Student Master Copies

Let's Get It Straight

Name _____
Date _____

A Tool from the Mathematical Toolbox

Part I

The equation of a line can be expressed as $y = mx + b$ where x and y are the coordinates of any point on the line, m is the value of the slope of the line and b is the value of the where the line crosses the y-axis (the y-intercept).

Exercise I

The following chart allows you to practice rearranging equations in x and y to determine algebraically the slope and y-intercept. Complete the chart. The first one is done for you.

	Expression	Solved for y	Slope	y-intercept
Example	$4H = 2y - ax$	$y = \frac{a}{2}x + 2H$	$m = \frac{a}{2}$	$b = 2H$
a)	$10 = 2y + x$			
b)	$y = 5 + knx$			
c)	$x = 2ay$			
d)	$A = 2By + 4B^2x$			
e)	$k = \sqrt{\frac{px - ny}{a}}$			

Part II

To calculate the value of the slope, the following formula can be used:

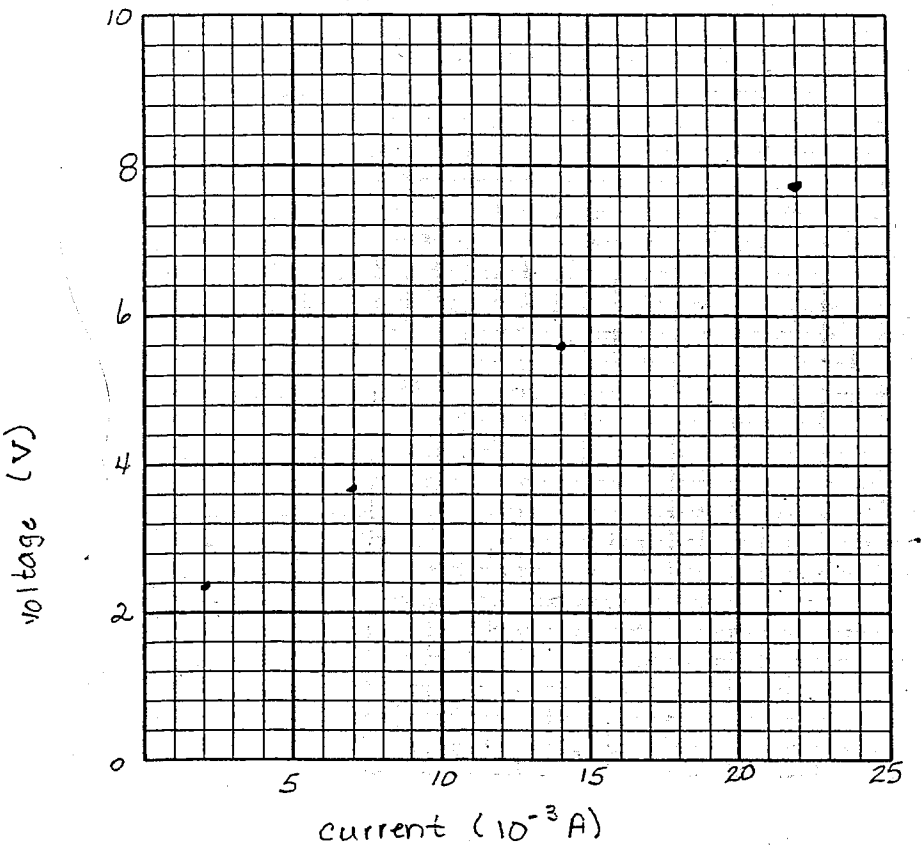
$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

Where (x_1, y_1) and (x_2, y_2) are easy to read points on the line.

Exercise II

The following three grids come with points plotted, a real life equation relating the x and y variables and a series of questions based on the information given. For each one, draw a best fit line for the data and then complete the questions.

Light Emitting Diode (LED)



The equation for this line is $V = ZI + 2.95 \times 10^{33} \bullet h$ where V is a voltage, I is the current, h is Planck's constant and Z is an experimentally determined constant.

