BH03: AAPT Summer 2002 Conference, Boise, ID

Physics Lab Reports
and
Final Exams
Any Relationships?

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Outline

A Pilot Study

1. **Introductory Physics: The format at the U of Minnesota**
   a) **Problem solving labs: Nature of labs, Grading the labs**
   b) **Student's Written Lab Reports**
2. **Final Exam Problems vs TA Lab Scores**
3. **Comparison of Exam Scores with Labs evaluated according to standards of organization, support, and content.**
4. **Next Steps**

A Pilot Study

- **What are Students Learning in the Physics Course?**
  - **How Physics Principles Relate to the Physical World?**
  - **How to Solve Problems?**

- **Can We Measure What They are Learning in the Course?**

- **Do Our Measurements Show any Correlation Between Lab Results and How Students do on Problem Solving in Final Exams?**

In labs students are given problems to solve.

They must organize their ideas, use supporting information,and they must understand the physics.

In final exams students are given problems to solve.

They must organize their ideas, use supporting information,and they must understand the physics.

Setting

- Lecture
  - ~200 students / 1 lecturer
  - 3 hours / week
- Recitation
  - 15 students / section
  - 1 hour / week
- Laboratory
  - 15 students / section
  - 2 hours / week

☆ **Note:**

All parts of the course are integrated such that the problems in lab and recitation are concurrent with the topics being covered in lecture

Laboratory

- cooperative group problem solving (3 students per group)
- each student hands in a laboratory report every two weeks
- TA assigns each student a different problem for a written report
  - no one knows which problems will be assigned ahead of time
- TA grades the reports
  - lab grade = 15% of course grade
  - a score of 60% in lab is required for passing the whole course

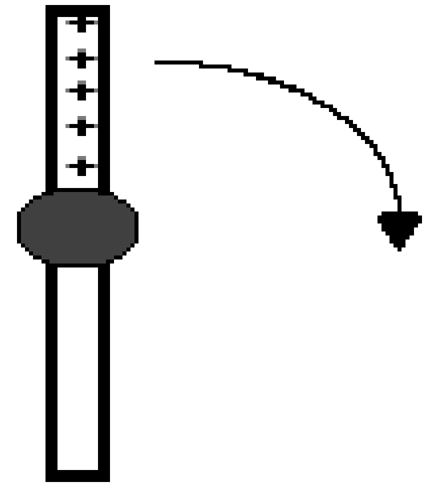
PROBLEM #1:
ANGULAR SPEED AND LINEAR SPEED

You have a summer job with a group testing equipment that might be used on a satellite. To equalize the heat load from the sun, the satellite will spin about its center. Your task is to determine the forces on delicate measuring equipment when it spins at a constant angular speed. Since any object requires a net force on it to travel in a circular path at constant speed, that object must be accelerating. You decide to first find the linear speed of any object in the satellite as a function of the distance of that object from the axis of rotation. From the linear speed of an object in circular motion, you can calculate its acceleration. You know the angular speed of the satellite's rotation.

What is the relationship between the linear speed of an object rotating at a constant angular speed and its distance from the axis of rotation? What is the object's acceleration?

EQUIPMENT

You will be using a beam that is free to rotate about its central axis. A top view of the device is shown to the right. You will have a meter stick, a stopwatch, and video analysis equipment.



PREDICTION

Make a graph of the linear speed of a point on the beam as a function of its distance from the axis of rotation when the beam has a constant angular speed. Calculate the acceleration of a point on the beam based on this graph.

METHOD QUESTIONS

1. Draw the trajectory of a point on the beam. Choose a coordinate system. Choose a point on that trajectory that is not on a coordinate axis. Draw vectors representing the position, velocity, and acceleration of that point.

2. Write equations giving the perpendicular components of the position vector as a function of the distance of the point from the axis of rotation and the angle the vector makes with one axis of your coordinate system. Calculate how that angle depends on time and the constant angular speed of the beam. Graph each of these equations as a function of time.

3. Using your equations for components of the position of the point, calculate the equations for the components of the velocity of the point. Graph these equations as a function of time. Compare these graphs to those representing the components of the position of the object. Put these components on your drawing and verify that their vector sum gives the correct direction for the velocity of the point.

Method Questions

4. Use your equations for the components of the velocity of the point to calculate its speed.

5. Write down the acceleration of the point as a function of its speed and its distance from the axis of rotation. Using step 4, calculate the acceleration of the point as a function of the beam's angular speed and its distance from the axis of rotation.

Exploration

Practice spinning the beam at different angular speeds. How many rotations does the beam make before it slows down appreciably? Select a range of angular speeds to use in your measurements.

Move the apparatus to the floor and adjust the camera tripod so that the camera is directly above the middle of the spinning beam. Make sure the beam is level. Practice taking some videos. Find the best distance and angle such that the motion has the least amount of distortion. How will you make sure that you always measure the same position on the beam?

Plan how you will measure the perpendicular components of the velocity to calculate the speed of the point. How will you also use your video to measure the angular speed of the beam?

Measurement

Take a video of the spinning beam. Be sure you have more than two complete revolution of the beam. For best results, use the beam itself when calibrating your video.

Determine the time it takes for the beam to make two complete revolutions and the distance between the point of interest and the axis of rotation. Set the scale of your axes appropriately so you can see the data as it is digitized.

