A Level Physics

Skills, Practicals and Analysis

Skills	Definitions
N. DWYER	

Define the following words:

Independent variable

Dependent variable

Control variable
Continuous variable
Discrete variable
Ordered variable
Categoric variable
Accuracy
Precision
Reliability
Calibration

Random error
Systematic error
Zero error
Mean value
Anomalous results
Line of best fit
Gradient
Y-Intercept

How do you improve the precision of a reading?

How do could you improve the reliability of your results?

If a weighing scale read 20g when nothing was placed on it how would you describe it?

If you used this to find the masses of different samples of metal what type of error would it produce?

How could you calculate the true value for each of the masses?

How do you calculate a mean value of 4 readings?

If all your readings are to 2 significant figures how many sig fig can your mean value be? Why?

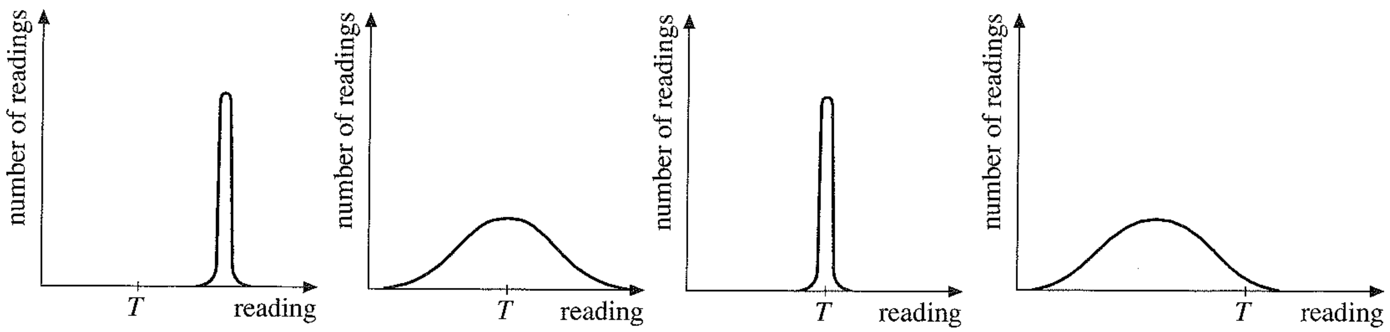
Which type of variable would the following be classed as:

Height in cm?
Gender?
Dress size?
Attractiveness?
Distance in m?
Brightness?
Volume of CO_2 produced in m^3?
Temperature in Fahrenheit?

Favourite chocolate bar?
Current in Amps?
Smelliness?
Age in days?
pH?
Pressure in Pa?
Loudness?
T-Shirt size?

If T represents the true value which of the graphs below represents:

A. Precise and accurate?
B. Precise but not accurate?
C. Accurate but not precise?
D. Neither accurate nor precise?



Skills	Prefixes
N. DWYER	

In Physics we have to deal with quantities from the very large to the very small. A prefix is something that goes in front of a unit and acts as a multiplier. This sheet will give you practice at converting figures between prefixes.

Symbol	Name	What it means		How to convert	
P	peta	10^{15}	1000000000000000		↓ x1000
T	tera	10^{12}	1000000000000	↑ ÷ 1000	↓ x1000
G	giga	10^{9}	1000000000	↑ ÷ 1000	↓ x1000
M	mega	10^{6}	1000000	↑ ÷ 1000	↓ x1000
k	kilo	10^{3}	1000	↑ ÷ 1000	↓ x1000
			1	↑ ÷ 1000	↓ x1000
m	milli	10^{-3}	0.001	↑ ÷ 1000	↓ x1000
μ	micro	10^{-6}	0.000001	↑ ÷ 1000	↓ x1000
n	nano	10^{-9}	0.000000001	↑ ÷ 1000	↓ x1000
p	pico	10^{-12}	0.000000000001	↑ ÷ 1000	↓ x1000
f	femto	10^{-15}	0.000000000000001	↑ ÷ 1000	

Convert the figures into the prefixes required.

s	ms	μs	ns	ps
134.6				
96.21				
0.773				

m	km	mm	Mm	Gm
12873				
0.295				
57.23				

kg	Mg	mg	g	Gg
94.76				
0.000765				
823.46				

A	mA	μA	nA	kA
0.000000678				
3.56				
0.00092				

Skills	

N. DWYER	Means and Anomalous Results

For each set of values calculate the mean and then calculate the mean ignoring any anomalous results.

1	**2**	**3**	**Mean**	
4152	2996	4018		
935.5	925.8	926.7		
16.2	19.1	17.4		
80.1316	80.1324	80.1466		
2229	2011	1610		
127.664	127.416	127.489		
55.88	11.97	37.59		
3.767	3.763	3.751		
375.5	511.5	463.4		
1048	888	1655		
0.507	0.415	0.230		
27145	25157	26017		
1450	1014	2238		
9104.32	10529.45	9160.97		

1	**2**	**3**	**4**	**Mean**	
63.10	62.97	62.53	62.99		
465.98	463.40	466.96	155.56		
3.61	7.39	3.55	3.64		
73.71	70.98	74.19	72.38		
2.058	1.566	2.078	1.787		
416	402	189	986		
700653	739762	742471	726161		
2670887	2670901	2669942	2670733		
110.4	260.1	1044.2	488.8		

1	**2**	**3**	**4**	**5**	**Mean**	
140	220	90	180	140		
56300	41200	58600	48300	53800		
0.186	0.341	0.276	0.216	0.314		
1.427	0.235	0.488	1.922	1.620		
34	62	46	12	39		
326.19	360.22	314.20	352.22	400.18		
1.4	5.3	2.7	3.9	2.6		

Skills	# Significant Figures
N. DWYER	

For each value state how many significant figures it is stated to.

Value	Sig Figs	Value	Sig Figs	Value	Sig Figs	Value	Sig Figs
2		1066		1800.45		0.07	
2.0		82.42		2.483×10^4		69324.8	
2.00		750000		2.483		0.0063	
0.136		310		5906.4291		9.81×10^4	
0.34		3.10×10^2		200000		6717	
54.1		3.1×10^2		12.711		0.91	

Add the values below then write the answer to the appropriate number of significant figures

Value 1	Value 2	Value 3	Total Value	Total to correct sig figs
51.4	1.67	3.23		
7146	–32.54	12.8		
20.8	18.72	0.851		
1.4693	10.18	–1.062		
9.07	0.56	3.14		
739762	26017	2.058		
8.15	0.002	106		
132.303	4.123	53800		
152	0.8	0.55		
0.1142	4922388	132000		

Multiply the values below then write the answer to the appropriate number of significant figures

Value 1	Value 2	Total Value	Total to correct sig figs
0.91	1.23		
8.764	7.63		
2.6	31.7		
937	40.01		
0.722	634.23		

Divide value1 by value 2 then write the answer to the appropriate number of significant figures

Value 1	Value 2	Total Value	Total to correct sig figs
5.3	748		
3781	6.434		

91×10^{2}	180		
5.56	22×10^{-3}		
3.142	8.314		

Skills	
N. DWYER	

Significant Figures 2

For each value state how many significant figures it is stated to.