a) the y – variable is _____

b) the x – variable is _____

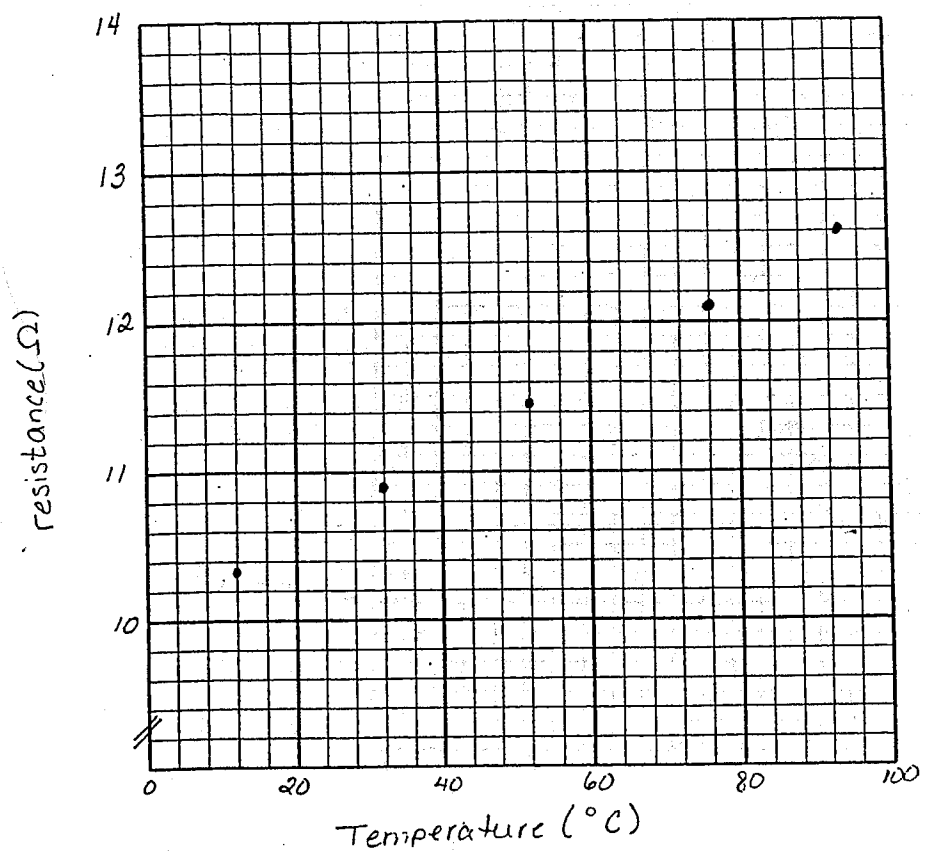
c) the algebraic significance of the slope is _____

d) the value of the slope is

e) the algebraic significance of the y – intercept is _____

f) the value of Planck's constant is

A Non-Ohmic Resistor



The equation of the line in this grid is $R = R_0(1 + \alpha T)$ where R is resitance measured in ohms, T is a temperature in degrees Celsius, and α a constant.

g) the y – variable is _____

h) the x – variable is _____

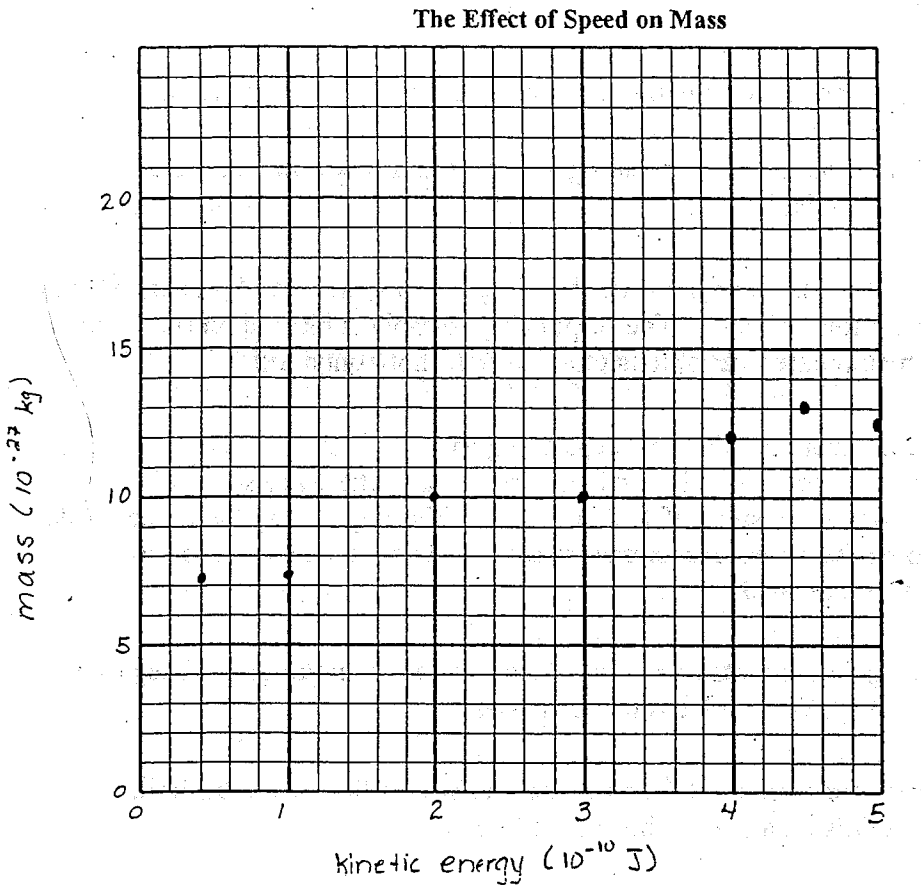
i) the equation of the line in the form $y = mx + b$ is _____