Decide how many different points you will measure to test your prediction. How will you ensure that the angular speed is the same for all of these measurements?

How many times will you repeat these measurements using different angular speeds?

ANALYSIS

Analyze your video by following a single point on the beam for at least two complete revolutions.

Use the velocity components to determine the direction of the velocity vector. Is it in the expected direction?

Analyze enough different points to make a graph of speed of a point as a function of distance from the axis of rotation. What quantity does the slope of this graph represent?

Calculate the acceleration of each point and graph the acceleration as a function of the distance from the axis of rotation. What quantity does the slope of this graph represent?

CONCLUSIONS

How do your results compare to your predictions and the answers to the method questions?

Reports

On the order of two to three pages, plus graphs and information from the student's lab notebook

Sample Student Lab Report

Introduction

Introduction:

Have you ever wondered how objects act on different parts of a spinning disk? Does an object further in on the disk tend to go faster or slower? In this lab we will be determining the relationship between the linear speed of an object rotating at a constant speed and its distance from the axis. From this determination we will also calculate the accelerations of the objects.

To carry out the experiment we will record a rotating disk at a constant speed. From there we will analyze two objects on the disk each a different distance from the axis.

Prediction

Prediction:

After a lengthy discussion with our group and some help from our TA we came up with half of the assigned prediction. The equation that we came up with for angular speed was:

$$V=wr$$

We got this by taking the derivative of the following two equations:

$$X=r\cos(wt)$$

$$Y=r\sin(wt)$$

After that we took the square root of the sum of the squares and that gave us our angular speed equation. From this equation we could determine that the farther away from the axis the object was the faster the speed would be.

Since the velocity vectors are always changing during uniform circular motion there is an acceleration present. We didn't get far enough to calculate that equation but I will be using it later in the data section. We finally got the equation for acceleration during the lab section so we couldn't use it for our predictions.

Procedure

Procedure:

To carry out this experiment we needed to use the video camera and VideoTOOL to analyze our data. We set up the camera so that the spinning disk was directly under the lens. This minimized our distortion possibilities. Then we spun the disk at a constant speed and recorded this motion, making sure that we got more than two revolutions in the video. While two group members were doing that, the third was timing a period so we would have some idea what to put in for our prediction curves.

We only had to make one video because we could re-use it for each computer analysis, since there were three marks on our disk.

Data & Analysis

Data and Analysis:

After we had collected all of our data we just needed to go through and plug in the numbers into the equation derived in the prediction. The angular velocities that we calculated were as follows:

.16 m away gave us 1.08 m/s

.20 m away gave us 1.3 m/s

We figured that this was correct because it followed the prediction between the distance from the axis and the speed of the object is a linear line. (See back pages for graph) This makes sense because the further out the object is from the axis means that it travels a greater distance. Therefore, the outermost object will have the greatest velocity.

Sample Student Lab Report

To calculate the acceleration of the objects we had to take the derivative with respect to time of our prediction equation. From that we got:

$$A=w^2r$$

Now using this equation we could calculate the accelerations of the two objects. The accelerations of the objects are as follows:

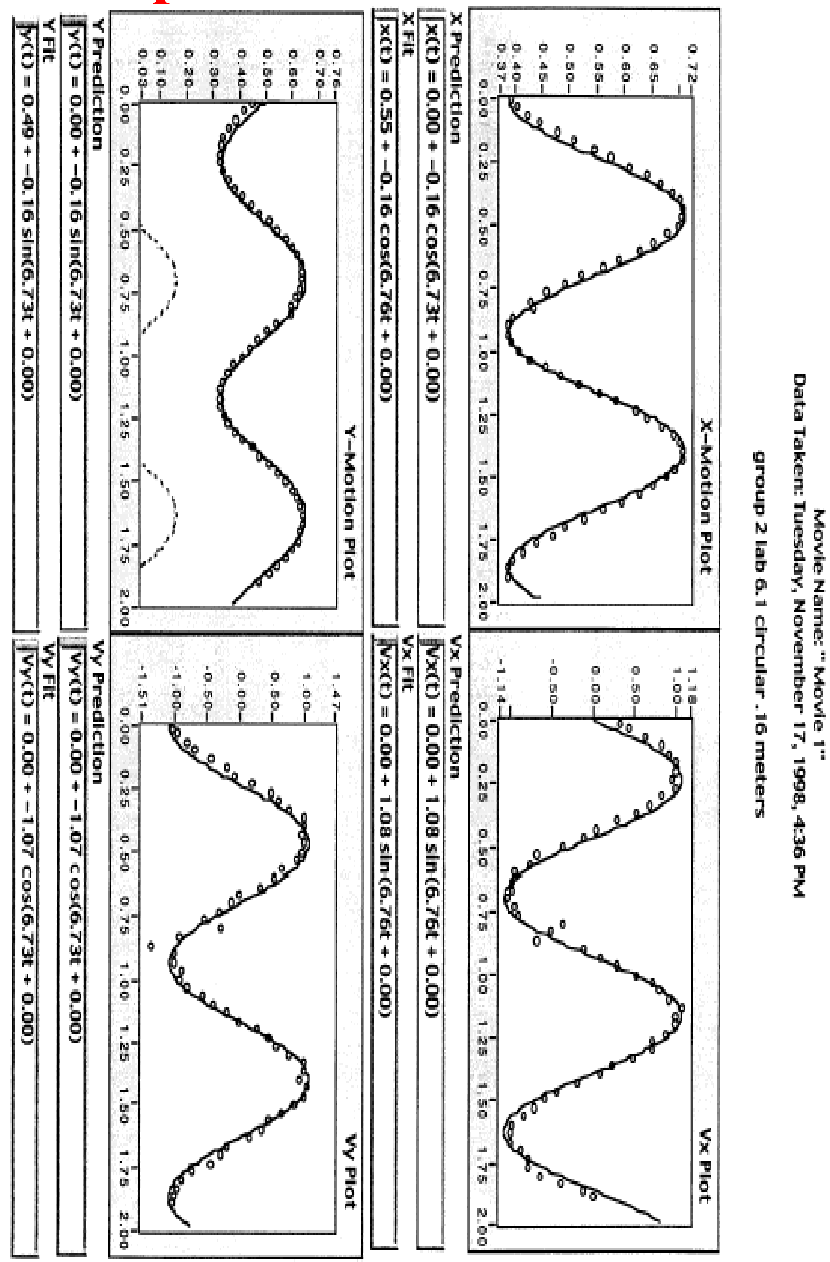
.16 m gave an acceleration of .186 m/s²

.20 m gave an acceleration of .36 m/s²

These also follow with our prediction that the larger the radius is the faster the speed of the object is which in turn, creates a larger acceleration.

<u>Conclusion:</u> ← **Conclusion**

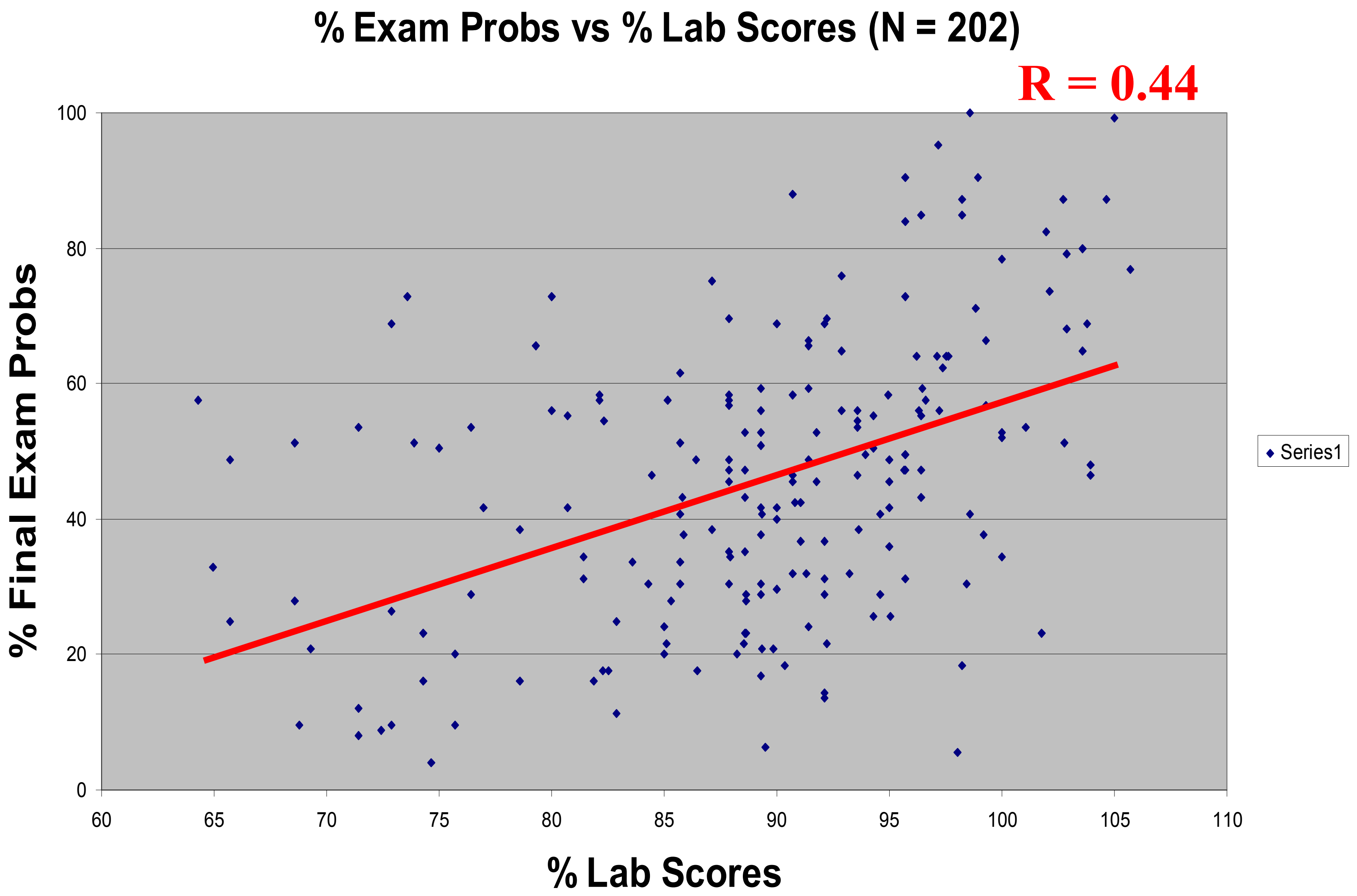
In conclusion we found that if a disk is rotating at a constant speed the further away from the axis the object is the greater the speed will be. Since velocity vectors are always changing during uniform circular motion, this creates an acceleration on the object. These we also calculated and found them to also rise when the distance from the axis was increased.