Value	**Sig Figs**	**Value**	**Sig Figs**	**Value**	**Sig Figs**	**Value**	**Sig Figs**
2.863		689671.49		100000		6.4981×10^{7}	
100		356865		8.5×10^{-3}		7.85	
24.92		13		6400		17.99	
5.18×10^{27}		182.15		875.4		3.189×10^{6}	
2.8		4.267		94		0.053	
2.9970		0.02		94.0		0.422	

Calculate the mean of the values below then write the answer to the appropriate number of significant figures

Value 1	**Value 2**	**Value 3**	**Mean Value**	**Mean to correct sig figs**
1	1	2		
435	299	4130		
500	600	900		
3.038	4.925	3.6		
720	498	168		
1655	2996	140		
0.230	925.8	56300		
26017	19.1	0.186		
2238	80.1324	1.427		
9160.97	2011	34		
62.99	127.416	326.19		
155.56	11.97	1.4		
3.64	3.763	700653		
72.38	511.5	2670887		
1.787	888	110.4		
986	0.415	62.97		
726161	25157	463.40		
2670733	1014	7.39		
488.8	10529.45	70.98		
0.186	140	1.566		

1.427	53800	402		
34	0.314	739762		
326.19	1.620	2670901		
1.4	39	260.1		

Skills	Calculating Errors
N. DWYER	

Complete the table.

Variable	**Reading 1**	**Reading 2**	**Reading 3**	**Mean Value**	**Uncertainty**	**% Uncertainty**
A	121	118	119			
B	599	623	593			
C	3.3	3.6	3.2			

What would be the percentage error in the following quantities?

Complete the table.

Variable	**Reading 1**	**Reading 2**	**Reading 3**	**Mean Value**	**Uncertainty**	**% Uncertainty**
D	17	17	17			
E	42.5	42.8	42.1			
F	3.60	3.28	3.73			
G	757	714	739			

What would be the percentage error in the following quantities?

Complete the table.

Variable	**Reading 1**	**Reading 2**	**Reading 3**	**Mean Value**	**Uncertainty**	**% Uncertainty**
H	58205	58309	58193			
I	82.3	81.4	82.8			
J	1985	1988	1980			
K	43	19	27			

What would be the percentage error in the following quantities?

Skills	Calculating Errors 2
N. DWYER	

Calculating Errors 2

Complete the table.

Variable	1	2	3	4	Mean Value	Uncertainty	% Uncertainty
L	11.49	11.56	11.63	10.53			
M	385	322	408	328			
N	2736	2729	2743	2643			
O	5101	5108	5003	5098			
P	125	137	167	142			
Q	6124	6118	6510	6123			
R	3.29	3.29	3.29	3.29			
S	4589	4606	4644	4596			
T	417	488	460	456			
U	1.506	3.061	3.085	1.513			
V	274	333	338	277			
W	33.46	33.45	33.96	33.65			

What would be the percentage error in the following quantities?

Skills	# Identifying Errors
N. DWYER	

For each of the measurements listed below identify the most likely source of error what type of error this is and one method of reducing it.

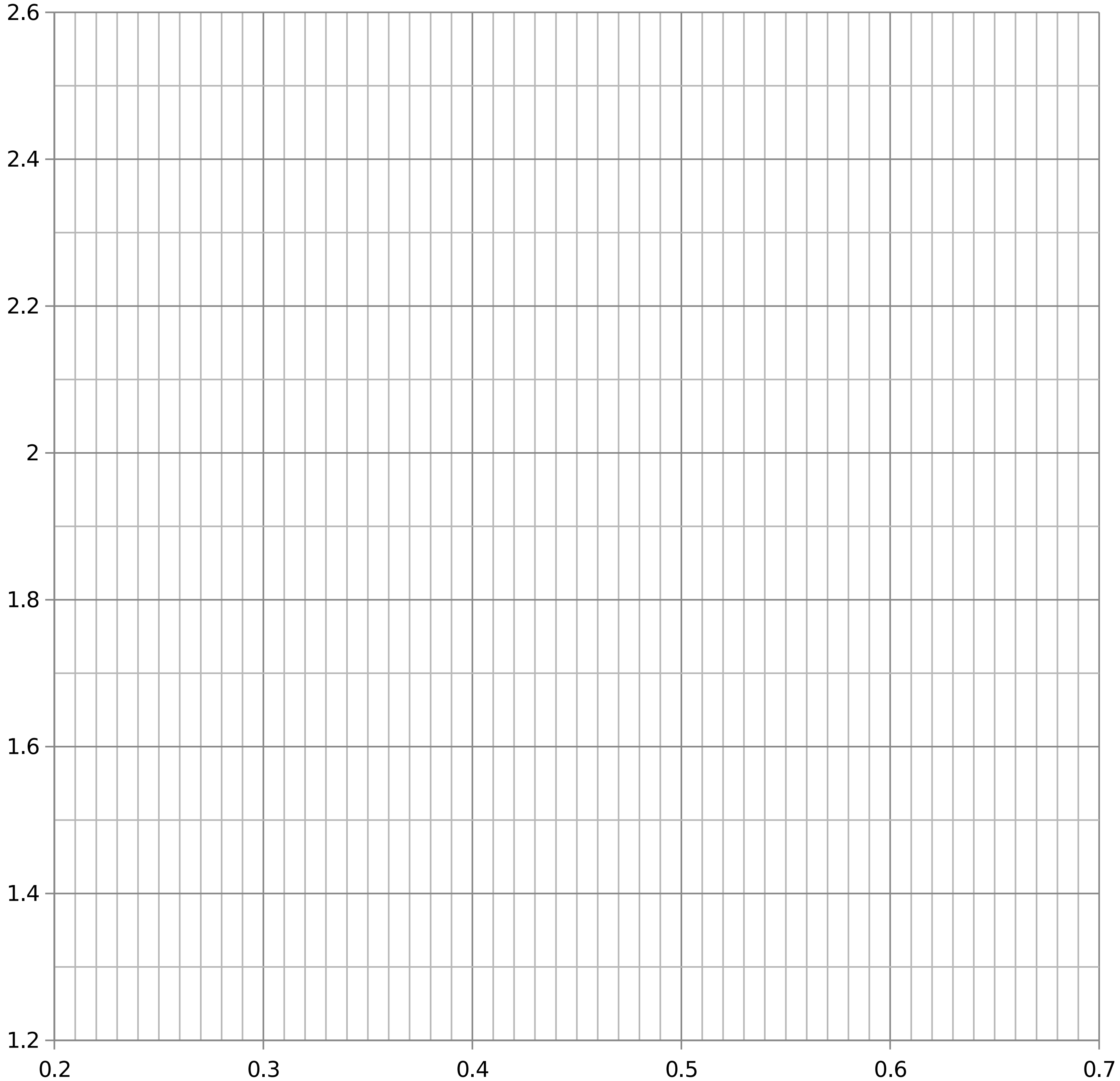
Measurement	Source	Type
A range of values are obtained for the length of a copper wire		
The reading for the current through a wire is 0.74A higher for one group in the class		
A beaker of hot water left on the desk appears to have gained temperature		
A mass of a beaker shows different values on different balances		
A range of values are obtained for the bounce back height of a dropped ball		
A few groups obtain different graphs of resistance vs light intensity for an LDR		
The time period (time of one oscillation) of a pendulum		
A range of values are obtained for the time a parachute takes to reach the ground from 0.5m		

N. DWYER

Points Plotting

You are going to practice plotting points on a graph. This skill carries up to 3 marks in the ISA.

x axis	y axis	x axis	y axis	x axis	y axis
0.44	2.44	0.34	1.75	0.67	2.12
0.27	1.39	0.49	1.99	0.58	1.64
0.39	2.13	0.26	2.22	0.65	2.52
0.62	1.23	0.31	2.49	0.29	1.92
0.37	1.52	0.52	2.36	0.45	1.47
0.22	2.56	0.61	2.23	0.53	1.27
0.42	1.84	0.64	1.83	0.24	1.71
0.48	1.70	0.55	2.15	0.67	1.45

