

SULE COLLEGE

HSC PHYSICS

PRACTICAL BOOKLET

S P A C E

TASK 1 (10%) WILL BE BASED ON THIS BOOKLET

NAME: _____

PHYSICS SKILLS > BOS OUTCOMES

H11. justifies the appropriateness of a particular investigation plan

11.1 identify data sources to:

- a) analyse complex problems to determine appropriate ways in which each aspect may be researched
- b) determine the type of data that needs to be collected and explain the qualitative or quantitative analysis that will be required for this data to be useful
- c) identify the orders of magnitude that will be appropriate and the uncertainty that may be present in the measurement of data
- d) identify and use correct units for data that will be collected
- e) recommend the use of an appropriate technology or strategy for data collection or information gathering that will assist efficient future analysis

11.2 plan first-hand investigations to:

- a) demonstrate the use of the terms 'dependent' and 'independent' to describe variables involved in the investigation
- b) identify variables that needed to be kept constant, develop strategies to ensure that these variables are kept constant, and demonstrate the use of a control
- c) design investigations that allow valid and reliable data and information to be collected
- d) describe and trial procedures to undertake investigations and explain why a procedure, a sequence of procedures or the repetition of procedures is appropriate
- e) predict possible issues that may arise during the course of an investigation and identify strategies to address these issues if necessary

11.3 choose equipment or resources by:

- a) identifying and/or setting up the most appropriate equipment or combination of equipment needed to undertake the investigation
- b) carrying out a risk assessment of intended experimental procedures and identifying and addressing potential hazards
- c) identifying technology that would be used during investigation determining its suitability and effectiveness for its potential role in the procedure or investigation
- d) recognising the difference between destructive and non-destructive testing of material and analysing potentially different results from these two procedures

H12. evaluates ways in which accuracy and reliability could be improved in investigations

12.1 perform first-hand investigations by:

- a) carrying out the planned procedure, recognising where and when modifications are needed and analysing the effect of these adjustments
- b) efficiently undertaking the planned procedure to minimise hazards and wastage of resources
- c) disposing carefully and safely of any waste materials produced during the investigation
- d) identifying and using safe work practices during investigations

12.2 gather first-hand information by:

- a) using appropriate data collection techniques, employing appropriate technologies, including data loggers and sensors
- b) measuring, observing and recording results in accessible and recognisable forms, carrying out repeat trials as appropriate

12.3 gather information from secondary sources by:

- a) accessing information from a range of resources, including popular scientific journals, digital technologies and the Internet
- b) practising efficient data collection techniques to identify useful information in secondary sources
- c) extracting information from numerical data in graphs and tables as well as written and spoken material in all its forms
- d) summarising and collating information from a range of resources
- e) identifying practising male and female Australian scientists, and the areas in which they are currently working and in formation about their research

12.4 process information to:

- a) assess the accuracy of any measurements and calculations and the relative importance of the data and information gathered
- b) identify and apply appropriate mathematical formulae and concepts
- c) best illustrate trends and patterns by selecting and using appropriate methods, including computer assisted analysis
- d) evaluate the validity of first-hand and secondary information and data in relation to the area of investigation
- e) assess the reliability of first-hand and secondary information and data by considering information from various sources
- f) assess the accuracy of scientific information presented in mass media by comparison with similar information presented in scientific journals

H13. uses terminology reporting styles appropriately and successfully to communicate information and understanding

13.1 present information by:

- a) selecting and using appropriate text types or combinations thereof, for oral and written presentations
- b) selecting and using appropriate media to present data and information
- c) selecting and using appropriate methods to acknowledge sources of information
- d) using symbols and formulae to express relationships and using appropriate units for physical quantities
- e) using a variety of pictorial representations to show relationships and present information clearly and succinctly
- f) selecting and drawing appropriate graphs to convey information and relationships clearly and accurately
- g) identifying situations where use of a curve of best fit is appropriate to present graphical information

H14. assesses the validity of conclusions drawn from gathered data and information

14.1 analyse information to:

- a) identify trends, patterns and relationships as well as contradictions in data and information
- b) justify inferences and conclusions
- c) identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem
- d) predict outcomes and generate plausible explanations related to the observations
- e) make and justify generalisations
- f) use models, including mathematical ones, to explain phenomena and/or make predictions
- g) use cause and effect relationships to explain phenomena
- h) identify examples of the interconnectedness of ideas or scientific principles

14.2 solve problems by:

- a) identifying and explaining the nature of a problem
- b) describing and selecting from different strategies, those which could be used to solve a problem
- c) using identified strategies to develop a range of possible solutions to a particular problem
- d) evaluating the appropriateness of different strategies for solving an identified problem

14.3 use available evidence to:

- a) design and produce creative solutions to problems
- b) propose ideas that demonstrate coherence and logical progression and include correct use of scientific principles and ideas
- c) apply critical thinking in the consideration of predictions, hypotheses and the results of investigations
- d) formulate cause and effect relationships

PHYSICS SKILLS > SIGNIFICANT FIGURES AND SCIENTIFIC NOTATION

Significant figures are critical when reporting scientific data because they give the reader an idea of how well you could actually measure/report your data.

Before looking at a few examples, let's summarize the rules for significant figures.

- 1) ALL non-zero numbers (1, 2, 3, 4, 5, 6, 7, 8, 9) are ALWAYS significant.
- 2) ALL zeroes between non-zero numbers are ALWAYS significant.
- 3) ALL zeroes which are SIMULTANEOUSLY to the right of the decimal point AND at the end of the number are ALWAYS significant.
- 4) ALL zeroes which are to the left of a written decimal point and are in a number ≥ 10 are ALWAYS significant.

Hint: A helpful way to check rules 3 and 4 is to write the number in scientific notation. If you can/must get rid of the zeroes, then they are NOT significant.

Examples: How many significant figures are present in the following numbers?

Number	# Significant Figures	Rule(s)
48,923	5	1
3.967	4	1
900.06	5	1,2,4
0.0004 (= 4 E-4)	1	1,4
8.1000	5	1,3
8 100 000 (= 8.1 E+6)	2	1
501.040	6	1,2,3,4
10.0 (= 1.00 E+1)	3	1,3,4

Rounding off

It was stated in a newspaper that the attendance at the SCG (Sydney Cricket Ground) for a football match was 64,000. But a friend who was attending the same match said the crowd was 64,492. The information from both sources is correct, but it was given to a different degree of accuracy.

64,492 might have been the exact number. When we round off 64,492 to two significant figures, it is 64,000.

Let's round off 64,492 to:

- 1 significant figure which is **60,000**
- 2 significant figures which is **64,000**
- 3 significant figures which is **64,500**
- 4 significant figures which is **64,490**
- 5 significant figures which is **64,492**

The accuracy of the answer will depend on the number of significant figures. The answer will be more accurate, if it is given to a higher number of significant figures.

64,492 is the most accurate answer and it is given to 5 significant figures.

PHYSICS SKILLS > SCIENTIFIC NOTATION

Scientific notation, also known as exponential notation, is a way of writing numbers that accommodates values too large or small to be conveniently written in standard decimal notation. Scientific notation has a number of useful properties and is often favored by scientists, mathematicians and engineers, who work with such numbers.