j) the algebraic significance of the slope is _____

k) the value of the slope is

l) the algebraic significance of the y – intercept is _____

m) the value of the variable α is



The equation of the line in this grid is $E_k = (m - m_o)c^2$ where E_k is the kinetic energy of an object, m is the mass and c is the speed of light, 3.00×10^8 m/s

n) the y – variable is _____

o) the x – variable is _____

p) the equation of the line in the form $y = mx + b$ *is* _____

q) the algebraic significance of the slope is _____

r) the value of the slope is

s) the algebraic significance of the y – intercept is _____

t) Identify the particle used in this experiment. When at rest, an electron has a mass of 9.11×10^{-31} kg, a proton has a mass of 1.67×10^{-27} kg, and an alpha particle as a mass of 6.65×10^{-27} kg.

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Plotting Data

When producing a graph from experimental data there are 5 principles that are followed:

1. **Title** – the title states the "responding" variable as a function or vs. the "manipulated" variable.

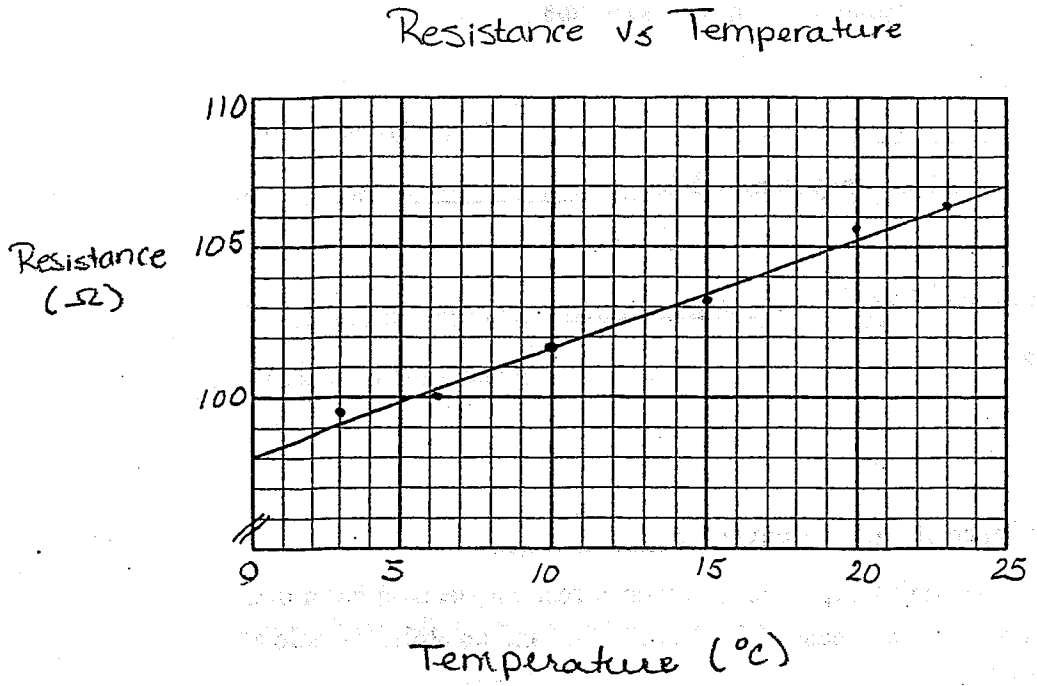
2. **Axes labels** – the name of the variable along with any units and powers of ten should appear for each axis. The responding variable is plotted on the vertical axis. The manipulated variable is plotted on the horizontal axis.

3. **Scale** – the numbers provide the steps along each of the axes. The steps along one axis must be constant. The values used to make the scale should be convenient to use, i.e. steps of 1, 2, 5, 10, etc. The steps along the two axes do not need to be the same. An axis does not need to start at zero but a broken axis should be indicated.

4. **Data plotting** – the points should be placed correctly on the grid. They may be placed as dots, dots with circles or crosses.

5. **Best fit line** – for data that falls on a line, the best fit line is a straight line. For data that falls on a curve, the best fit line is a curve.

Examples of the above principles can be found on the graph below.