Guideline for grading laboratory reports

Problem Report:	Score
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (GROUP PREDICTIONS) (clear and readable; units and uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	

Is there any correlation between student scores on TA graded lab reports and scores on final exam problems?


% Exam Probs vs % Lab Scores (N = 202)
R = 0.44
% Final Exam Probs
100
80
60
40
20
0
60
65
70
75
80
85
90
95
100
105
110
% Lab Scores
Series1

Three different ways I judged lab reports

1. **Organization:** Complete yet concise; indicates strong topic sentences that indicate focus of section; appropriate headings; demonstrates coherence throughout report

Three different ways I judged lab reports

2. **Support:** Includes appropriate illustrations, logical statements to support ideas and conclusions, relevant charts, graphs, or tables and cross references
3. **Content:** Includes accurate & complete technical information, including equations, correct explanations of the physics concepts, and data

Evaluation Criteria for Support

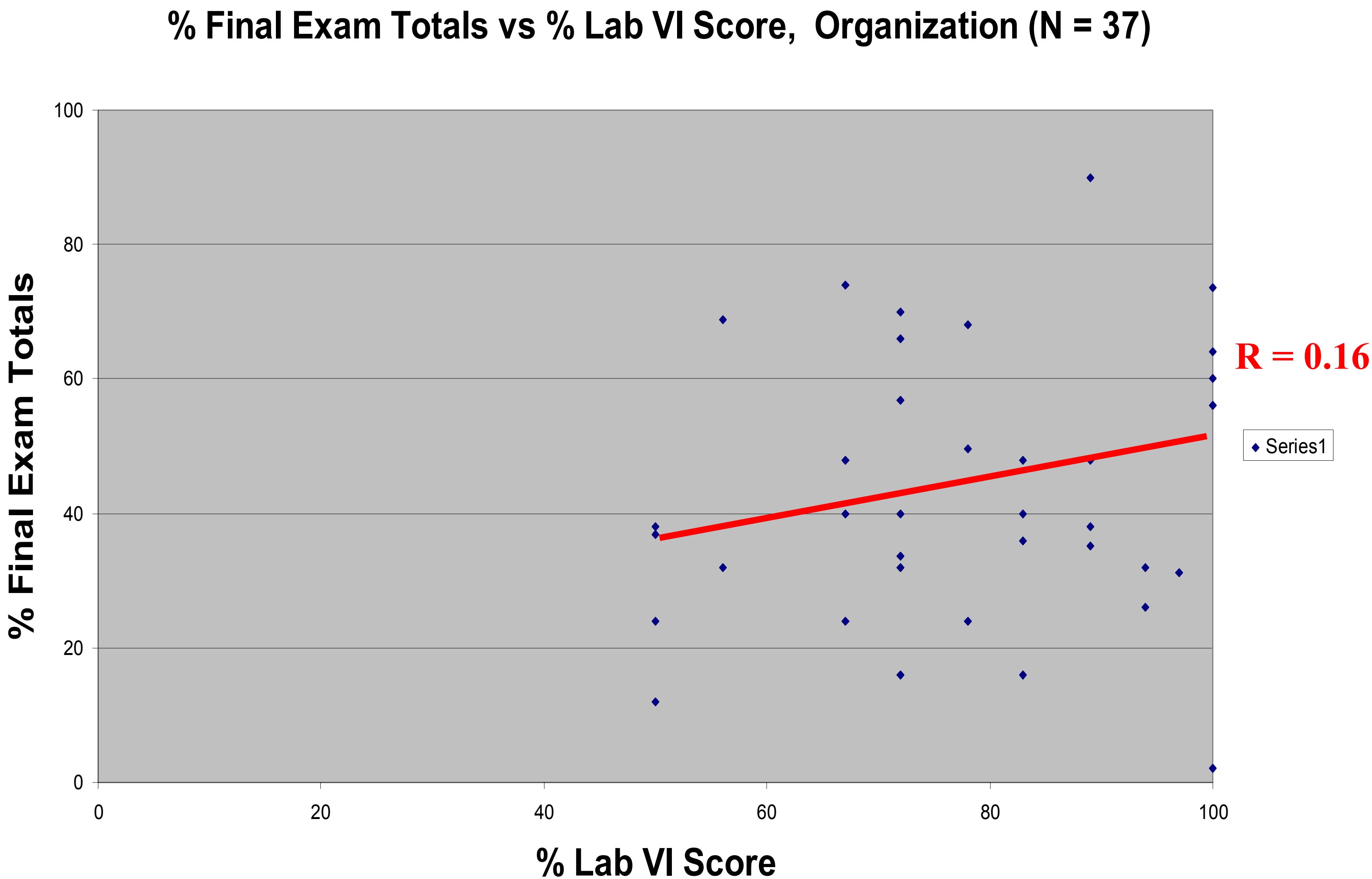
- **Illustrations or Visual Figures**
  1. Sketch or diagram of the equipment
  2. Inclusion of the graphs from LabVIEW
  3. Sketch for the prediction questions