In scientific notation all numbers are written like this:

$a \times 10^b$ ("a times ten to the power of b")

Ordinary decimal notation	Scientific notation (normalized)
300	3×10^2
4,000	4×10^3
5,720,000,000	5.72×10^9
−0.0000000061	-6.1×10^{-9}

Other Examples

- An electron's mass is about 0.0000000000000000000000000091093822 kg. In scientific notation, this is written $9.1093822 \times 10^{-31}$ kg.
- The Earth's mass is about 5973600000000000000000 kg. In scientific notation, this is written 5.9736×10^{24} kg.
- The Earth's circumference is approximately 40000000 m. In scientific notation, this is 4×10^7 m. In engineering notation, this is written 40×10^6 m. In SI writing style, this may be written "40 Mm" (*40 megameters*).

PHYSICS SKILLS > SI (Système International) PREFIXES

10 ⁿ	Prefix	Symbol	Since	Short scale	Decimal
10 ²¹	zetta	Z	1991	Sextillion	1 000 000 000 000 000 000 000
10 ¹⁸	exa	E	1975	Quintillion	1 000 000 000 000 000 000
10 ¹⁵	peta	P	1975	Quadrillion	1 000 000 000 000 000
10 ¹²	tera	T	1960	Trillion	1 000 000 000 000
10 ⁹	giga	G	1960	Billion	1 000 000 000
10 ⁶	mega	M	1960	Million	1 000 000
10 ³	kilo	k	1795	Thousand	1 000
10 ²	hecto	h	1795	Hundred	100
10 ¹	deca	da	1795	Ten	10
10 ⁰	(none)	(none)	NA	One	1
10 ⁻¹	deci	d	1795	Tenth	0.1
10 ⁻²	centi	c	1795	Hundredth	0.01
10 ⁻³	milli	m	1795	Thousandth	0.001
10 ⁻⁶	micro	μ	1960 ^[2]	Millionth	0.000001
10 ⁻⁹	nano	n	1960	Billionth	0.000000001
10 ⁻¹²	pico	p	1960	Trillionth	0.000000000001
10 ⁻¹⁵	femto	f	1964	Quadrillionth	0.000000000000001
10 ⁻¹⁸	atto	a	1964	Quintillionth	0.000000000000000001
10 ⁻²¹	zepto	z	1991	Sextillionth	0.000000000000000000001
10 ⁻²⁴	yocto	y	1991	Septillionth	0.000000000000000000000001

PHYSICS SKILLS > ACCURACY, RELIABILITY and VALIDITY

a) ACCURACY: *Exactness or conformity to truth.*

Science texts refer to **accuracy** in two ways:

- (i) **Accuracy** of a result or experimental procedure can refer to the percentage difference between the experimental result and the accepted value. The stated uncertainty in an experimental result should always be greater than this percentage accuracy.
- (ii) **Accuracy** is also associated with the inherent uncertainty in a measurement. We can express the accuracy of a measurement explicitly by stating the estimated uncertainty or implicitly by the number of significant figures given. For example, we can measure a small distance with poor accuracy using a metre rule, or with much greater accuracy using a micrometer. Accurate measurements do not ensure an experiment is valid or reliable. For example consider an experiment for finding g in which the time for a piece of paper to fall once to the floor is measured very accurately. Clearly this experiment would not be valid or reliable (unless it was carried out in vacuum).

b) RELIABILITY: *Trustworthy, dependable.*

In terms of first hand investigations the Board seems to define **reliability** as repeatability or consistency. If an experiment is repeated many times it will give identical results if it is reliable. In terms of second hand sources reliability refers to how trustworthy the source is. For example the NASA web site would be a more reliable source than a private web page. (This is not to say that all the data on the site is valid.) The reliability of a site can be assessed by comparing it to several other sites/sources.

c) VALIDITY: *Derived correctly from premises already accepted, sound, supported by actual fact.*

A **valid** experiment is one that fairly tests the hypothesis. In a valid experiment all variables are kept constant apart from those being investigated, all systematic errors have been eliminated and random errors are reduced by taking the mean of multiple measurements. An experiment could produce reliable results but be invalid (for example Millikan consistently got the wrong value for the charge of the electron because he was working with the wrong coefficient of viscosity for air). An unreliable experiment must be inaccurate and invalid as a valid scientific experiment would produce reliable results in multiple trials.

ERRORS

The two different types of **error** that can occur in a measured value are:

Systematic error – this occurs to the same extent in each one of a series of measurements eg zero error, where for instance the needle of a voltmeter is not correctly adjusted to read zero when no voltage is present.

Random error – this occurs in any measurement as a result of variations in the measurement technique (eg parallax error, limit of reading, etc).

Consider three experimental determinations of g , the acceleration due to gravity.

Experiment A	Experiment B	Experiment C
$8.34 \pm 0.05 \text{ m/s}^2$	$9.8 \pm 0.2 \text{ m/s}^2$	$3.5 \pm 2.5 \text{ m/s}^2$

We can say that **Experiment A** is more **reliable** (or precise) than Experiment B because its relative error is smaller and therefore if the experiment was repeated we would be likely to get a value for g which is very close to the one already obtained. That is, Experiment A has results that are very repeatable (reproducible).

Experiment B, however, is much more **accurate** than Experiment A, since its value of g is much closer to the accepted value. Clearly, Experiment C is neither accurate nor reliable.

In terms of **validity**, we could say that **Experiment B** is quite valid since its result is very accurate and reasonably reliable – repeating the experiment would obtain reasonably similar results. Experiment A is not valid, since its result is inaccurate and Experiment C is invalid since it is both inaccurate and unreliable.

How do you improve the reliability of an experiment? Clearly, you need to make the experimental results highly reproducible. You need to **reduce the relative error** (or spread) in the results as much as possible. To do this you must reduce the **random errors** by: (i) using appropriate measuring instruments in the correct manner (eg use a micrometer screw gauge rather than a metre ruler to measure the diameter of a small ball bearing); and (ii) taking the mean of multiple measurements.

To **improve the accuracy and validity** of an experiment you need to keep all variables constant other than those being investigated, you must eliminate all systematic errors by careful planning and performance of the experiment and you must reduce random errors as much as possible by taking the mean of multiple measurements.

PHYSICS SKILLS > VARIABLES

Question: What's a variable?

Answer: A variable is an object, event, idea, feeling, time period, or any other type of category you are trying to measure. There are two types of variables-independent and dependent.

Question: What's an independent variable?

Answer: An independent variable is exactly what it sounds like. It is a variable that stands alone and isn't changed by the other variables you are trying to measure. For example, someone's age might be an independent variable. Other factors (such as what they eat, how much they go to school, how much television they watch) aren't going to change a person's age. In fact, when you are looking for some kind of relationship between variables you are trying to see if the independent variable causes some kind of change in the other variables, or dependent variables.

Question: What's a dependent variable?

Answer: Just like an independent variable, a dependent variable is exactly what it sounds like. It is something that depends on other factors. For example, a test score could be a dependent variable because it could change depending on several factors such as how much you studied, how much sleep you got the night before you took the test, or even how hungry you were when you took it. Usually when you are looking for a relationship between two things you are trying to find out what makes the dependent variable change the way it does.