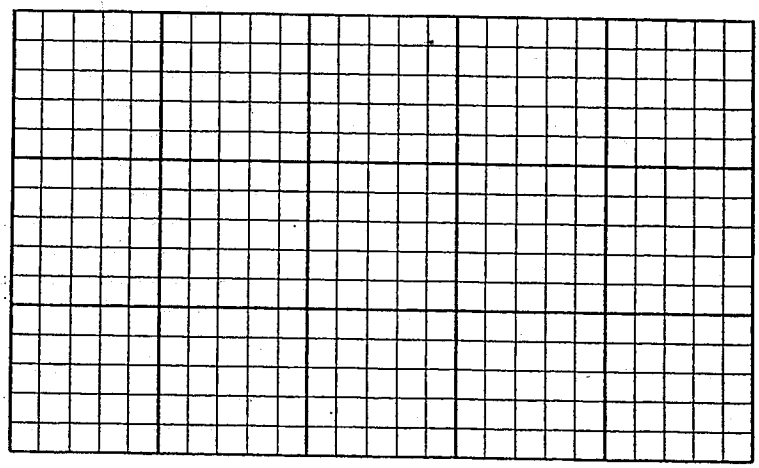


Exercise

This assignment contains three sets of experimental observations. For each set, complete the graph paying attention to the 5 principles outlined above, and answer any questions that may be included with the grid.

1. A string is attached to the end of thin board and different weights are hung on the string. The amount of bending of the board is measured by how far the tip of the board drops. The equation that applies to this situation is $F = -kx$ where F is the force, (the weight) hung on the end of the board, x is the distance of bending and k is called the spring constant.

Force (N)	Bending (cm)
4.0	0.10
14.0	0.40
32.0	0.90
46.0	1.30

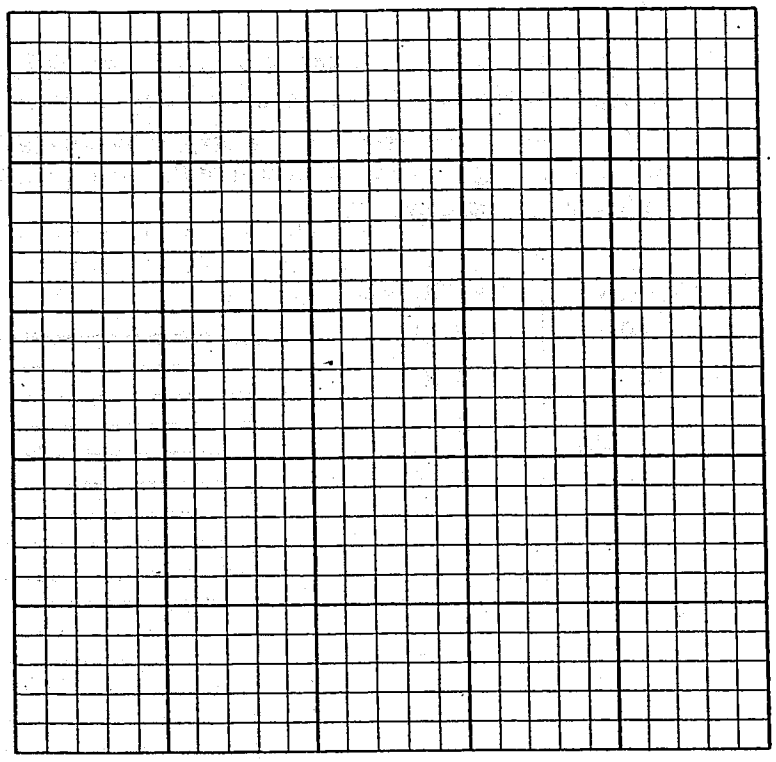


a) Determine the value of the slope including units. Express your answer to 2 digits.

b) What is the significance of the slope?

2. A resistor with a constant resistance, R, is connected to an ammeter and a variable power supply. For different currents, I, through the resistor, the voltage, V, required is measured. Ohm's Law, $V = IR$, applies to resistors with a constant resistance.