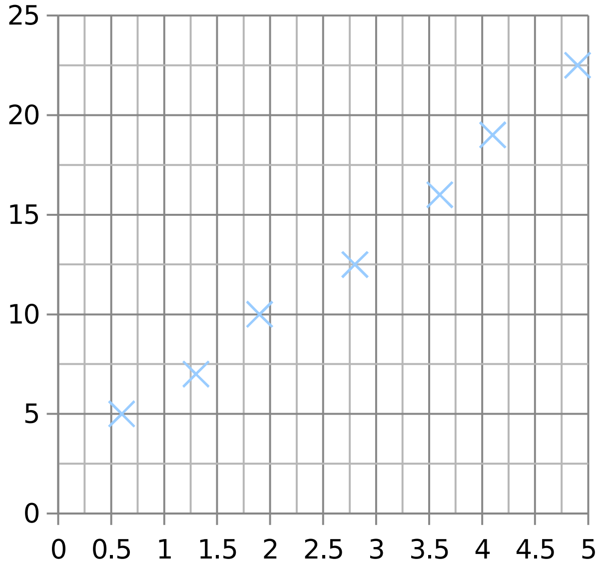


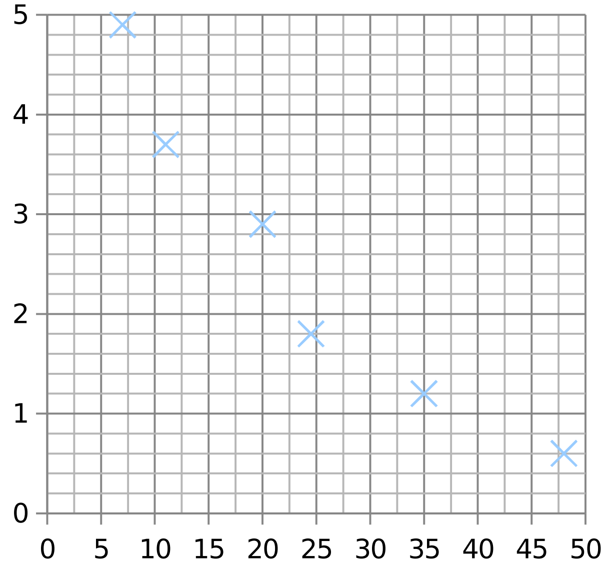
Skills

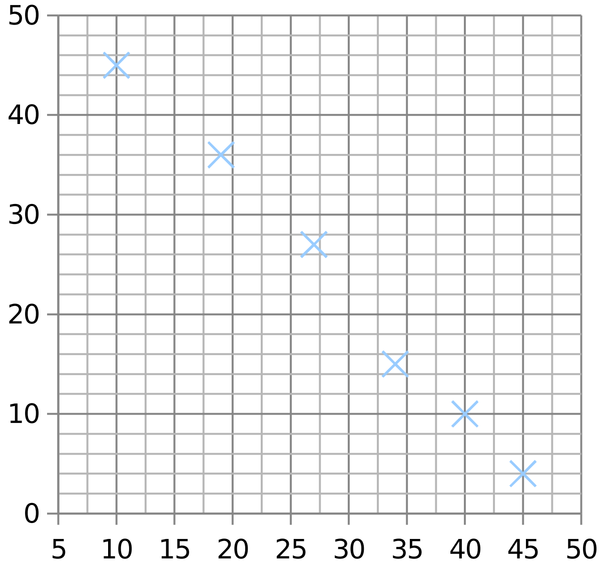
N. DWYER

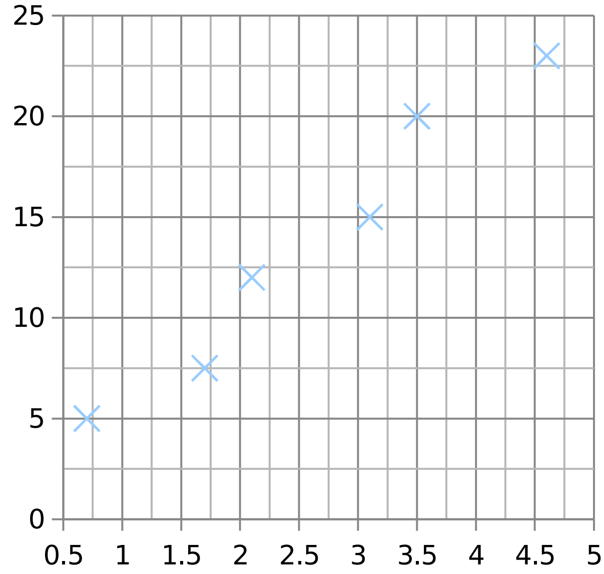
Lines of Best Fit

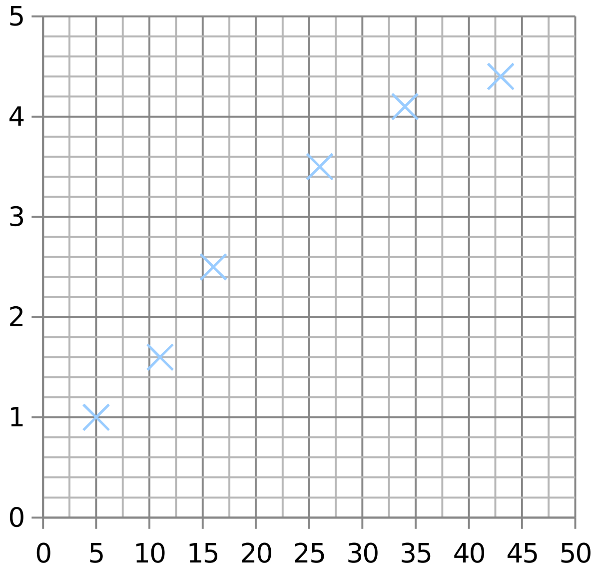
Draw a line of best fit for each of the graphs.