The independent variable is typically the variable being manipulated or changed and the dependent variable is the observed result of the independent variable being manipulated.

- Independent variables answer the question "What do I change?"
- Dependent variables answer the question "What do I observe?"
- Controlled variables answer the question "What do I keep the same?"

Examples

Example 1

A group of college students were given a short course in speed-reading. The instructor was curious if a monetary incentive would influence performance on a reading test taken at the end of the course. Half the students were offered \$5 for obtaining a certain level of performance on the test, the other half were not offered money.

Variables Independent variable: Monetary incentive (\$5 or no money)
 Dependent variable: Performance on reading test

Groups Experimental group: \$5 group (receive monetary incentive)
 Control group: \$0 group (no monetary incentive)

Example 2

A social psychologist thinks that people are more likely to conform to a large crowd than to a single person. To test this hypothesis, the social psychologist had either one person or five persons stand on a busy walking path on campus and look up. The psychologist stood nearby and counted the number of people passing by who also looked up.

Variables Independent variable: Size of group (5 people or 1 person)
 Dependent variable: Conformity (measured by number of people looking up)

Groups Experimental group: People passing 5 person group
 Control group: People passing single person.
 (This group gets "less" of the independent variable)

Example 3

To test a new voice feature in a cockpit design a flight simulator was used. The simulator was programmed to give visual readings of flight information, or to give visual and auditory (voice) readings of flight information. All test pilots were put through a simulated emergency landing procedure, but were randomly assigned to

the visual, or visual and auditory conditions. Flight experts rated each pilot's performance in the simulator on a scale of 1 (very poor) to 10 (excellent).

Variables Independent variable: Presence or absence of auditory (voice) readings.
 (All pilots received visual readings, so that is a constant variable.)
 Dependent variable: Ratings of pilots' performance

Groups Experimental group: Pilots in auditory readings condition (visual + auditory)
 Control group: Pilots in visual reading only condition (no auditory)

Example 4

I want to know if a common plant will grow better in light of one color than it will in light of other colors. I am going to manipulate the color of the light that several test plants will be exposed to. Light color is the Independent Variable. The growth of the plants during the experiment is the Dependent Variable. Amount of plant growth will (it is theorized) depend on the different colored light that plants will be exposed to. Of course, there are many variables that will have to be controlled (the control variables). Plants should start out at the same or very similar size and age, soil and water conditions will have to be kept constant as will temperature and humidity, etc.

Example 5

For example concerning nutrition, the independent variable of your daily vitamin C intake (how much should I take) can determine the dependent variable of your life span (what is the result or observation as a result of manipulating the 'independent variable'). Scientists will manipulate the vitamin C intake in a group of lets say 100 people who are over the age of 65. Half of the group, 50 people will be given a daily high dose of vitamin C (lets say 2000 mg) and 50 people will be given a placebo pill (no vitamin C dose or a pill with zero vitamin C) over a period of 25 years. The scientists will log the life span of the 100 people to see if there is any statistically significant change in the life span of the people who took the high dose and those who took the placebo (no dose). The goal is to see if the independent variable of high vitamin C dosage affects the dependent variable of people's life span.

1

USING PENDULUM TO DETERMINE “g”

“What is “g” in Sule College?”

Date:

Group Members:

BOS Syllabus Reference

“Students perform an investigation and gather information to determine a value for acceleration due to gravity using pendulum motion or computer-assisted technology and identify reasons for possible variations from the value 9.8 m/s^2 .”

Aim

To determine the rate of acceleration due to gravity using the motion of a pendulum.

Apparatus

retort stand
boss head and clamp
approximately 1 metre of string
50 g mass carrier or pendulum bob
Stopwatch
metre rule

Theory

When a simple pendulum swings with a small angle, the mass on the end performs a good approximation of the back-and-forth motion called *simple harmonic motion*. The period of the pendulum, that is, the time taken to complete a single full back-and-forth swing, depends upon just two variables: the length of the string and the rate of acceleration due to gravity. The formula for the period is as shown below:

$$T = 2\pi \sqrt{\frac{l}{g}}$$

where T = period of the pendulum (s)
 l = length of the pendulum (m)
 g = rate of acceleration due to gravity (m/s^2).

Method

1. Set up the retort stand and clamp on the edge of a desk as shown in figure 1.7. Tie on the string and adjust its length to about 90 cm before attaching the 50 g mass carrier or pendulum bob to its end.
2. Using the metre rule, carefully measure the length of the pendulum from the knot at its top to the base of the mass carrier. Enter this length in your results table.
3. Set the pendulum swinging gently (30° maximum deviation from vertical) and use the stopwatch to time 10 complete back-and-forth swings. Be sure to start and stop the stopwatch at an extreme of the motion rather than somewhere in the middle. Enter your time for 10 swings in the results table.
4. Repeat steps 2 and 3 at least five times, after shortening the string by 5 cm each time.

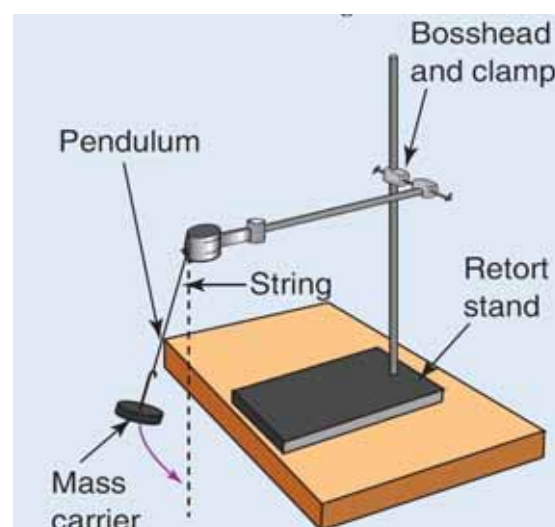


Figure 1.7 Apparatus for practical activity 1.1

Results

Record your results in the data table provided, and then complete the other columns of information.