Current (A)	Voltage (V)
0.30	1.2
1.15	4.0
1.60	6.4
2.00	8.0
2.50	9.6

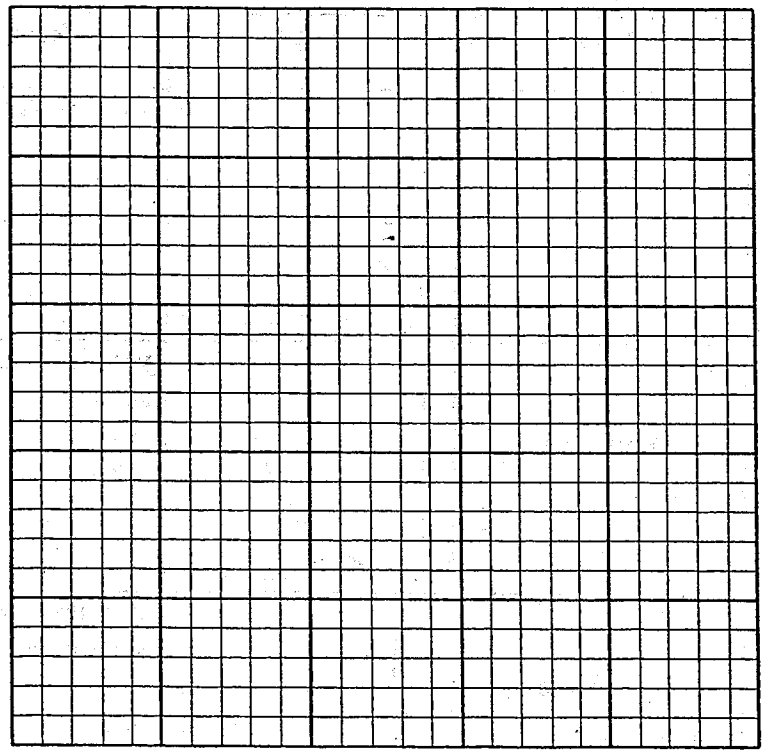


c) Determine the resistance of the resistor. Show all your work.

3. This data comes from a variation of the Millikan Oil Drop experiment. A polystyrene ball is given a charge, q, and placed between parallel plates that can be moved closer together or further apart. The electric potential difference, V, required to suspend the ball is measured for different plate separations, d.

Observations from the experiment: mass, $m = 3.0\times10^{-15}$ kg
gravity, $g = 9.81$ m/s^2

Plate Separation (mm)	Electric Potential Difference (V)
1.1	110
2.0	170
2.4	210
3.1	270
3.5	300
5.0	420



d) Determine the value with units of the slope of the best fit line.

e) The relationship between the variables in this experiment can be expressed as $\frac{V}{d}q = mg$. Determine the value of the charge, q, on the ball.

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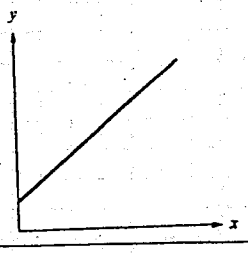
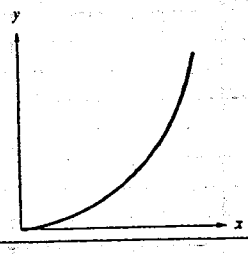
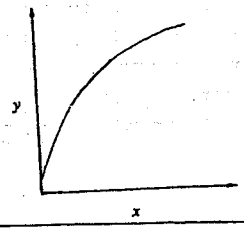
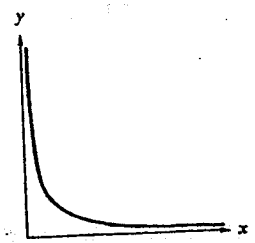
Shape Recognition and Curve Straightening

Linear graphs are the nicest to work with. The equation $y = mx + b$ can be used to in the sciences and in mathematics to describe all sorts of things that happen in the real world. Unfortunately, not all experiments produce linear graphs.

This table contains the four most common shapes of graphs obtained from plotting experimental data.

Name	Shape	Relationship	Manipulation to produce a linear graph
linear		y varies directly with x $y \alpha x$	
parabolic		y varies directly with the square of x $y \alpha x^2$	Take the square of each x value
parabolic		y varies directly with the square root of x $y \alpha x^{1/2}$	Take the square root of each x value
hyperbolic		y varies inversely with x $y \alpha \frac{1}{x}$ *or* y varies inversely with the square of x $y \alpha \frac{1}{x^2}$	Take the reciprocal of each x value. If this produces a parabola, take the square of the reciprocal of each x value.

The purpose of this exercise is allow you to become familiar with the common shapes of graphs obtained from experimentation.

Exercise I

Complete the chart.

	Name	Shape	Relationship
a)			$a \alpha \frac{1}{b}$
b)	j varies inversely as the square of n		$j = \frac{PZ}{n^2} + L$
c)	H varies directly as B		
d)			$T = 2\pi\sqrt{\frac{m}{k}}$
e)	d varies directly as the square of t		

The following three questions work you through the ideas contained in the table along with using the equation of a line, $y = mx + b$.

Exercise II

1. Two equally charged pith balls with equal surface area are placed near to each other and the repulsive force they exert on each other is measured. They are moved slightly further apart and the force is again measured. This is repeated for several distances, r.

   f) What formula describes the experiment described above?

   g) Sketch a graph of the relationship between force and distance.

   h) What is the name of the shape?