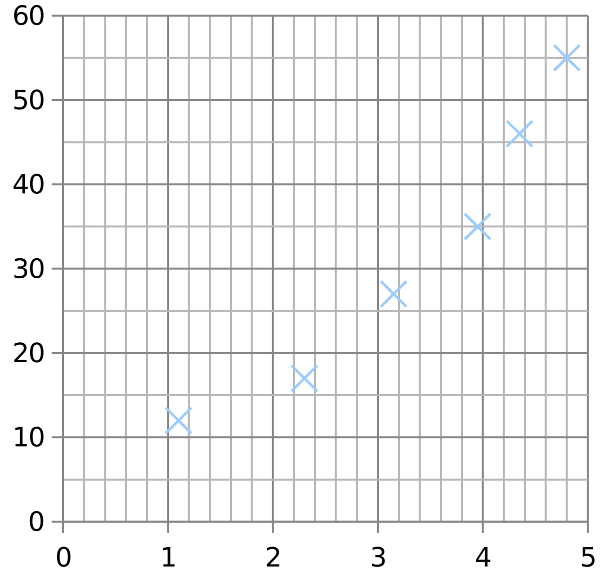








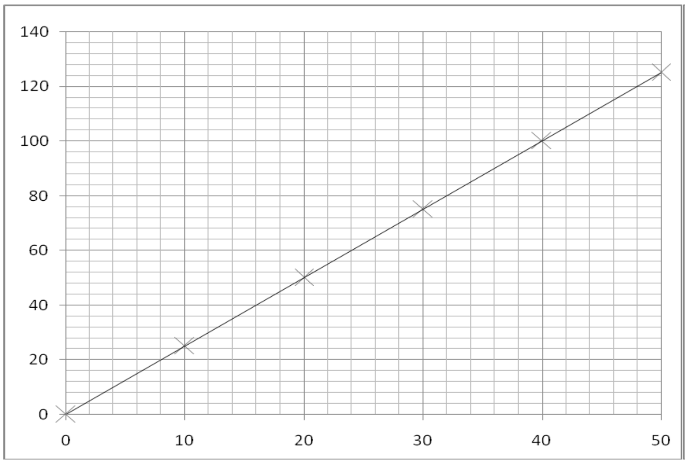


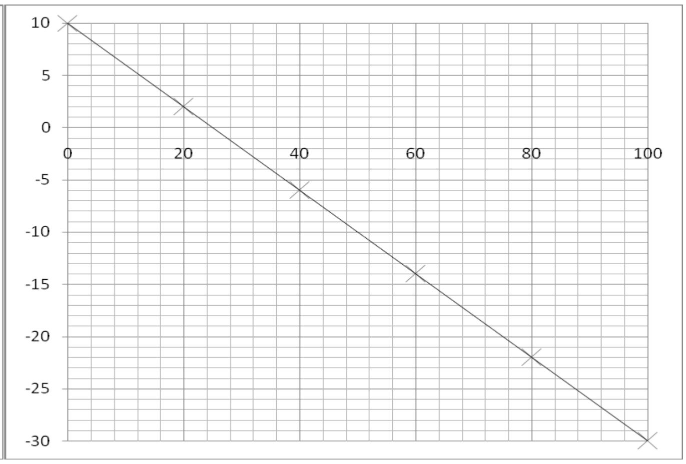


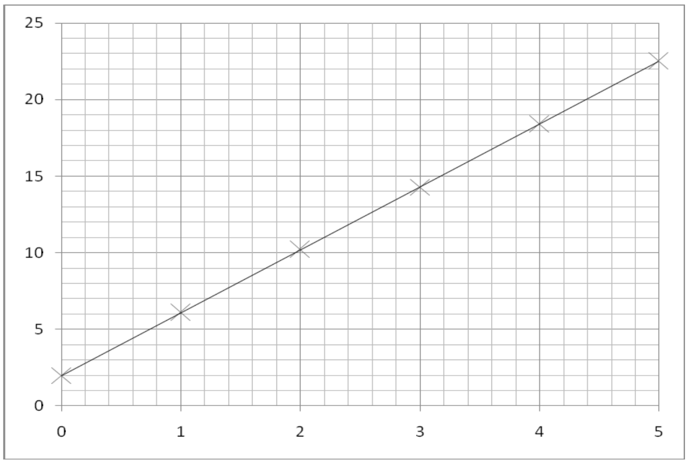
Skills	
N. DWYER	

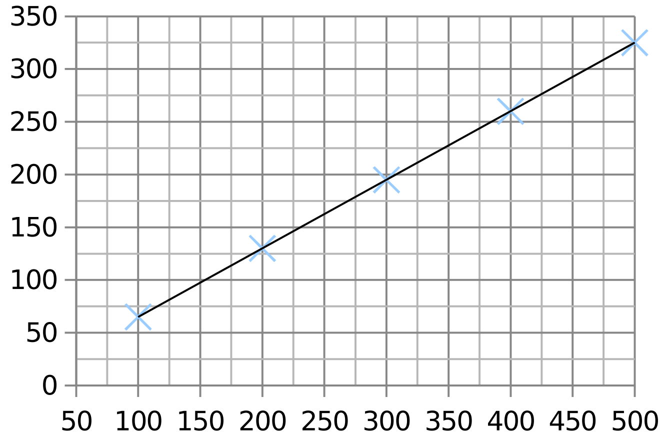
Gradients

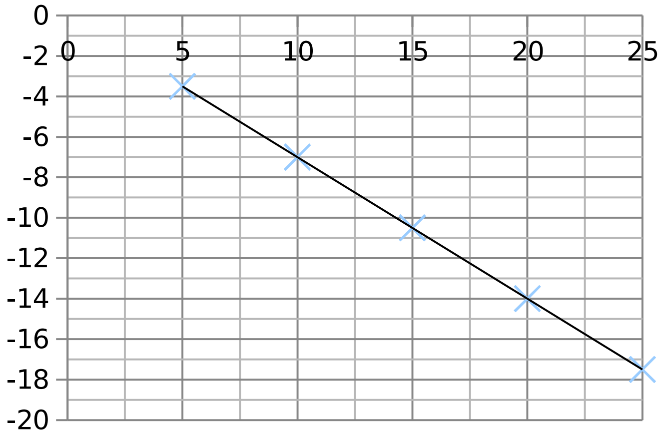
Calculate the gradients of the graphs below. Work out the equation for the line.

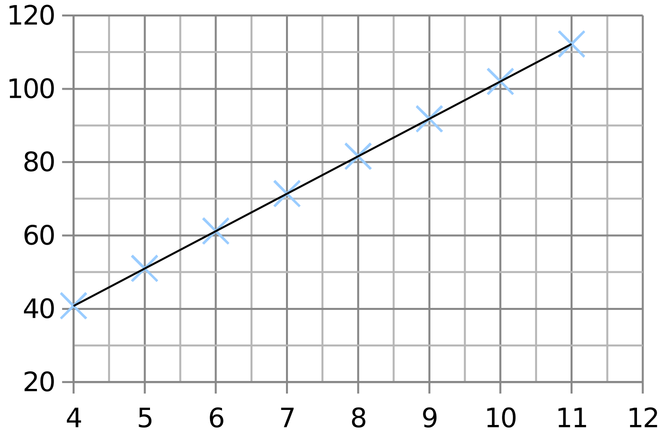


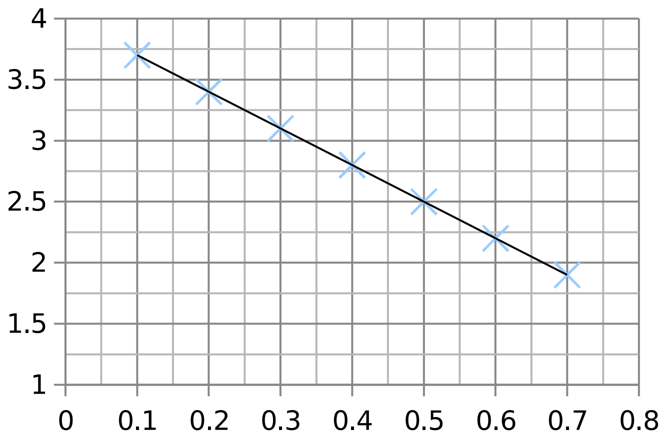


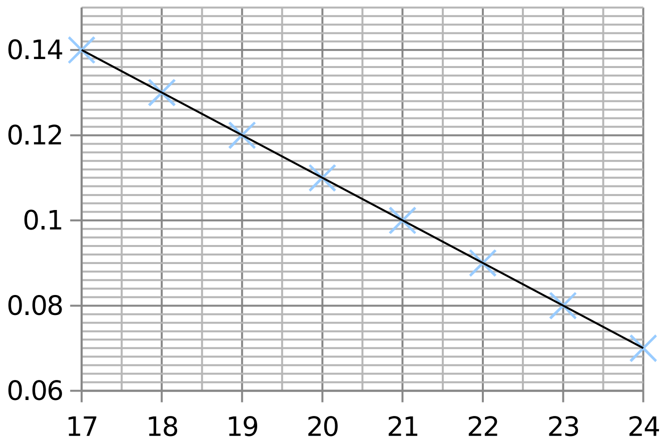












Skills	# Gradient Equations
N. DWYER	

Complete the table below about graphs and gradients

Equation	**Graph**	**Rearrange Equation**	**Gradient**	**Intercept**
	y plotted on the y axis x plotted on the x axis		m	c
	y axis = V x axis = I		R	0
	y axis = t x axis = Q			
	y axis = l x axis = R			
	y axis = V x axis = I			
	y axis = E/t x axis = V			
	y axis = E_K x axis = f			
	y axis = $1/v$ x axis = m			
	y axis = mg x axis = E_P			
	y axis = e x axis = $1/F$			
	y axis = $1/\lambda$ x axis = f			
	y axis = a x axis = $1/t$			
	y axis = v^2 x axis = s			
	y axis = v x axis = s			
	y axis = λ x axis = w			