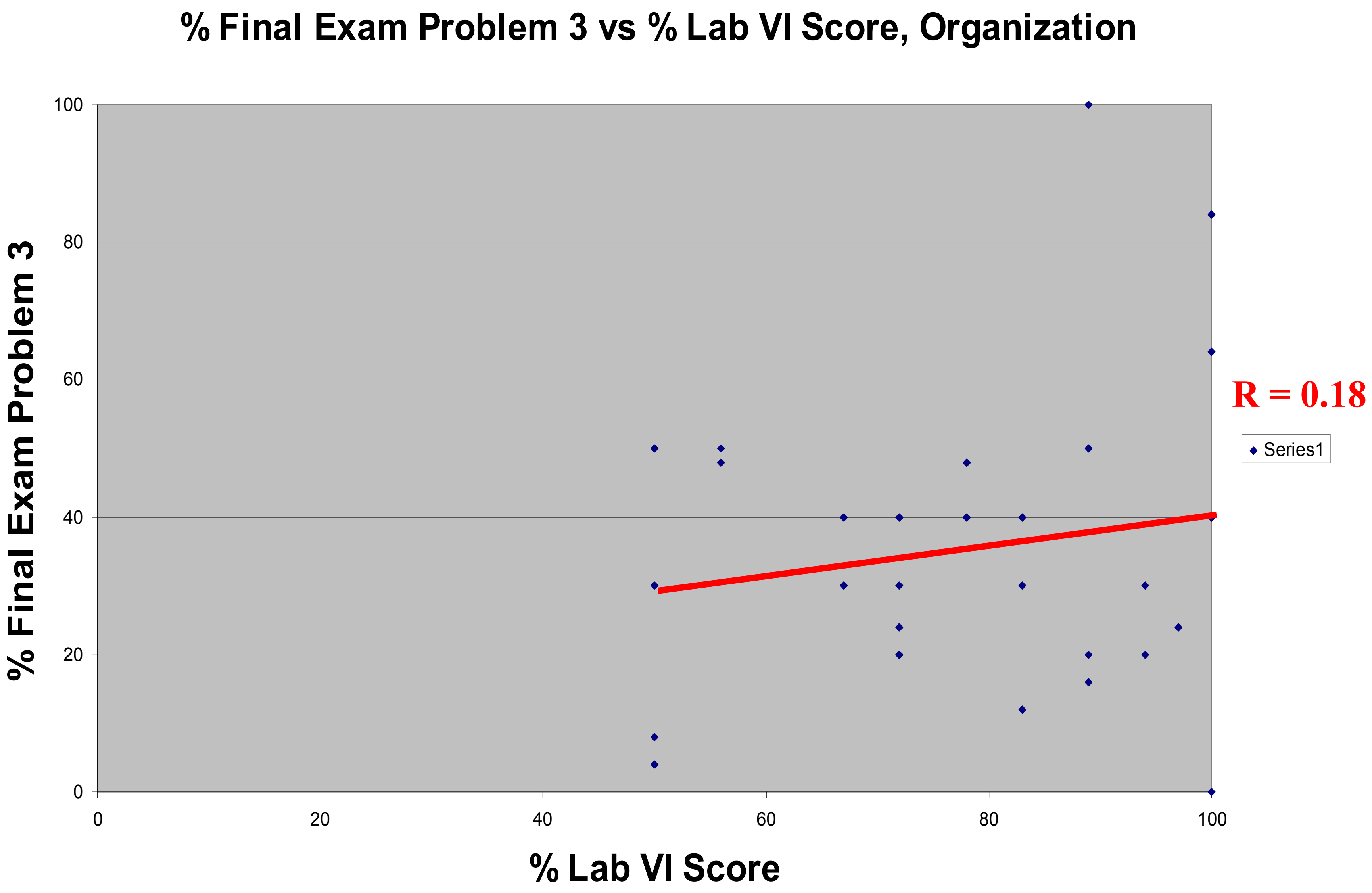
- **Relevant Data – Charts, Graphs, or Tables**
  1. Clear representation of the values for:

     a) Radius of ring b) acceleration of the string

     c) acceleration of the weight d) angular acceleration
  2. Indicates sources of above information

- **Background Information**
  1. Explains methods for obtaining numerical values
  2. Derives or explains the source or meaning of equations