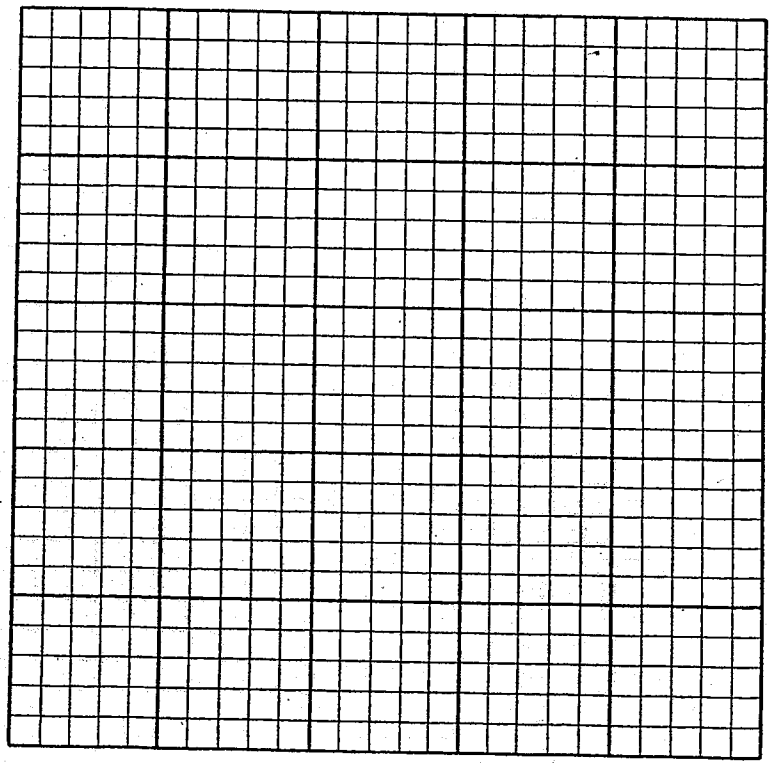
   i) What manipulation should be done to produce a linear graph?

   j) Predict the significance of the slope.

2. A student varied the current in a fixed resistor and measured the power dissipated in the resistor for different currents. The experimental data are recorded below:

Current (A)	Power (W)
0.10	0.56
0.20	2.30
0.30	4.90
0.40	8.80
0.50	13.0

k) Plot the data.

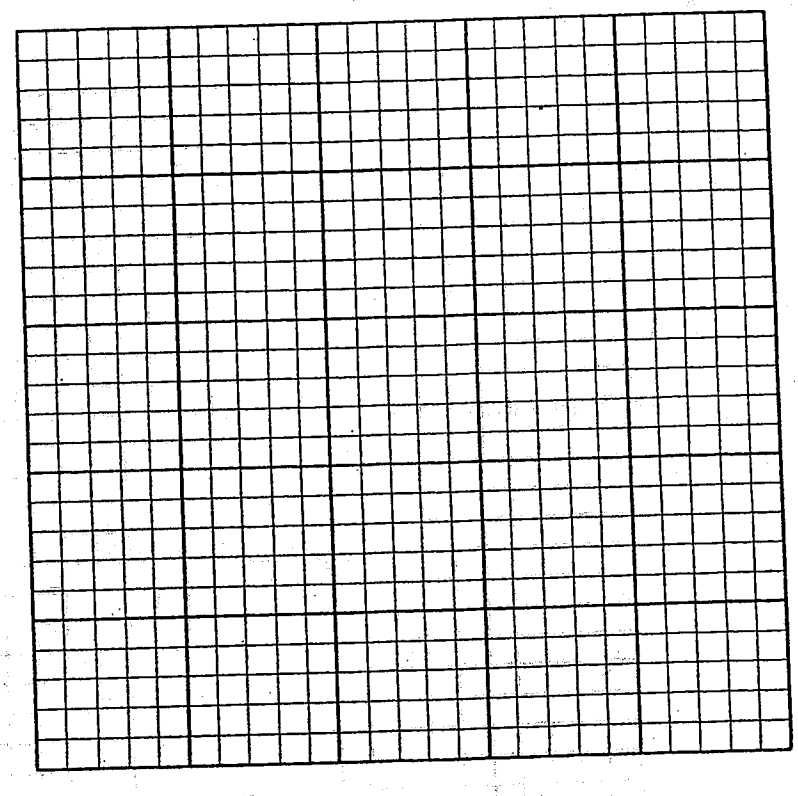


l) The name of the shape of the above graph is _____.

m) The procedure to be followed to produce a linear graph is

n) Complete a data table of manipulated data.

o) Plot a linear graph of the observations of current and power.