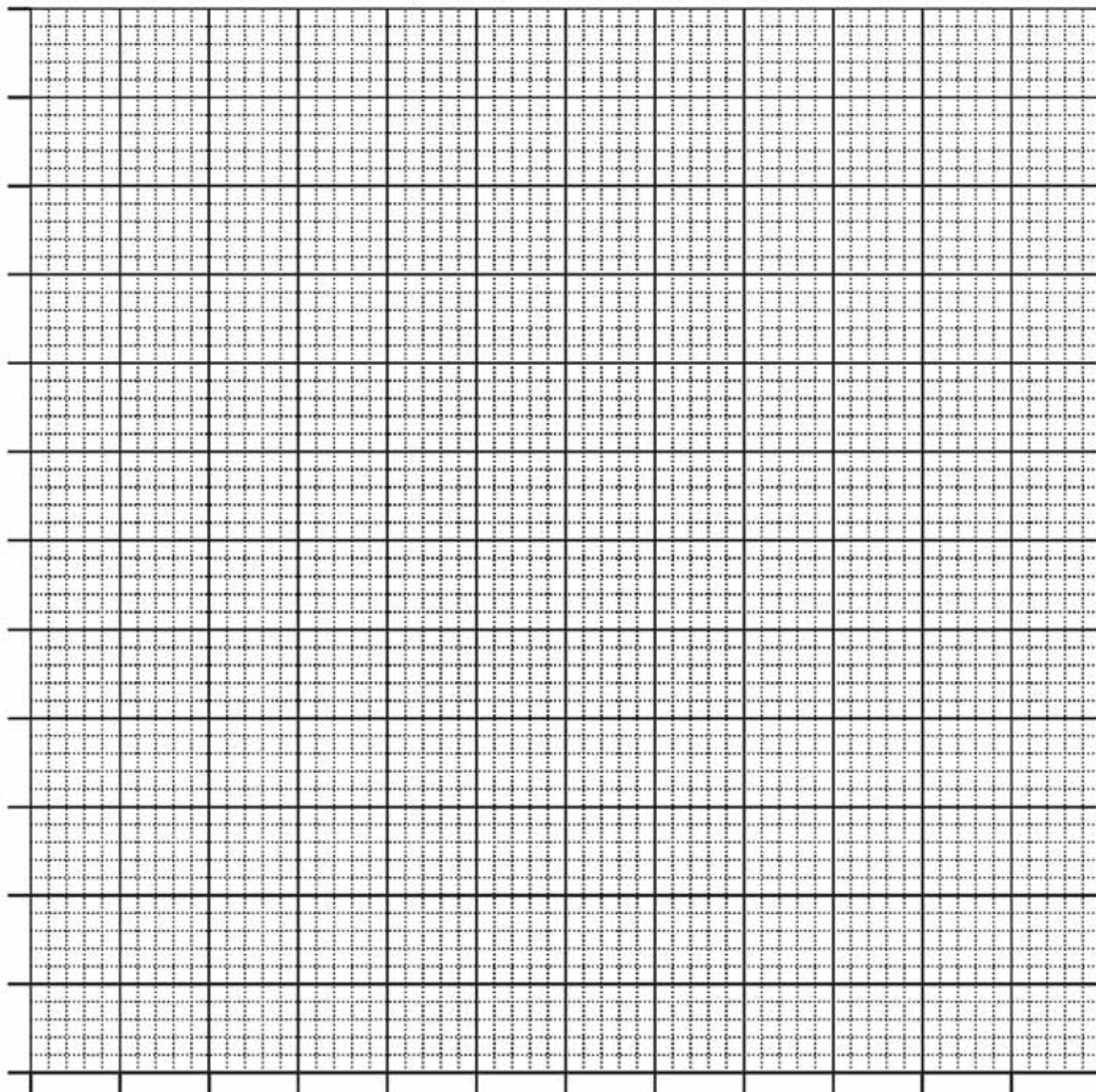
Trial number	Length of the Pendulum, l (m)	Time for 10 oscillations (s)			Period, T (s)	Period squared, T^2 (s^2)	
1							
2							
3							
4							
5							
6							
7							
8							

Variables

List the variables of this investigation

Independent	Dependent	Control

Draw a graph of period squared versus length of the pendulum. Plot T^2 on the vertical axis and length on the horizontal axis.



Analysis

1. Your graph should display a straight-line relationship. Draw a line of best fit and evaluate the gradient.
2. Rearrange the pendulum equation given earlier to the form, $T^2 = k/l$, where k is a combination of constants.

3. Compare this formula with the general equation for a straight line: $y = kx$. This comparison shows that if T^2 forms the y -axis and length, l , forms the x -axis, the expression you derived for k in step 2 should correspond to the gradient of the graph you have drawn. Write down your expression:

gradient = _____ (complete).

4. Use your expression to calculate a value for g , the acceleration due to gravity.

Questions

1. This method usually produces very accurate results. Can you suggest a reason why it should be so reliable?

2. What are the sources of error in this experiment?

3. What could you do to improve the method of this experiment to make it even more accurate?

4. Why did we draw the graph and work on the gradient rather than finding “g” from the formula for each trial and then taking the average?

2

WEIGHT VALUES IN THE SOLAR SYSTEM AND “g”

BOS Syllabus Reference

“gather secondary information to predict the value of acceleration due to gravity on other planets”

“analyse information using the expression $F = mg$ to determine the weight force for a body on Earth and for the same body on other planets”

Aim

To research g and weight values throughout the solar system.

Theory

The value of g on the surface of a planet depends upon the mass of the planet and its radius. The equation relating these variables is?

