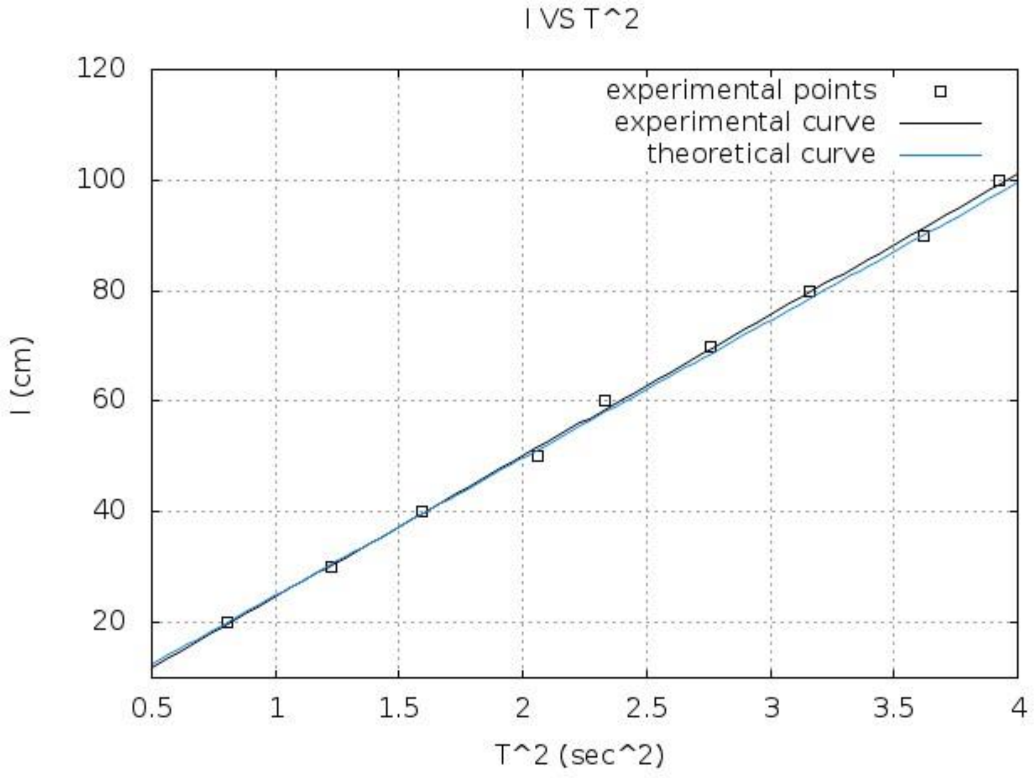
X-AXIS *l* (cm)	Y-AXIS T (s)
20	0.898
30	1.108
40	1.263
50	1.436
60	1.526
70	1.661
80	1.778
90	1.903
100	1.982



Graph 10: Time Period VS Pendulum Length

Table 11: Relation between (time period)[2] and length of the pendulum

X-AXIS T^2 (s^2)	Y-AXIS l (cm)
0.8064	20
1.2277	30
1.5952	40
2.0621	50
2.3287	60
2.7589	70
3.1613	80
3.6214	90
3.9283	100



Graph 11: Pendulum Length VS (Time Period)^2

RESULT

It can be seen from the graph that the experimental data and the experimental curve are fairly close enough to the theoretical curve which are drawn with the assumption that 'g' is 981cm/s^2.

PRECAUTIONS

1. Least count of the astable 555 timer should be found accurately using a CRO, or a multimeter.
2. The counting done by the decade counter which is connected to monostable 555 timer is monitored with caution using LEDs at its output terminals, so that is doesn't skip its count.
3. Light condition of the room should not change as it may interfere with the desire detector output.

CONCLUSION

This project provides a platform where students learned to integrate various topics studied in digital electronics and classical physics. It also give exposure to troubleshooting, datasheets, design parameters and experimentation.

Besides this project, the method involved can be made to use in various other fields, like measuring rpm of a wheel etc.

ACKNOWLEDGEMENT

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REFERENCES

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