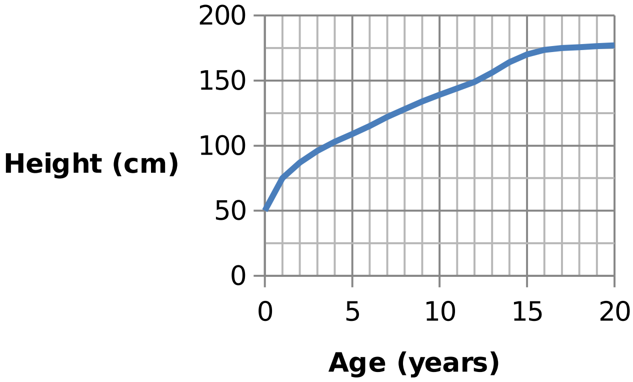
Skills	# Gradient Equations 2
N. DWYER	

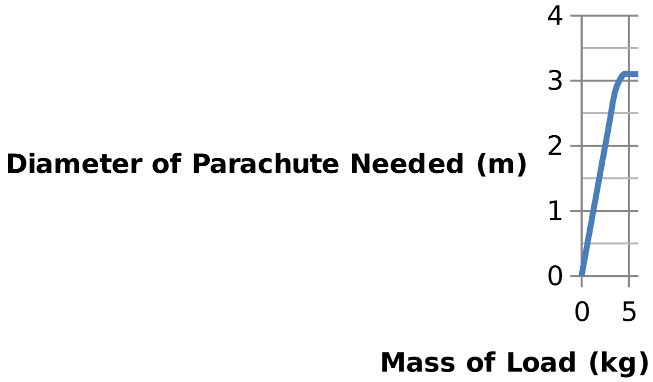
Complete the table below about graphs and gradients

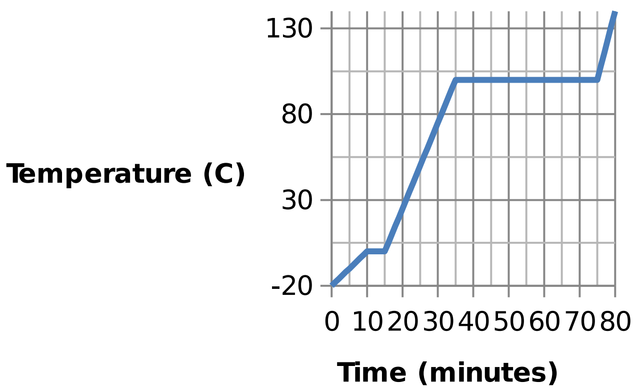
Equation	**Graph**	**Rearrange Equation**	**Gradient**	**Intercept**
	y plotted on the y axis x plotted on the x axis		m	c
	y axis = V x axis = I		R	0
	y axis = v x axis = F/m			
	y axis = r x axis = F/m			
	y axis = l x axis = g			
	y axis = T^2 x axis = m			
	y axis = M x axis = g			
	y axis = F x axis = q/r^2			
	y axis = V x axis = Q			
	y axis = $\ln(Q/Q_0)$ x axis = t			
	y axis = ε x axis = N			
	y axis = N_P x axis = N_S			
	y axis = R^3 x axis = A			
	y axis = T x axis = V			
	y axis = T x axis = Q			

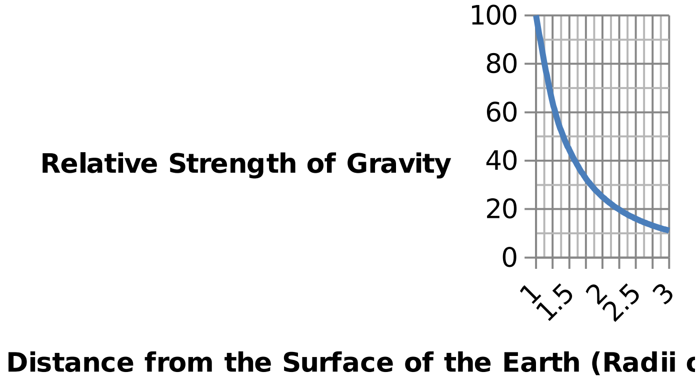
Skills	Interpreting Graphs
N. DWYER	

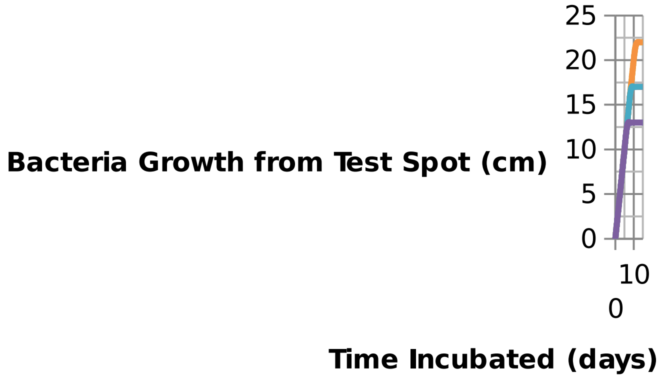
Explain the relationship between the two variables shown in the graphs below.
Describe the general trend/relationshipIdentify sections of highest/lowest gradient
Quote any significant numerical valuesCalculate any gradients you can

