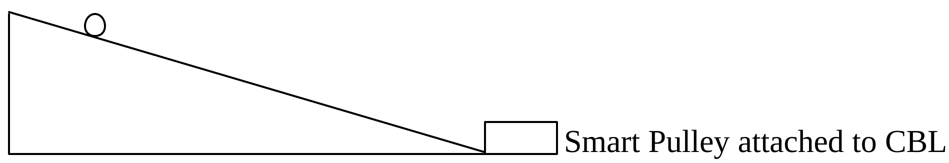
Name: ________________________

Experiment Example, Acceleration due to Gravity

The purpose of this experiment is to measure the acceleration due to gravity. We will use a nearly-frictionless inclined plane. The acceleration of a point particle sliding freely down an inclined plane is given by

$$a = g\sin\theta$$

By varying the angle of the incline and measuring the acceleration, the acceleration due to gravity g can be determined. We will use a smart-pulley attached to a CBL to determine the acceleration of the object. By graphing the acceleration versus $\sin\theta$, the acceleration due to gravity can be determined. The general set-up is shown below.



In your write-up, please include the following sections:

(1) Title, Names, etc. (Section 1 on the handout: Lab Reports)
(2) Purpose (Section 2 on the handout: Lab Reports)
(3) Method (Section 3 on the handout: Lab Reports)
(4) Data (Section 4 on the handout: Lab Reports)
You will want to think about how much data you will require. Obviously, more data is better; however, you have a limited amount of time. Make sure you obtain enough data points and trials to create a good graph.
(5) Analysis (Section 5 on the handout: Lab Reports)
Include a graph of Acceleration versus $\sin\theta$. Include an appropriate regression equation with R^2 value. Determine the acceleration due to gravity.
(6) Conclusion (Section 6 in the handout: Lab Reports)
Your conclusion will need to be a couple of good paragraphs. You will want to consider the following questions: What factors affected your result for the acceleration due to gravity? How does your value for g compare with the accepted value? Quantitatively compare your value of g with the accepted value.

Acceleration Due to Gravity
Example 1

Date: August 23, 2001

Purpose: The purpose of this experiment is to measure the acceleration due to gravity g.

Method: A cart is accelerated down a nearly frictionless inclined plane. If we assume $\mu = 0$, then the acceleration of the cart down the plane is given by

$$a = g\sin\theta .$$

We will vary the angle of inclination and measure the acceleration with a CBL. We will plot the acceleration versus the sine of the angle of inclination. Since this graph should be linear, we will determine the best fit line to this data using linear regression. The slope of this line will be the acceleration due to gravity.