% Final Exam Totals vs % Lab VI Score, Organization (N = 37)
% Final Exam Totals
100
80
60
40
20
0
0
20
40
60
80
100
% Lab VI Score
R = 0.16
Series1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% Final Exam Problem 3
% Lab VI Score
0
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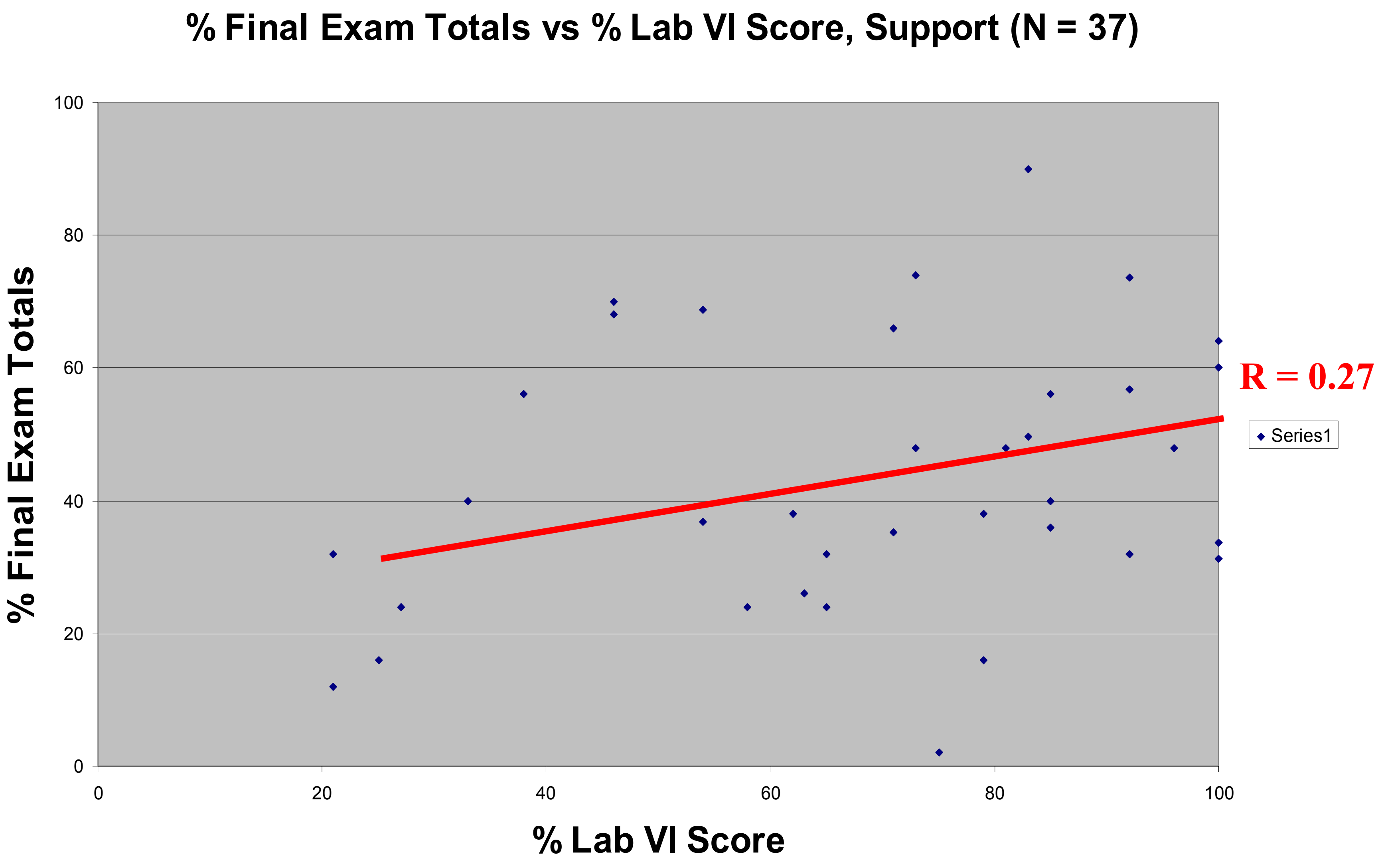
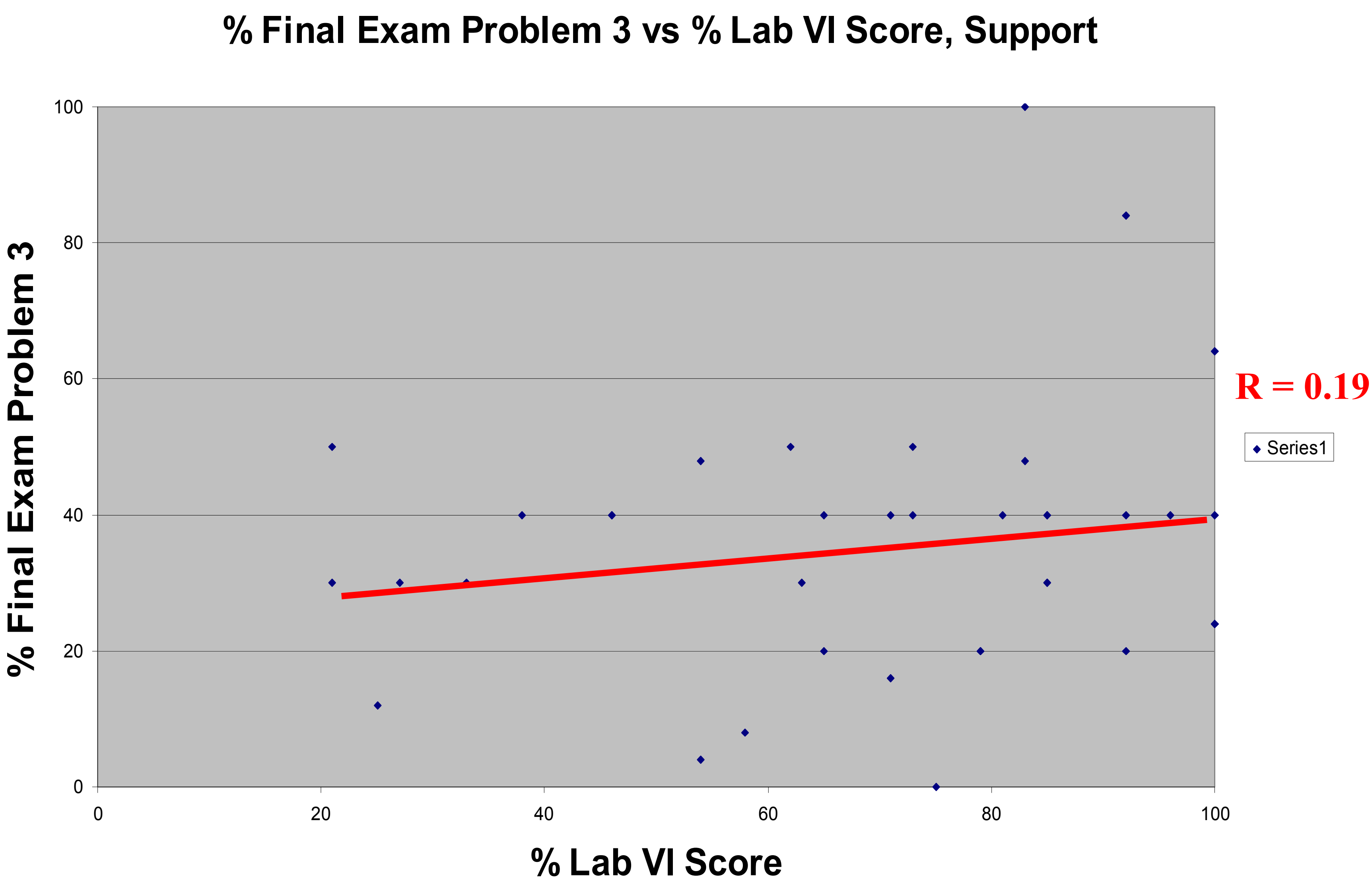
40
60
80
100
R = 0.18
Series1