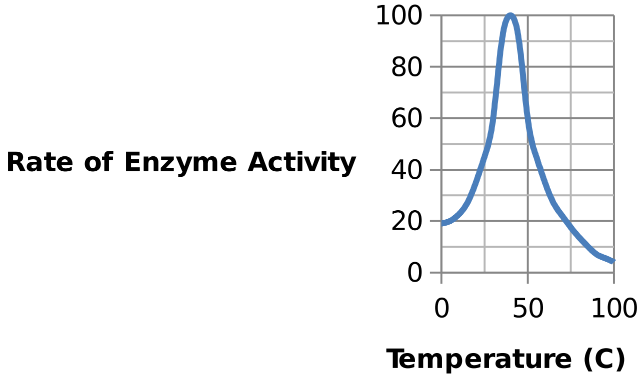


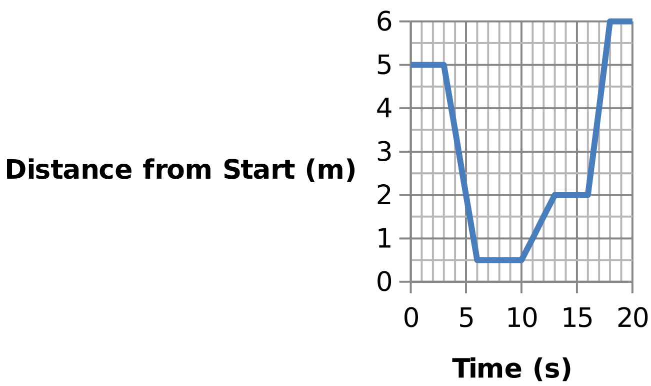


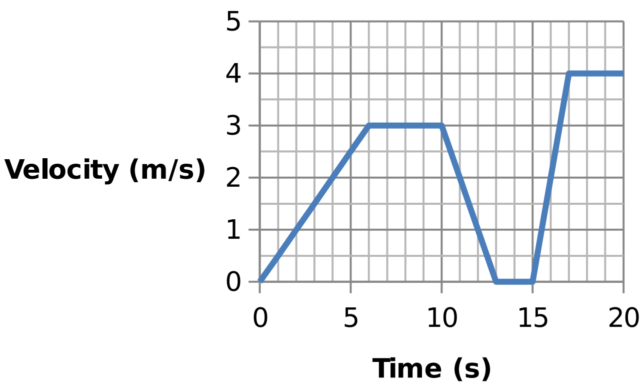










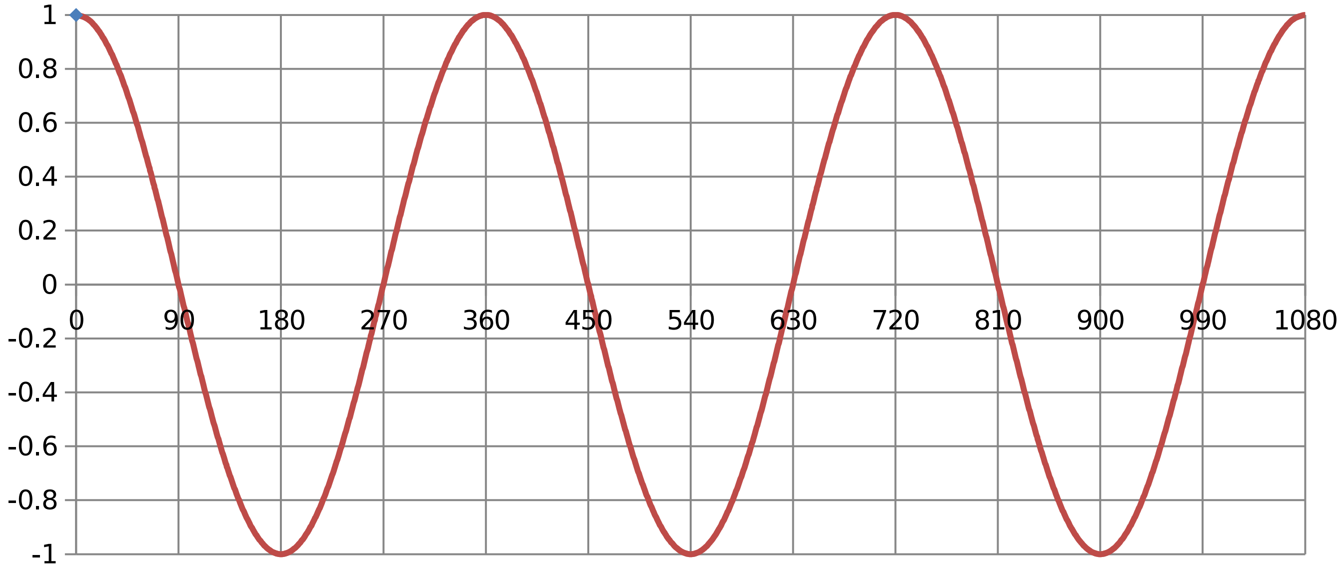


Skills

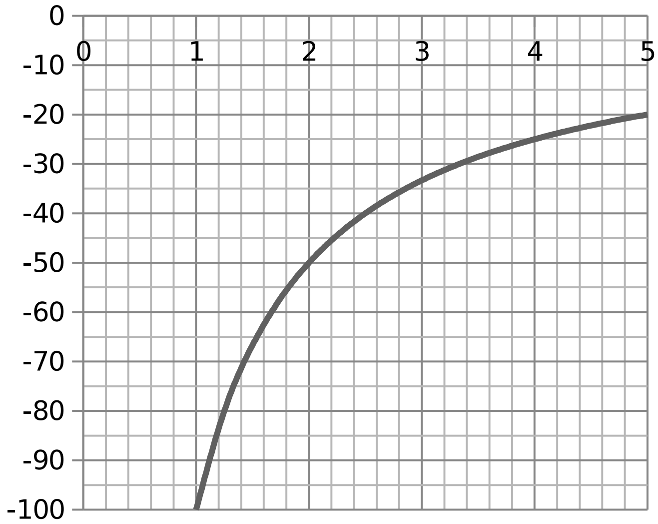
N. DWYER

Tangents

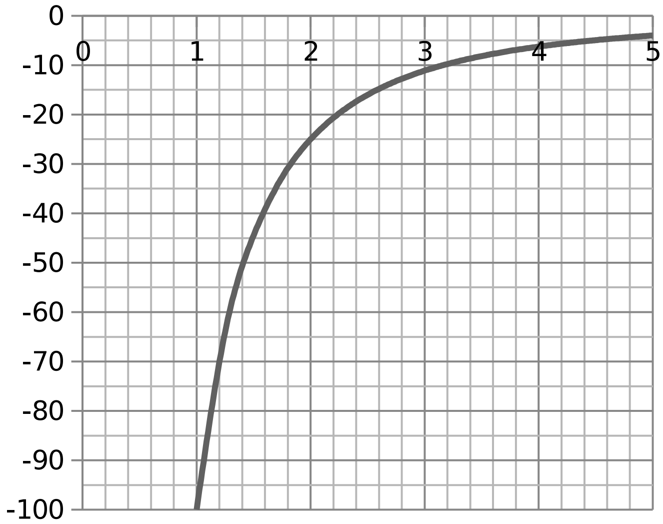
Draw tangents to the line at the following values along the x-axis: 225, 360, 630 and 1035



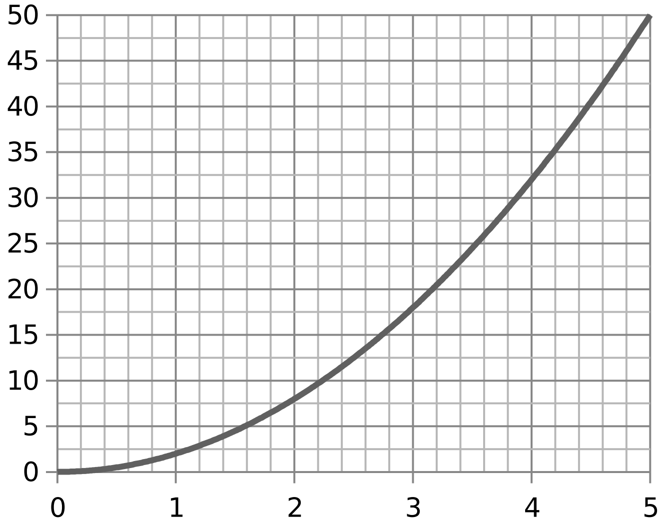
Draw a tangent to the line and calculate its gradient at the following x-axis values:



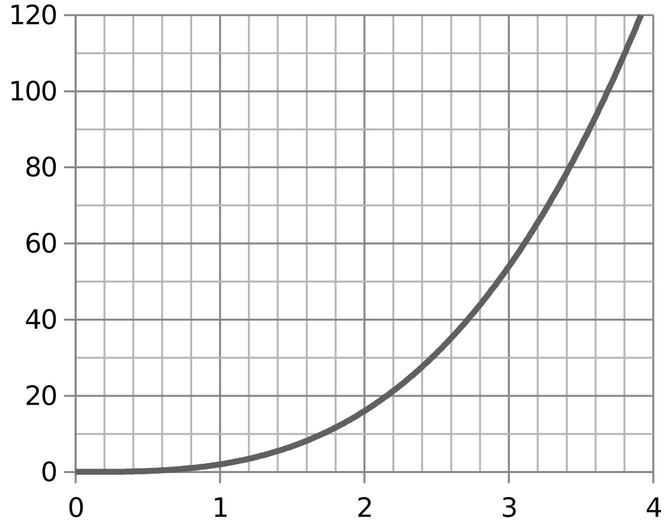
2.0 and 3.9



1.5 and 3.0



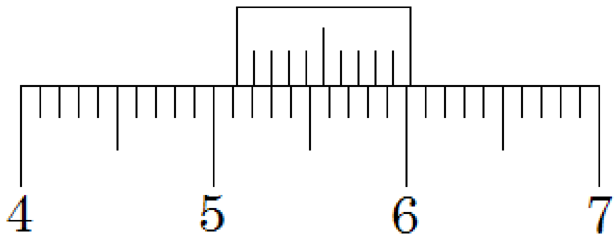
2.2 and 4.0

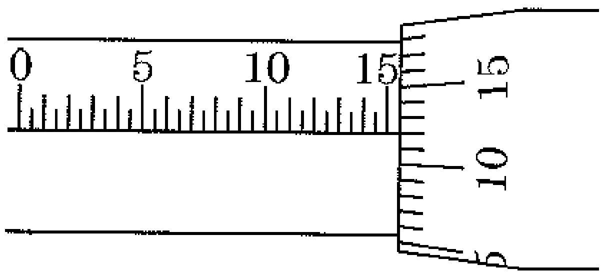


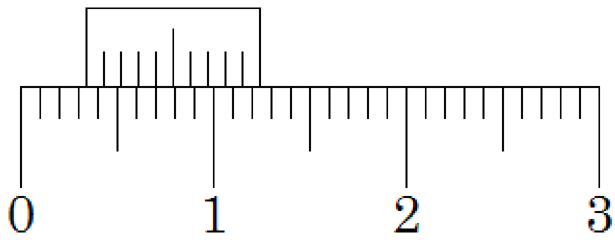
1.6 and 3.4

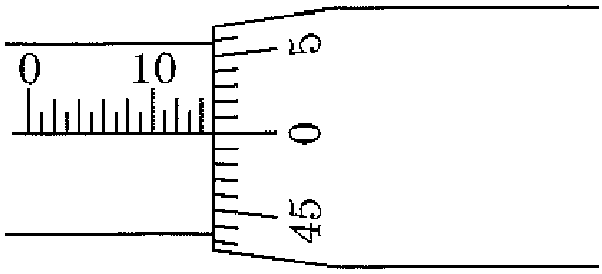
N. DWYER	# Vernier Callipers and Micrometers

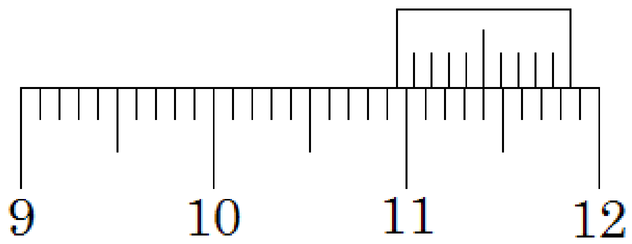
State the reading on the Vernier Callipers to the left and the micrometers to the right.

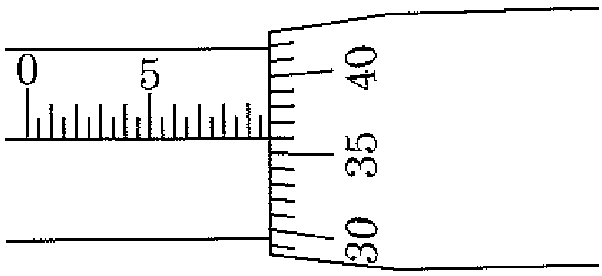


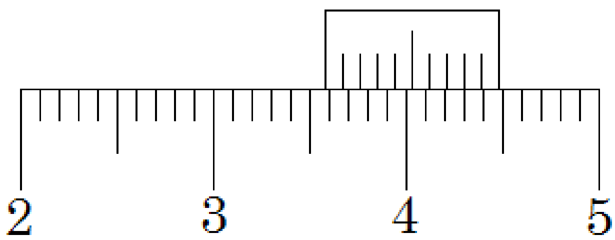


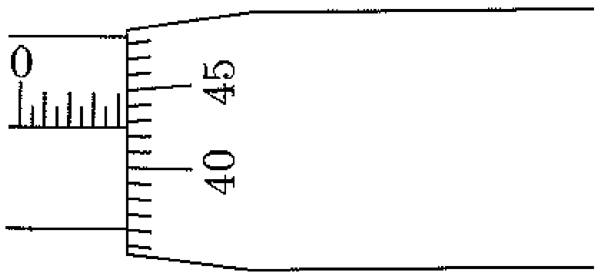


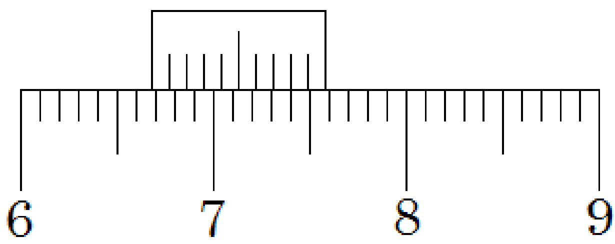


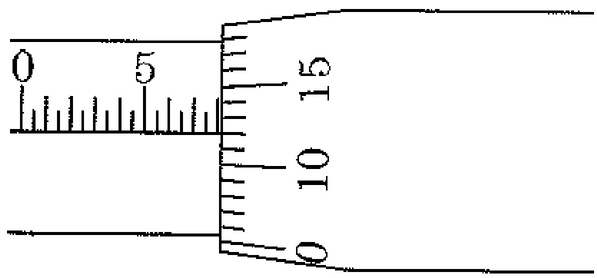


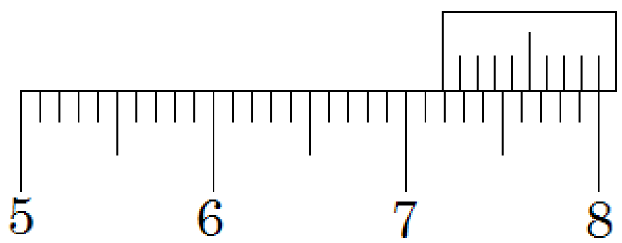


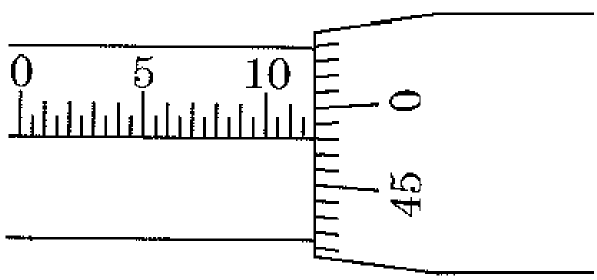












Skills	# Describing Experiments
N. DWYER	

The last question of the ISA often requires the description of an experiment to support a theory.