$$g = G \frac{m_{\text{planet}}}{r_{\text{planet}}^2}$$

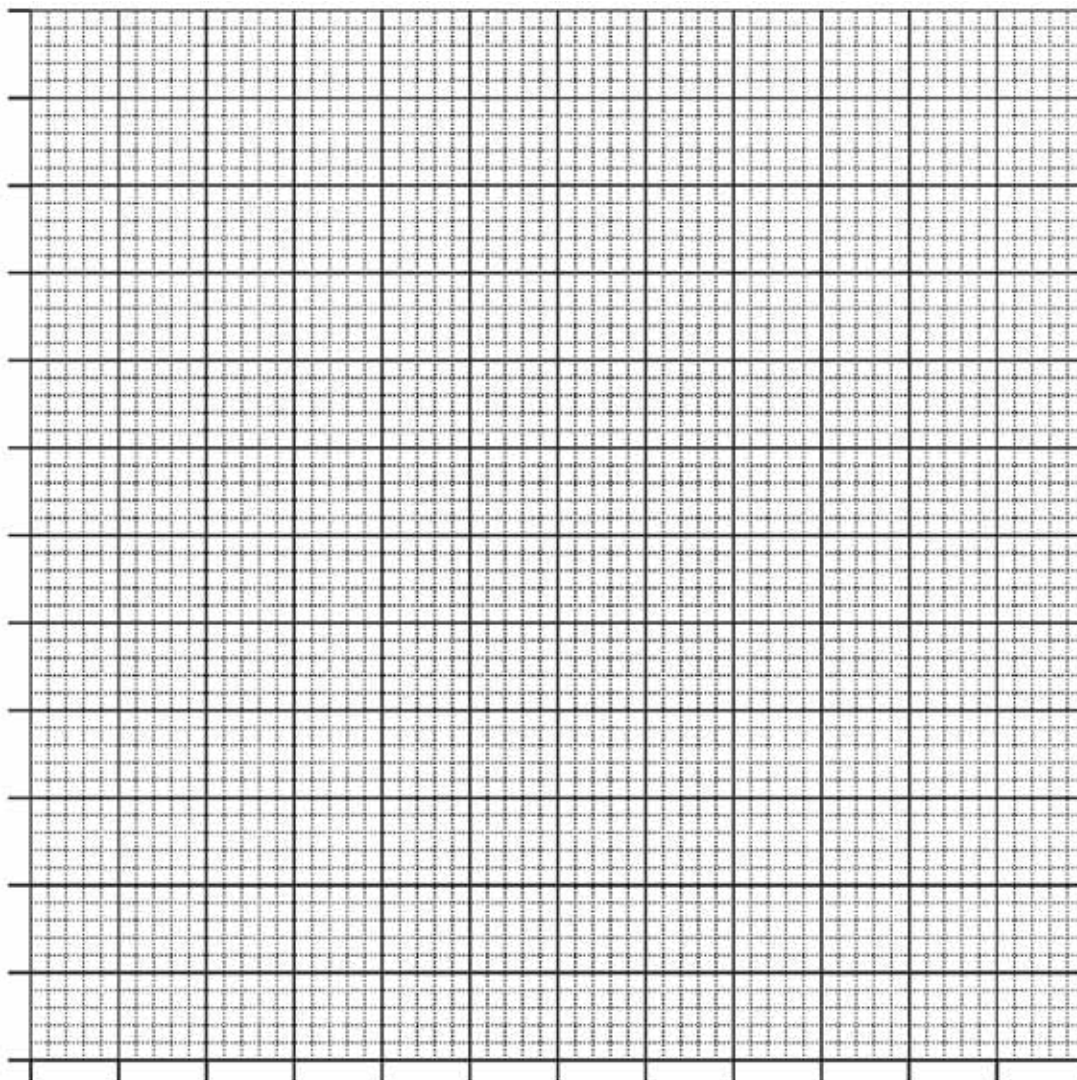
Method

The table below lists the 16 most massive objects in our solar system, excluding the Sun, in descending order of mass. However, the mass values and radii have not been provided. Conduct research to determine these figures and then perform the calculations to complete the table as shown.

Body	Centre of Orbit	Mass (kg)	Radius (km)	“g” on surface (m/s ²)	Weight of 100 kg person on surface (N)
Jupiter	Sun				
Saturn	Sun				
Neptune	Sun				
Uranus	Sun				
Earth	Sun				
Venus	Sun				
Mars	Sun				
Mercury	Sun				
Ganymede	Jupiter				
Titan	Saturn				
Callisto	Jupiter				
Io	Jupiter				
Moon	Earth				
Europa	Jupiter				
Triton	Neptune				
Pluto	Sun				

Analysis

Draw a bar graph of your results, with the bodies in their mass order along the horizontal axis, and acceleration due to gravity on the vertical axis. You may be surprised at some of the results.



Questions

1. How does g on Jupiter compare with the rest of the plotted results?

2. How does g on Saturn, Neptune, Uranus and Venus compare with g on Earth?

3. How does g on Uranus compare with g on Venus?

4. How does g on Mars compare with g on Mercury?

5. How does g on all of the natural satellites (moons) listed compare with g on Pluto?

6. There is some debate over whether Pluto should be downgraded in official status from a 'planet'. Can you provide one good argument?
7. g of Earth and Neptune are very close even though Neptune is much more massive than Earth. Suggest a reason for this.
8. Pulsars are extremely dense corpses of big stars. Estimate g on the surface (!) of a typical neutron star if it is as small as Charon, the partner of Pluto and three times as massive as Sun.
9. List your resources. Assess the accuracy and reliability of your information.

3

SPACE EXPLORATION AND ROCKET SCIENCE PIONEERS

BOS Syllabus Reference

"identify data sources, gather, analyse and present information on the contribution of one of the following to the development of space exploration: Tsiolkovsky, Oberth, Goddard, Esnault-Pelterie, O'Neill or von Braun"

Read the following data from your textbook

The Chinese discovered gunpowder and used it to create fireworks. By the eleventh century, the Chinese were using simple rockets called *fire arrows* as weapons. In the late 1700s a British artillery officer, William Congreve, developed simple rockets for use by the British army. The Hale rockets followed 50 years later. Despite all of this, modern rocket science didn't begin in earnest until the late 1800s and early 1900s. Listed here are some of the most notable pioneers.

- Konstantin Tsiolkovsky (1857–1935) was a Russian mathematics teacher who took an interest in rocketry, being inspired by Jules Verne's book *From the Earth to the Moon*. Working entirely on his own, he developed precise calculations for space flight and the details of many aspects of rocket design and space exploration. His work was purely theoretical as he performed no experiments, but his published work influenced rocket development around the world, especially in Russia. His ideas were wide ranging — from the very pragmatic, such as the design of a liquid-fuel rocket engine featuring throttling capability and multi-staging, to the (then) fanciful, such as space stations and artificial gravity, terraforming of other planets and extraterrestrial life. He was the inspiration for men such as Sergei Korolev (1906–1966) who was the Russian Chief Constructor responsible for *Sputnik 1* and the Vostok rocket. *Sputnik 1* was the world's first artificial satellite, while the Vostok rocket was used to send Yuri Gagarin into a single orbit of the Earth on 12 April 1961. This was the first time that a person had entered space.
- Robert H. Goddard (1882–1945) was an American college professor of physics with a passion for rocketry. Also inspired by Jules Verne as a boy, Goddard decided early to dedicate his life to rocketry. Unlike Tsiolkovsky, Goddard was an engineer and an experimentalist. He conceived ideas then tested them, patenting those that were successful. He built and tested the world's first liquid-fuel rocket, which solved many technical problems such as fuel valving for throttle, start and stop, fuel injection, engine cooling and ignition. He was the first to use gyroscopes and vanes for guidance, and to separate the payload from the rocket in flight and return it to Earth.
- Herman Oberth (1894–1992) was born in Romania but lived in Germany. Purely a theorist, he was yet another inspired by Jules Verne. He wrote a doctoral thesis titled *By Rocketry to Space*. Although the University of Heidelberg rejected the thesis, he had the work published privately as a book. It promptly sold out. The subject of rocketry captured the public's imagination and Oberth was himself inspiring a new generation of rocket scientists. He was an early member of the VfR, or Society for Space Travel, and published another book titled *The Road to Space Travel*. This work won an award and Oberth used the prize money to purchase rocket motors for the VfR, assisting its development efforts. One of those inspired by Oberth was Wernher von Braun (1912–1977) who became the rocket engineer responsible for the development of the V2 rocket, which was used to bomb London during World War II, and later the Mercury-Redstone rocket which put the first Americans into space.
- Robert Esnault-Pelterie (1881–1957) was a French rocket pioneer. He published two important books — *Astronautics* in 1930 and *Astronautic Complement* in 1934. He suggested the idea that rockets be used as long-range ballistic missiles, and the French Army employed him to develop these rockets. He experimented with various liquid fuels in rocket motors of his design, starting with liquid oxygen and gasoline, then nitrogen peroxide and benzene, before attempting liquid oxygen and tetranitromethane. This last combination caused him a major hand injury.
- Theodore von Karman (1881–1963) was born in Hungary but later settled in America. In the 1930s he became a professor of aeronautics at Caltech. There he established the 'Jet Propulsion Laboratory' dedicated to rocket work. The JPL still exists today, working closely with NASA and specialising in exploration of the solar system by space probe.

[illegible]

4

MODELLING PROJECTILE MOTION

Date:

Group Members:

BOS Syllabus Reference

“perform a first hand investigation, gather information and analyse data to calculate initial and final velocity, maximum height reached, range and time of flight of a projectile for a range of situations by using simulations, data loggers and computer analysis”

Aim

To model projectile motion by studying the motion of a ball bearing projected onto an inclined plane.