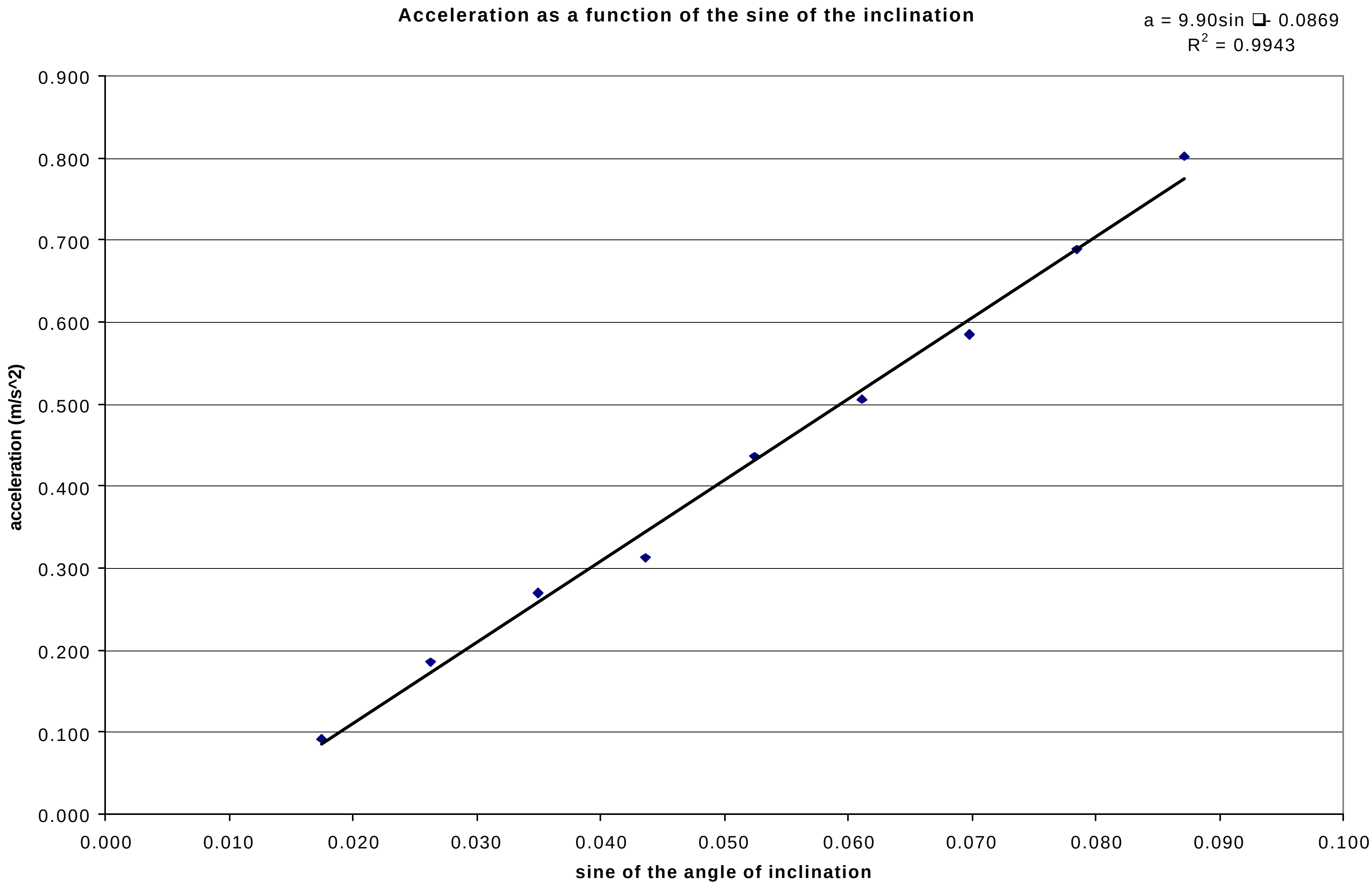
Data:

N	Angle (degrees)	Accel. Trial 1 (m/s^2)	Accel. Trial 2 (m/s^2)	Accel. Trial 3 (m/s^2)	Accel. Trial 4 (m/s^2)	Accel. Trial 5 (m/s^2)	Sine of Angle	Average Accel. (m/s^2)
1	1.0	0.0937	0.0897	0.0897	0.0932	0.0942	0.018	0.0921
2	1.5	0.185	0.186	0.182	0.189	0.186	0.026	0.186
3	2.0	0.274	0.262	0.262	0.273	0.277	0.035	0.270
4	2.5	0.327	0.317	0.302	0.310	0.309	0.044	0.313
5	3.0	0.437	0.436	0.429	0.440	0.439	0.052	0.436
6	3.5	0.493	0.511	0.507	0.508	0.508	0.061	0.505
7	4.0	0.606	0.579	0.532	0.606	0.601	0.070	0.585
8	4.5	0.691	0.699	0.690	0.682	0.683	0.079	0.689
9	5.0	0.783	0.856	0.852	0.844	0.676	0.087	0.802

Angle refers to the angle of inclination of the inclined plane. Average Accel. is the average of the five trials.

Results:

Shown below is the graph of acceleration versus the sine of the angle of inclination for the inclined plane. A linear regression line is fit to the data. The slope of this line is the acceleration due to gravity.


Acceleration as a function of the sine of the inclination
a = 9.90sin ❑- 0.0869
R^2 = 0.9943
acceleration (m/s^2)
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.100
sine of the angle of inclination

Measured acceleration due to gravity:	9.90 m/s^2
Accepted value of acceleration due to gravity:	9.80 m/s^2
Percent difference:	1.02%

Conclusion:

The measured value of the acceleration due to gravity was quite good only 1.02 % larger than the accepted value of 9.80 m/s^2. It is surprising that this value is larger than the accepted value. The negligible amount of friction on the inclined plane certainly does not account for the larger acceleration. I suspect that the major source of error was the measurement procedure for the acceleration. A small paper clip was attached to the cart by fishing twine. This twine was placed over a smart pulley to measure the acceleration. Unfortunately, this procedure resulted in a non-uniform acceleration for the paper clip, string, cart system which we saw in the graph of acceleration versus time generated by the CBL. Any trials where the acceleration was grossly non-uniform were excluded; however, all trials seemed to have non-uniform acceleration which was evident through small oscillations about the expected linear velocity versus time graph given by the CBL. I suspect this resulted in the small difference in the acceleration due to gravity. It would be better to measure to acceleration by timing the cart over a known distance and calculating the acceleration since we know it is uniform. Then, these smart pulley problems would be avoided.