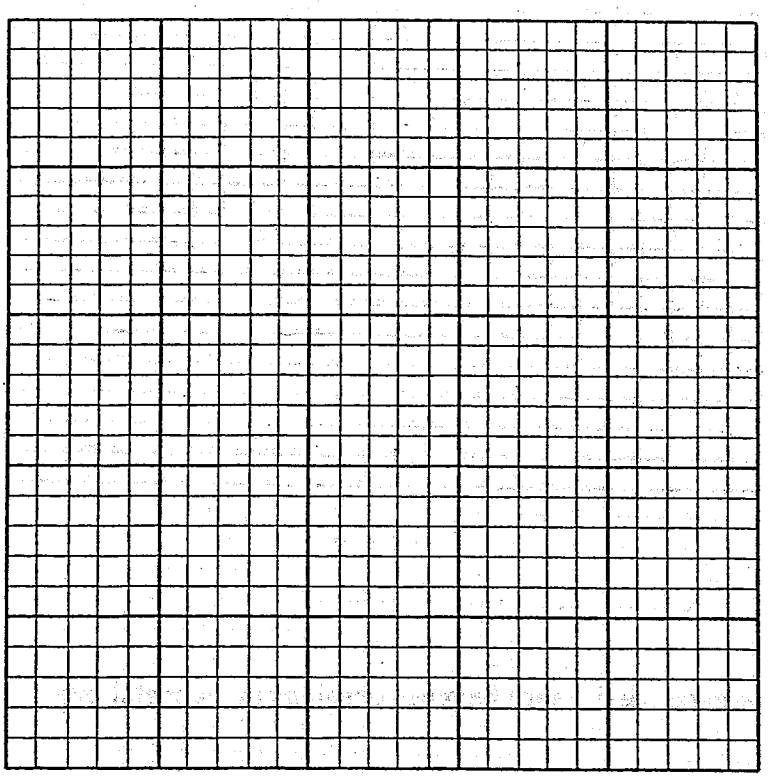
p) Calculate the slope of the line.

q) What is the significance of the slope?

3. A microwave generator with a variable frequency, f, is used to measure the distance d, between openings in a metal mesh by observing the diffraction pattern 5.0 m away from the metal mesh. The distance from the central maximum to the first antinode is measured for various frequencies and the data is given.

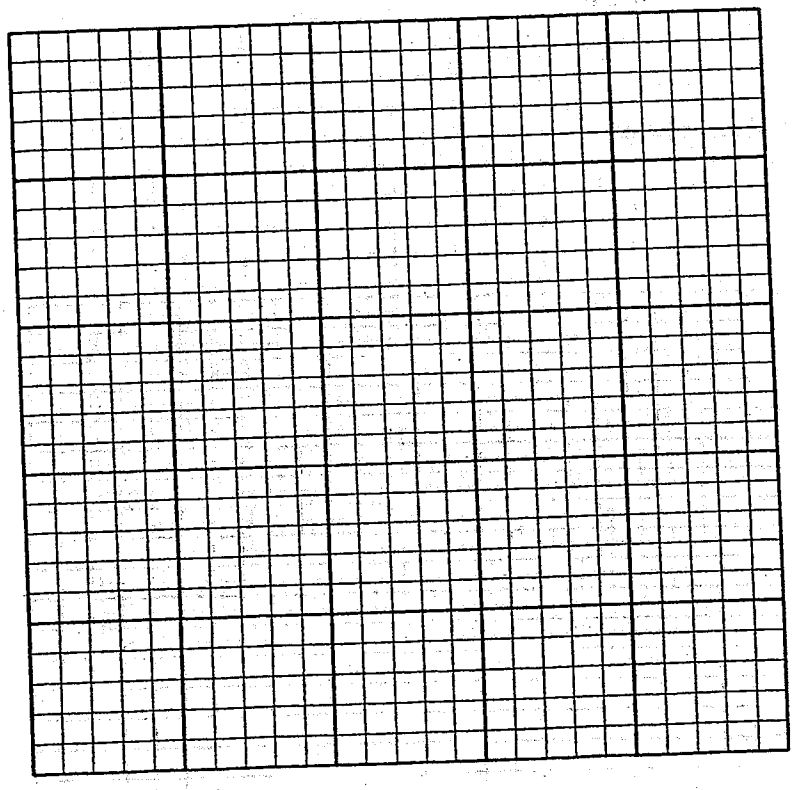
Frequency (10^{11} Hz)	Distance to first antinode (cm)
4.0	3.6
3.0	4.8
2.0	7.4
1.3	12.0
1.0	14.2
0.8	20.4
0.6	24.6

r) Plot the observations.



s) Manipulate the data and produce a new data chart so that when the new data is plotted a linear graph is produced.

t) Plot the new data.



u) Determine the distance between openings in the metal mesh.