% Final Exam Totals vs % Lab VI Score, Support (N = 37)
% Final Exam Totals
% Lab VI Score
R = 0.27
Series1
0
20
40
60
80
100
0
20
40
60
80
100


% Final Exam Problem 3 vs % Lab VI Score, Support
% Final Exam Problem 3
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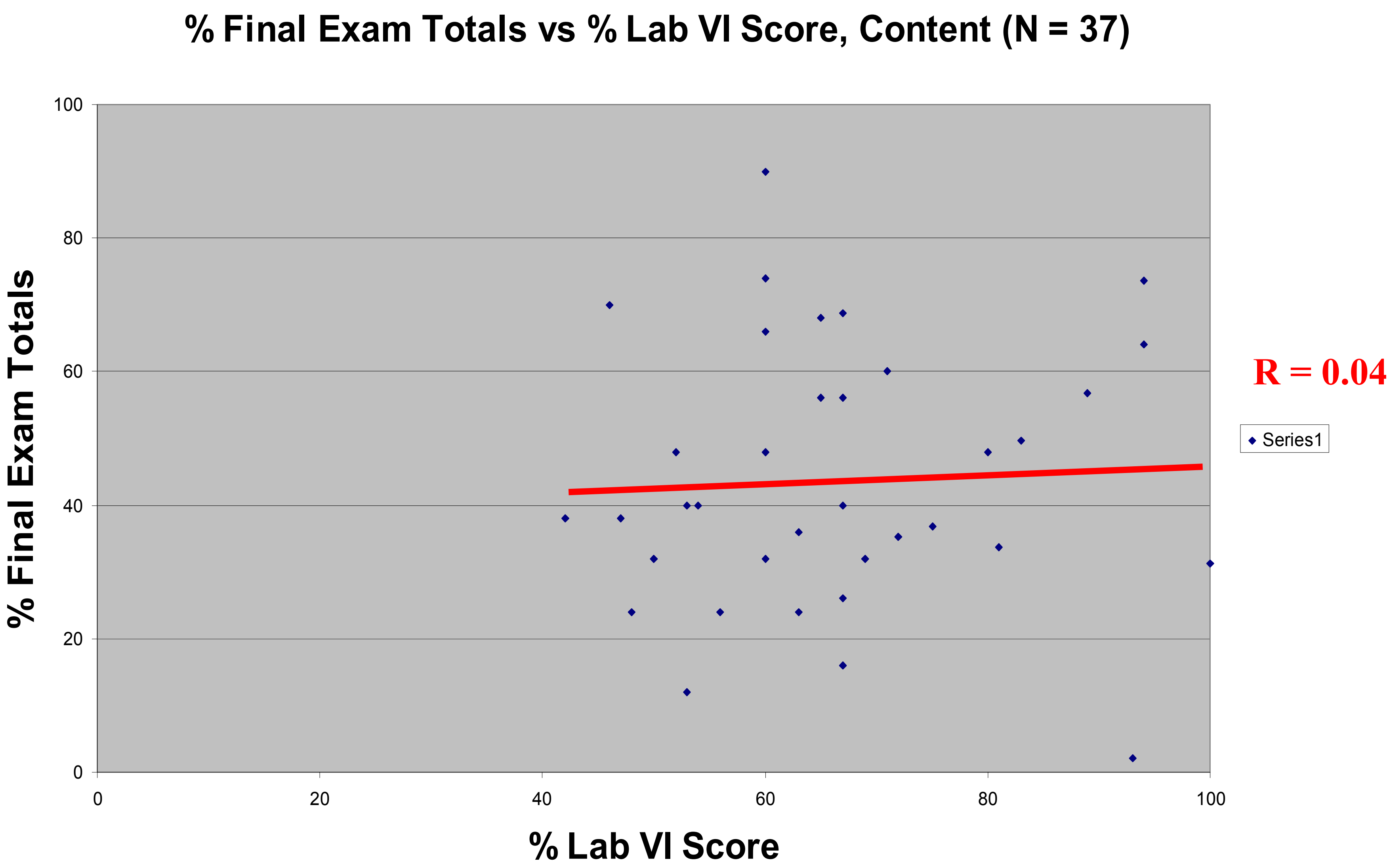
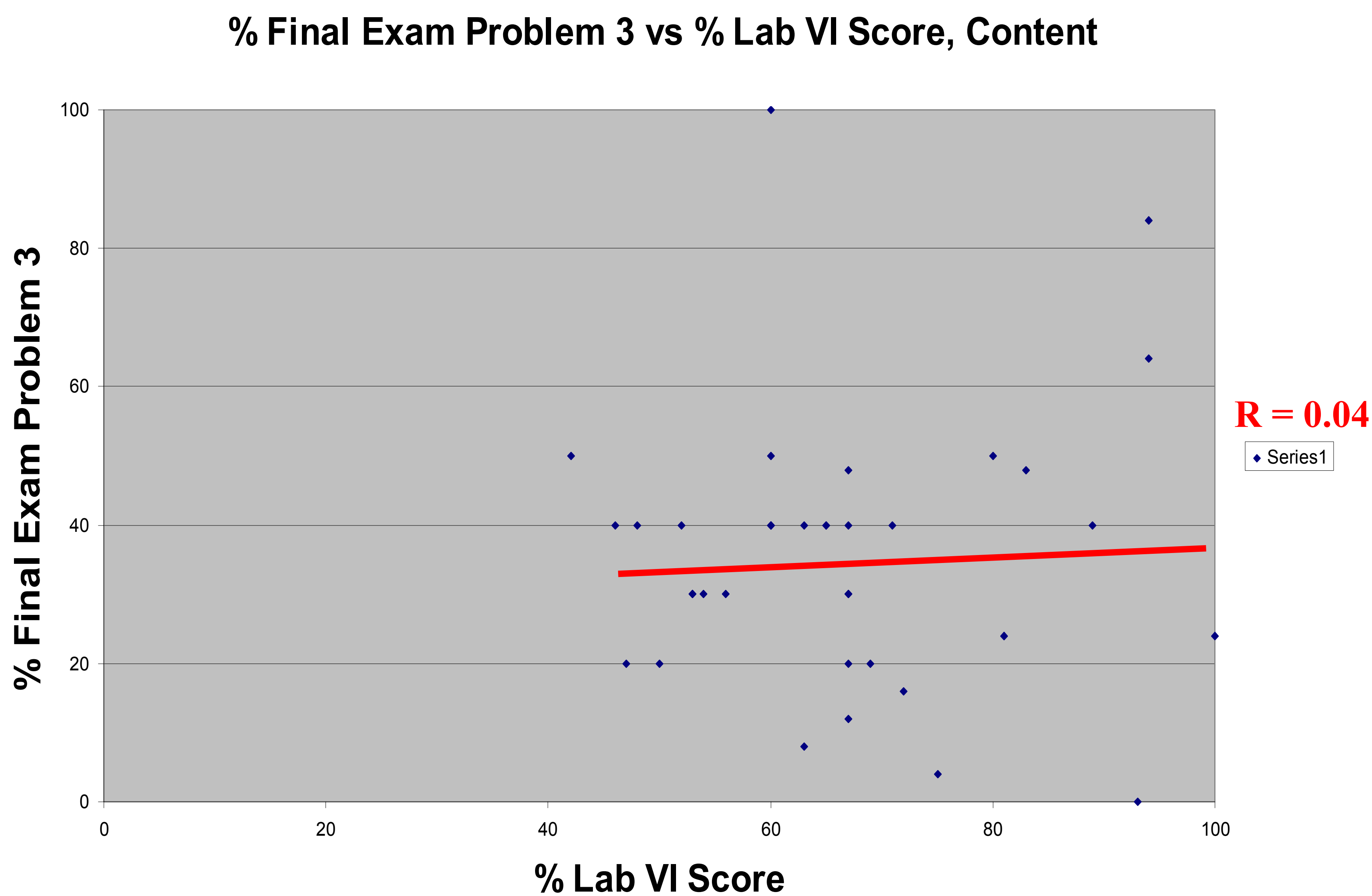
60
40
20
0
0
20
40
60
80
100
% Lab VI Score
R = 0.19
Series1


% Final Exam Totals vs % Lab VI Score, Content (N = 37)
% Final Exam Totals
% Lab VI Score
100
80
60
40
20
0
0
20
40
60
80
100
R = 0.04
Series1


% Final Exam Problem 3 vs % Lab VI Score, Content
% Final Exam Problem 3
100
80
60
40
20
0
0
20
40
60
80
100
% Lab VI Score
R = 0.04
Series1

Conclusions

Obviously there are no big correlations observed so far.

If there is a small correlation it is very difficult to see it with this small sample size (N = 37)

Next Steps

Does student success on final exam problems correlate with their success in labs as shown by their lab reports?

Examine Much Larger Sample

And Ask: Are we making the right measurements?

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