As a interesting side note, the coefficient of friction of the inclined plane can be estimated through this experiment. From Newton's Second Law, the acceleration of the cart down the plane is given by:

$$a = g\sin\theta - \mu g\cos\theta$$

Since $\theta \in [1.0°, 5.0°]$, $\cos\theta \approx 1$. Thus, the y-intercept of the above graph can be used to estimate the coefficient of friction.

$$\mu g = 0.0869 \Rightarrow \mu = 0.00878$$

Certainly, our approximation that the inclined plane was frictionless is justified.

Comments:

Notice that this report contains all the required parts listed on the handout and answers all the discussion questions. However, the answers are quite thorough showing a true understanding of the experiment. In particular, notice:

- A clear explanation for the 1.02% error is given. Plus, a suggestion for improvement is offered.

- The y-intercept of the acceleration versus sin θ is discussed. Often, there is a simple explanation of the y-intercept or of any other characteristic of the graph. Be sure to think about these characteristics in future experiments.
- The data was quite reliable. Five trials for eight data points certainly gives a good sample for the experiment.
- Note that the required number of significant digits is given. Plus, compare the method sections of this experiment with the next experiment.
- Be sure to compare this experiment with example 2 below. There are a couple of significant differences that lead to the different grades. Be sure you understand these differences before you complete your first lab report.

This lab report would earn a grade: A.

Acceleration Due to Gravity
Example 2

Date: August 20, 2001

Purpose: The purpose of this experiment is to measure the acceleration due to gravity g.

Method: Using a CBL, the acceleration of a cart moving freely on an inclined plane is measured. Since the incline is essentially frictionless, a component of gravity produces the acceleration along the plane. The acceleration is given by

$$a = g\sin\theta$$

By varying the angle and measuring the acceleration, the acceleration due to gravity g can be determined.

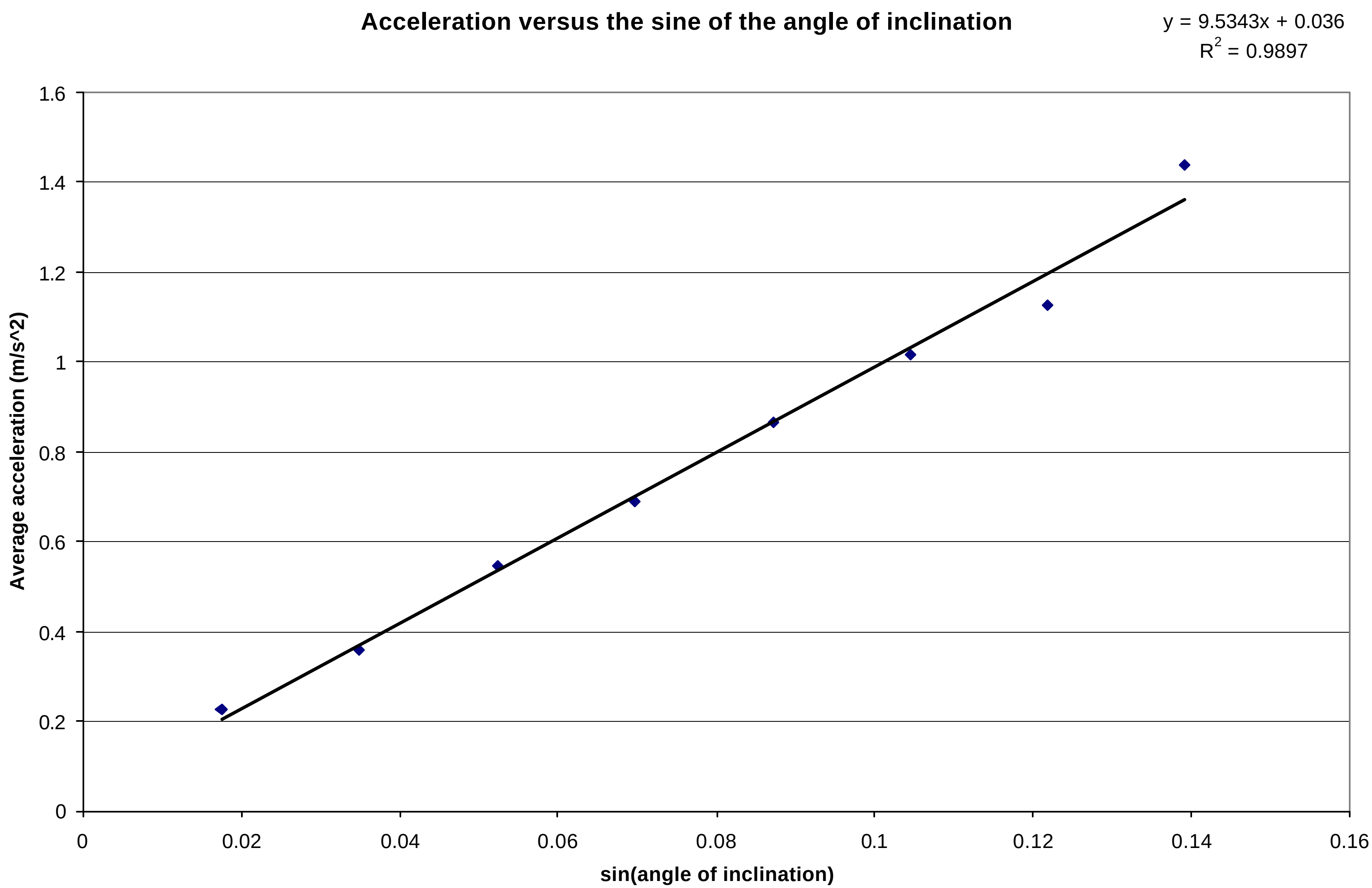
Data:

Angle (deg.)	a1 (m/s^2)	a2 (m/s^2)	sin(Angle)	Ave. Accel (m/s^2)
1.0	0.229	0.225	0.0174524	0.227
2.0	0.355	0.359	0.0348995	0.357
3.0	0.546	0.543	0.052336	0.5445
4.0	0.688	0.690	0.0697565	0.689
5.0	0.863	0.871	0.0871557	0.867
6.0	1.017	1.017	0.1045285	1.017
7.0	1.144	1.110	0.1218693	1.127
8.0	1.478	1.400	0.1391731	1.439

Angle refers to the angle of inclination of the frictionless plane. a1 and a2 are the two trials for the acceleration at that angle. Sin(angle) is the sine of the angle of inclination. Ave. Accel is the average of the two trials.

Results:

Shown below is the graph of acceleration versus the sine of the angle of inclination for the inclined plane. A linear regression line is fit to the data. The slope of this line is the acceleration due to gravity.


Acceleration versus the sine of the angle of inclination
y = 9.5343x + 0.036
R2 = 0.9897
Average acceleration (m/s^2)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
sin(angle of inclination)

Measured acceleration due to gravity:	9.53 m/s^2
Accepted value of acceleration due to gravity:	9.8 m/s^2
Percent difference:	−2.76%

Conclusion:

The measured value of the acceleration due to gravity was only 2.76% lower than the commonly accepted value of 9.8 m/s^2. It was certainly expected that the measured value would be lower since the tracks are only assumed to be frictionless.

Further factors that affected this result were the ability to read the angle indicator. Certainly, it is difficult to measure such small differences very accurately, especially since the method was quite crude. In general, though, the experiment yielded good results.

Comments:

This write-up includes everything that was asked of the student. Each question on the handout was answered. However, note the following:

- More analysis of the discrepancies would strengthen the report. Compare this conclusion with example 1. This conclusion is quite weak and weighs heavily in the final evaluation.
- If frictional losses were the only factor in the experimental results, a negative y-intercept would be expected on the regression line. Here, the y-intercept is positive indicating either that the data points were not measured carefully or that there is some other effect present in the experiment.
- Although eight data points was sufficient for this experiment, only two trials at each angle was not sufficient.
- The data are not all reported to the correct amount of significant digits—particularly the calculated values of the sine of the angle of inclination and the average acceleration. Determining the number of significant digits and the degree of uncertainty is generally a complicated process. As a rule of thumb, do not give calculated answers to more significant digits than the original data.
- Rather than report in the conclusion something that is unreliable in the data, e.g. the angle measurements, you should retake the data. Be sure to start your report soon enough so that any unreliable data can be retaken.

This lab report would earn a grade: B.