Apparatus

- 30 cm x 30 cm board
- retort stand and clamp
- carbon paper
- ball bearing
- graph paper
- 30 cm ruler (the ramp)

Theory

Galileo found that he could slow down the action of acceleration due to gravity by rolling a ball down a slope. In this way things happened slow enough for him to observe them. We are going to use that same strategy to slow down a projectile motion by projecting a ball bearing across an inclined plane. Recall that projectile motion can be considered as the addition of two linear motions at right angles to each other — the horizontal, constant velocity motion and the vertical, constant acceleration motion.

In the horizontal motion: $x = u_x t$

In the vertical motion: $y = u_y t + \frac{1}{2} a_y t^2$

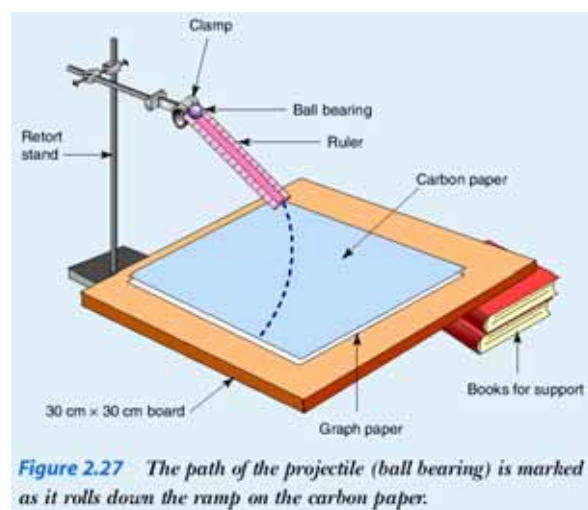
but we will let $u_y = 0$

Thus $y = \frac{1}{2} a_y t^2$

We will assume that frictional forces can be neglected.

Method

1. Set up the apparatus as shown in figure 2.27.
2. Set up the inclined plane at an angle of approximately 20° and place the graph paper on it so that the ball will enter onto the inclined plane at a major division on the paper.
3. Clamp the ruler so that the ball bearing rolling from it onto the inclined plane will be projected horizontally. Adjust the angle of the ruler so the path of the ball bearing will fit on the graph paper.
4. Having adjusted the apparatus, place a piece of carbon paper on the graph paper and record the motion of the ball bearing projected onto the inclined plane.
5. Remove the carbon paper and highlight the path for easier analysis.
6. We will assume that the horizontal velocity of the ball bearing's motion remained constant. Therefore, the ball bearing took equal times to travel horizontally between the major divisions on the graph paper. Thus we can arbitrarily call one of these major divisions a unit of time. Beginning at the point where the ball entered the graph paper, label these major divisions 0, 1, 2, 3 . . . time intervals.
7. Stick the A4 size copy of the original data paper on the next page.



YOUR
DATA
SHEET
COMES
HERE

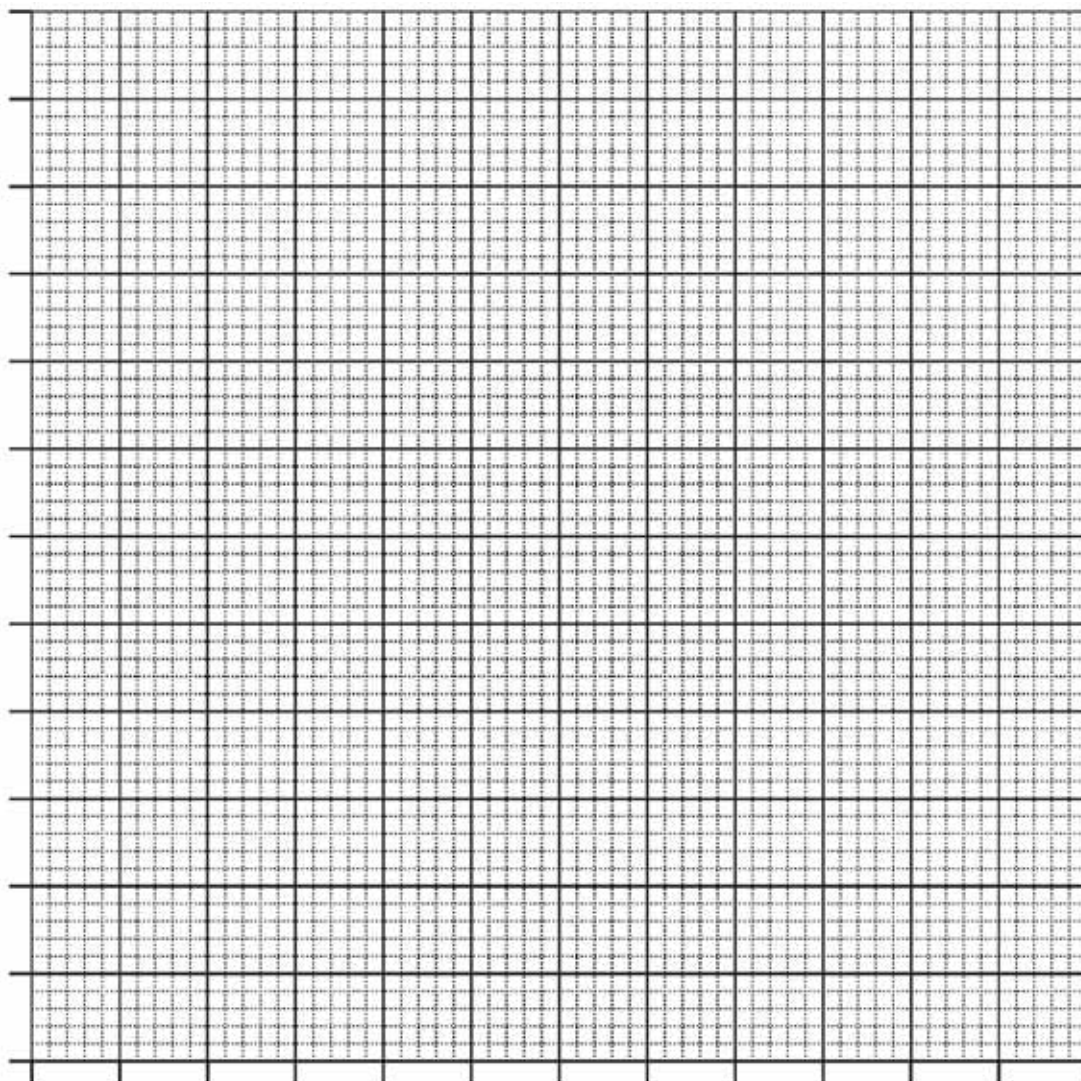
Analysis

1. Record and tabulate the distance down the slope that the ball bearing travelled during each time interval.
2. Determine the average speed of the ball bearing down the slope during each time interval. Your answers should be in cm per time unit.

Fill in the data table

Time interval	1	2	3	4	5	6	7	8	9	10
Duration (unit of time)	1 unit of time									
Vertical distance (cm)										
Average vertical velocity (cm/unit of time)										

3. Plot a graph of average speed down the slope versus time and determine a value for the acceleration of the ball down the slope. Your answer will be in cm per (time unit)².



Variables

List the variables of this investigation

Independent	Dependent	Control

Questions

1. What do these graphs indicate about the motion of the ball down the plane?

2. What assumptions have been made in order to obtain these results?

3. How would the path of the ball bearing differ if:

(a) the inclined plane was raised to a steeper angle while keeping the ramp as it was?