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Putting it all together

A wire that has a current in it will have a magnetic field which surrounds it. The

$$|\vec{B}| = \frac{\mu}{2\pi}\left(\frac{I}{r}\right)$$

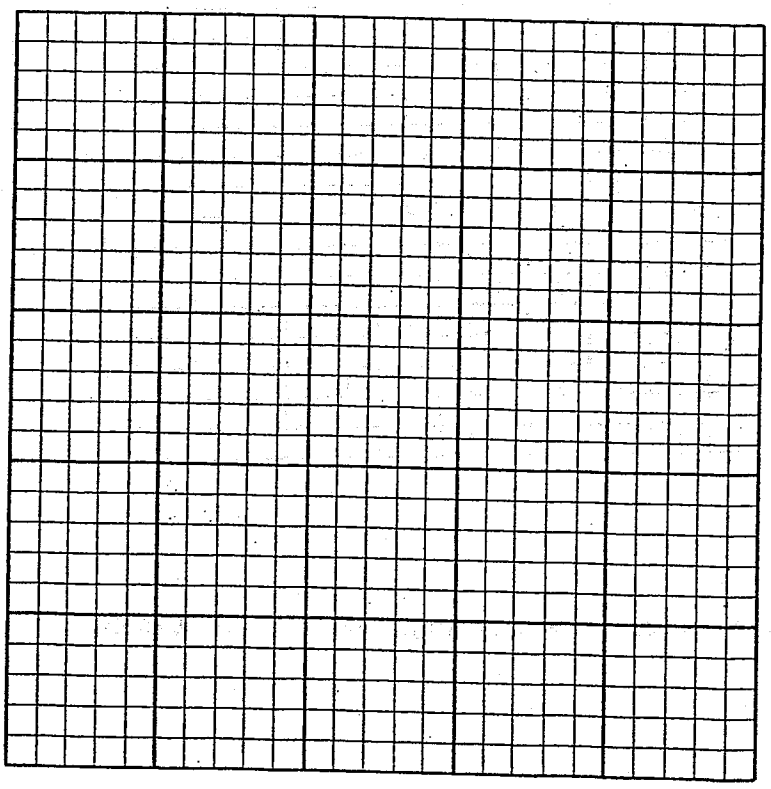
magnitude of this field can be calculated using

where $|\vec{B}|$ is the magnetic field strength in teslas (T), I is the current in the wire in amperes (A), r is the distance from the wire in metres (m), and μ is a constant called the permeability of space.

An experiment was performed to determine the value and units of the permeability of space. The current in the wire was held at a constant 2.50 A and the following observations were recorded.

Distance from the wire (m)	**Magnetic field Strength (μT)**
0.10	31.4
0.20	15.7
0.30	10.5
0.40	7.8
0.50	6.3

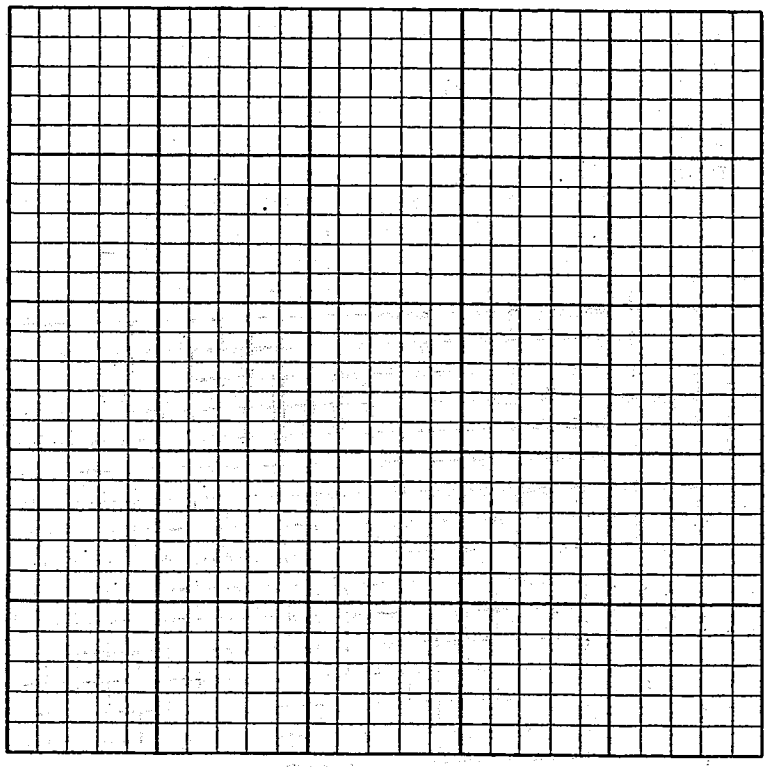
Plot the data.



What is the name of the shape of the graph?

Produce new data that, when plotted, would produce a linear graph. Explain how you produced the new data.

Plot the new data.



Determine the experimental value of μ. Include units. Express your answer to two digits.