(b) the angle of the ramp was raised and the inclined plane was kept as it was?

4. The ball moves faster across the bottom of the paper than across the top, which represents an increase in kinetic energy. What is the source of this extra energy? Try to find out why the rolling mass of the ball introduces a problem into this energy conversion.

5

INVESTIGATING CIRCULAR MOTION

Date:

Group Members:

BOS Syllabus Reference

“solve problems and analyse information to calculate the centripetal force acting on a satellite undergoing uniform circular motion about the Earth using”

$$F = \frac{mv^2}{r}$$

Aim

To examine some of the factors affecting the motion of an object undergoing uniform circular motion, and then to determine the quantitative relationship between the variables of force, velocity and radius.

Apparatus

rubber stopper	glass tube
50 g mass carrier	stopwatch
string	sticky tape
metre rule	50 g slot masses

Theory

Recall that the expression for the centripetal force that causes circular motion is as follows:

$$F_C = \frac{mv^2}{r} \text{ where}$$

F_C = centripetal force (N)

m = mass of object in motion (kg)

v = instantaneous velocity of mass (m/s)

r = radius of circular motion (m).

In this experiment, the centripetal force is provided by the weight of some masses hanging on a mass carrier, so that here:

$$F_C = m_c g \text{ where}$$

m_c = mass of mass carrier + masses (kg) g = acceleration due to gravity = 9.8 m/s²

You should also recall the relationship between the period of an object in circular motion and its orbital velocity:

$$T = \frac{2\pi r}{v} \text{ where}$$

T = period (s)

r = radius of motion (m)

v = orbital velocity (m/s)

Method

1. Record the mass of the rubber stopper being used as a bob.
2. Attach the rubber stopper to a length of string approximately 1.5 m long, then thread the loose end of the string through the glass tube.
3. Attach the mass carrier to the loose end of the string as shown in Figure 3.12.
4. Place a piece of sticky tape on the string at the point shown in Figure 3.12 so that the distance, r , is 40 cm.

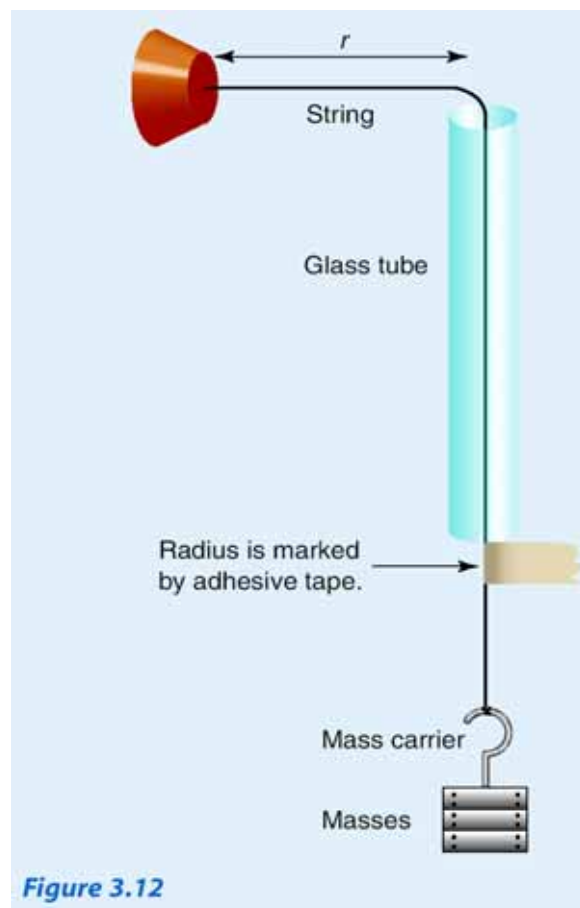


Figure 3.12

5. Hold the glass tube and move it in a small circle so as to get the rubber bob moving in a circular path. The mass carrier will provide the centripetal force to keep the bob moving in its circular path. Adjust your frequency of rotation so that the sticky tape just touches the bottom of the glass tube. This will keep the radius of the bob's orbit steady.
6. Record the time for the bob to complete 10 revolutions at a constant speed then calculate and record the period. Do this three times and then use the average of these as the correct period. Use the radius and period to calculate the orbital velocity of the bob.
7. Repeat steps 4 to 6 for radii of 0.55 m, 0.70 m, and 0.85 m.
8. Repeat steps 3 to 7 using masses of 100 g and then 150 g.

Results

Tabulate your results as shown in the table below.

Force (the weight of ...)	Radius (m)	Time for 10 revolutions (s)			Mean Period (s)	Orbital Velocity (m/s)
50 gram						
100 gram						
150 gram						

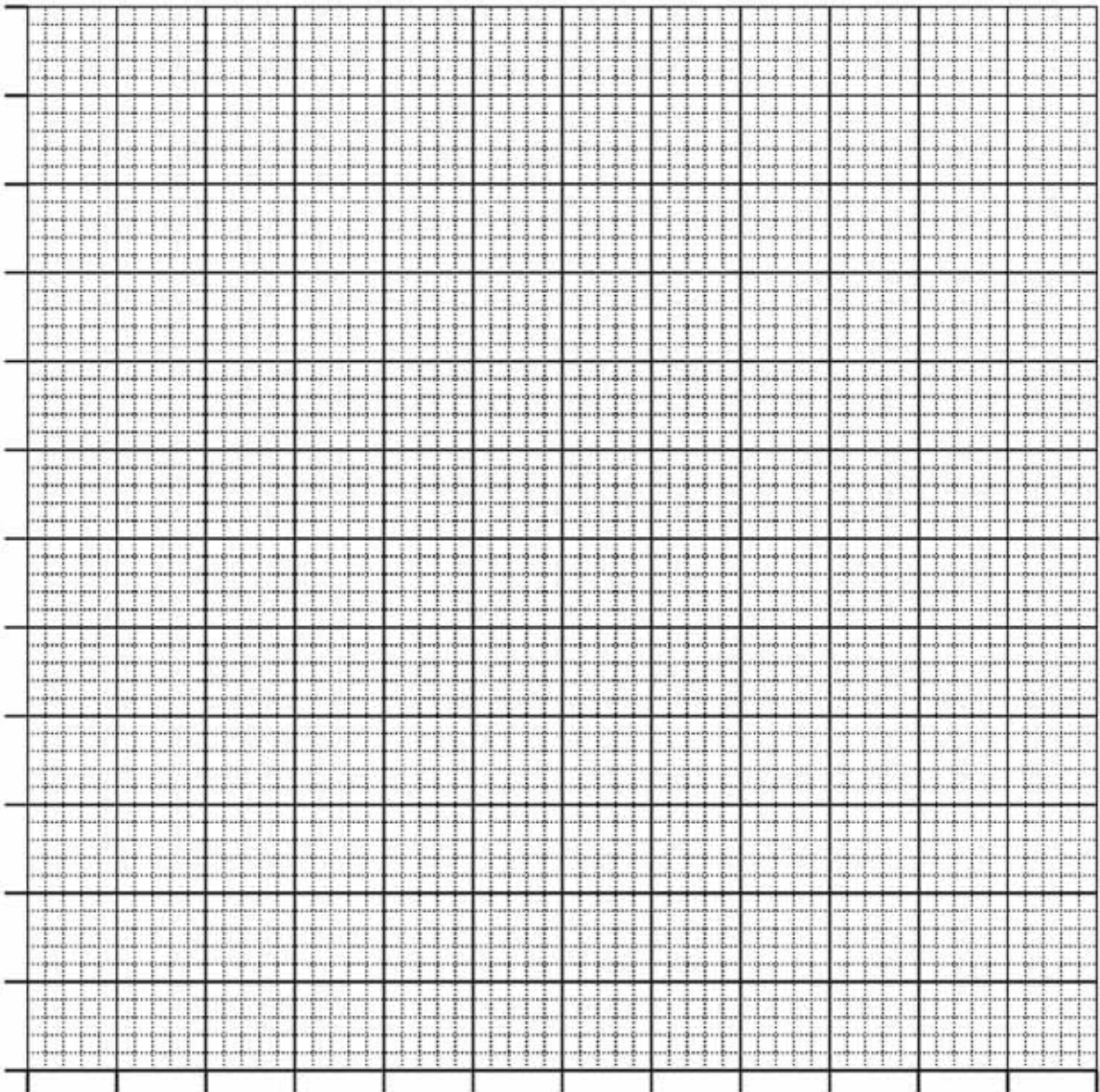
Variables

List the variables of this investigation

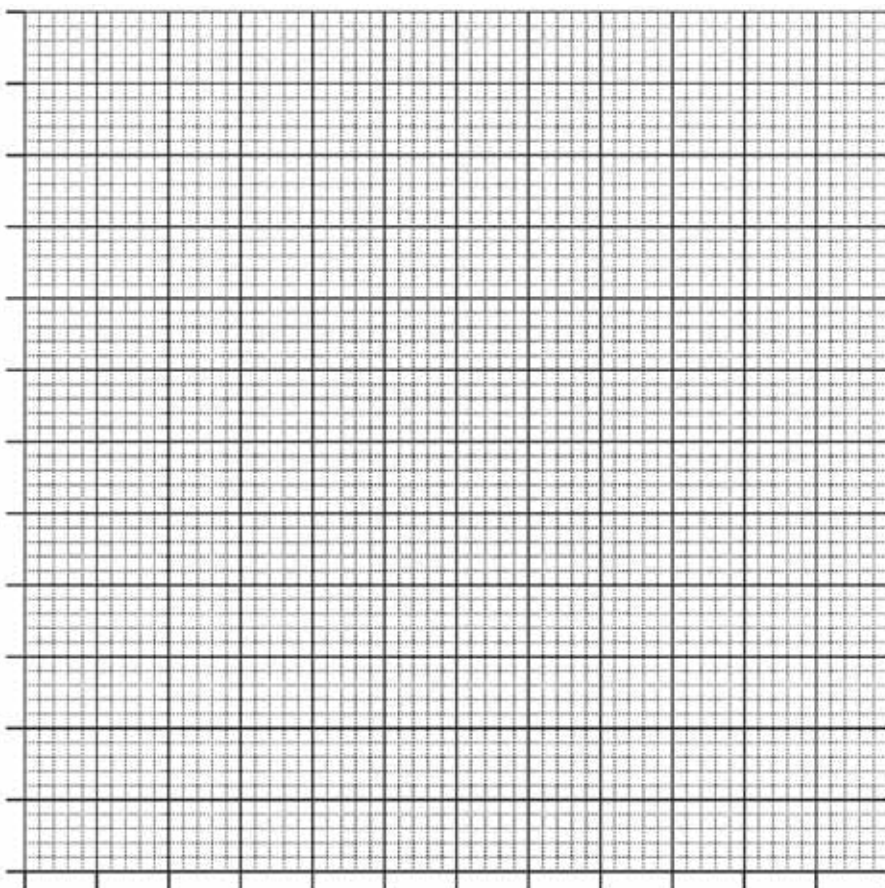
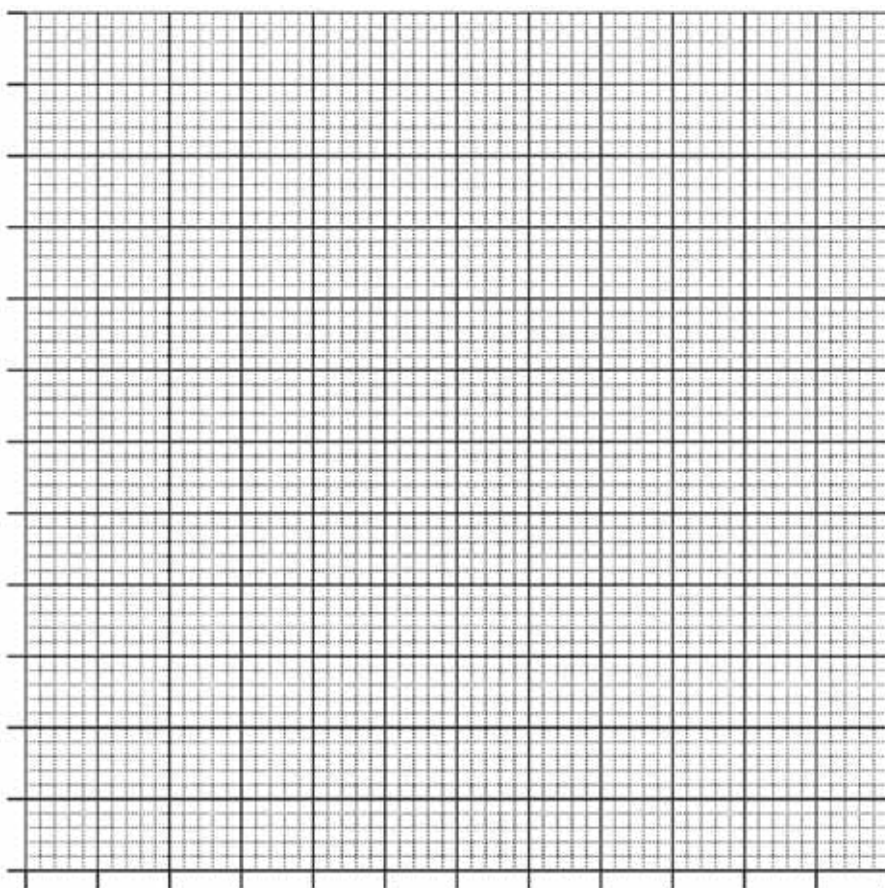
Independent	Dependent	Control

Analysis

- 1. From the results above, calculate the orbital velocity of the bob and complete the table.
- 2. For each of the radii used with 50 g, construct a graph of v^2 versus r .



3. Repeat this for the 100 g and 150 g results.



Questions

1. What is the relationship that these graphs indicate?
2. What does the slope of your v^2 versus r graph represent?
3. What role does gravity play in the results in this experiment?
4. If you are asked to find the mass of the rubber stopper how would you do it? Explain your method and then find the mass of the rubber stopper by using this method.
5. Carry out a risk assessment of intended experimental procedures and identify and address potential hazards in this investigation.