Change – Which variables will you keep the same and which will you change?
Range – Give specific values for the variables you will use.
Calculate – What will you calculate or plot?
Conclude – What result will help you either prove or disprove the theory?

GCSE.A student suggests that if an egg was dropped from different heights the area of splatter would increase as the height increases but only until a certain point. How could you investigate this?

GCSE. Is the flight time of a paper plane directly proportional to the angle of the nose (θ), the sine of the angle ($\sin\theta$) or neither?

GCSE. What is the relationship between the time that a fizzy pop bottle is shook up for and the volume of liquid that is lost when the bottle is opened?

U1. How could you investigate the theory that the surface temperature of a resistor is directly proportional to the current flowing through it?

U1. A battery with internal resistance r is connected in series with a resistor of resistance R. A student suggests that the power of the resistor will be a maximum when it has a value equal to the internal resistance of the battery.

U1. How could you investigate the connection between the temperature at which a resistor stops obeying Ohm's law and the value of the resistor?

U1. The photoelectric effect experiment is set up so that photoelectrons are released. How could you prove that the intensity does affect the rate of electron emission but only when above the threshold frequency?

U1. A potato can be used as a battery if electrodes of copper and zinc are inserted into it. Explain how you could find the internal resistance and the emf of the potato using resistors of 5 different values.

U1. How could you find the relationship between the resistivity of a metal and the temperature?

U2. Water is placed in a plastic tray, one end it raised, dropped and the speed of the water wave is measured. A student suggests that the speed of the wave depends on the height of the water in the tray. How could you prove this?

U2. A cylinder of solid metal is rolled down a ramp and the speed is calculated from the distance rolled and the time taken to roll. There is a suggestion that if the cylinder was hollow it would be affect more by the air resistance. How could you investigate this?

U2. How could you investigate whether or not the critical angle of a Perspex block is affected by the colour of light that is incident on the block?

U2. A fellow scientist suggests that the Young modulus of a material depends on the temperature of the material. How could you find any possible relationship between the variables?

U2. A speaker is attached to the top of an open glass tube and set to give out a sound of fixed frequency. The bottom of the tube is placed in water and the height is adjusted until the first harmonic is heard. There is a claim that the height will vary depending on the diameter of the glass tube. How could you investigate this?

Skills	# Describing Experiments 2
N. DWYER	

The last question of the ISA often requires the description of an experiment to support a theory.
Change – Which variables will you keep the same and which will you change?
Range – Give specific values for the variables you will use.
Calculate – What will you calculate or plot?
Conclude – What result will help you either prove or disprove the theory?

AS. Explain how it is possible to find the resistivity of a conducting material at room temperature. The material is a cylinder of radius *r* and length l.

AS. Describe the experiment and accompanying calculations/graphs to find the Young modulus of a material of original length l and cross sectional area A.

AS. Explain how to find the spring constant of a metal spring with five 100g masses and a 30 cm ruler.

AS. Describe the experimental set up and the graph you would draw to find the refractive index of a transparent material. How would your graph give you an answer?

U4. A mass and spring system is set up with a piece of card placed between two of the masses. The time period of this damped system is measured. It is suggested that the area of the card does not affect the time period but the shape of the card does, how could you investigate this?

U4. A pendulum and a mass/spring system are set up to have the same time period of oscillation. You are to investigate which SHM system will suffer the greatest degree of damping and conclude which will stop first.

U4. A capacitor has the capacitance and maximum voltage printed on the casing. How could you investigate that this was the largest voltage allowed before the capacitor breaks?

U4. Car A is crashed into stationary car B. How could you investigate the theory that the collisions will be elastic when car B has less mass than car A but inelastic when car B has an equal or greater mass than car A?

U4. How could you investigate whether the angle a pendulum is displaced from affects the time period?

U4. A student suggests that the efficiency of a transformer is directly proportional to the diameter of the wire which is wrapped around the primary coil. How could you prove this theory, what would you plot on a graph and what result would support the theory?

U5. A student uses a GM tube to investigate the inverse square law. How could she investigate if the inverse square law holds true in all direction from an alpha source?

U5. Explain how it is possible to find the absolute zero temperature using air trapped in a glass tube in a science lab which is well above the value itself.

U5. How could you find the constant of proportionality between the volume of a gas and the temperature when investigating Charles' gas law?

U5. With the use of a block of ice, a temperature probe and Bunsen burner that provides a constant energy supply, explain how you could find out how many times bigger the specific latent heat of vaporisation is than the specific latent heat of fusion.

Skills	Rearranging & Deriving Equations
N. DWYER	

Rearrange to make a the subject	
Substitute this into	
Substitute this into the equation	
Substitute this into the equation	
Use to simplify the equation	

Substitute into the equation	
Multiply out the brackets	
Substitute this into the equation	
Rearrange the equation to find the angle to the 3rd maxima	

Substitute into the equation	
Substitute into the equation	
Substitute into the equation	
Use to remove t from the equation	
Simplify this	

Elastic energy is converted into kinetic	
Make v^2 the subject	
Replace this with	
If u=0 rearrange the equation to make a the subject	
Use to make F the subject	

Calculate the Energy stored using if the distance moved is e	

Skills	Rearranging & Deriving Equations 2
N. DWYER	

The centripetal force of a satellite is due to the gravitational force between it and the planet	
Simplify the equation and much as you can and rearrange to make r the subject	
Use to remove v from the equation	
Simplify the equation and use to replace ω	
Use to remove f from the equation	

Rearrange to make the subject	
Make the subject	
Rearrange the equation to make t the subject	

The centripetal force of a charged particle is due to the magnetic force acting on it	
Rearrange the equation to make Q the subject	
Substitute into the equation	
Use to remove B from the equation	

Rearrange to make the subject	
Make the subject	
Substitute into the equation	

Rearrange to make T the subject	
Substitute this into the equation	

If the V is volume of a cube of side l, rearrange the equation to make F the subject	

Skills	Units
N. DWYER	

Write down the standard units for the following quantities.

Energy
Wavelength
Frequency
Current
Potential Difference
Resistance
EMF
Resistivity
Power
Moment
Velocity
Acceleration
Mass
Weight
Force
Work Done

Density
Tensile Strength
Tensile Stress
Refractive Index
Momentum
Impulse
Angular Displacement
Angular Speed
Time Period
Gravitational Field Strength
Gravitational Potential
Electric Field Strength
Electric Potential
Capacitance
Time Constant

Energy Stored
Force on a Moving Charge
Magnetic Flux
Magnetic Flux Density
Magnetic Flux Linkage
Induced EMF
Intensity
Activity
Half Life
Pressure
Volume
Temperature
Specific Heat Capacity
Specific Latent

There are 7 base units (SI units) which all other units can be derived from.

Length in metre, mMass in kilogram, kgTime in second, sElectric Current in ampere, A Thermodynamic Temperature in kelvin, KAmount of Substance in mole, molLuminous Intensity in candela, cd

Write down the units for the following quantities in SI units.

Area
Volume
Current
Voltage
Resistance
Resistivity
Power
Energy
Distance
Speed
Acceleration
Force
Work Done
Energy
Moment
Weight
Power
Gravitational Field Strength
Pressure
Density
Spring Constant
Tensile Stress
Tensile Strain

Young Modulus
Elastic Energy Stored
Frequency
Wavelength
Refractive Index
Momentum
Force
Impulse
Planck’s Constant
De Broglie Wavelength
Angular Displacement
Angular Velocity
Centripetal Acceleration
Centripetal Force
Gravitational Field Constant
Gravitational Potential
Electric Field Strength
Electric Potential
Permittivity of Free Space
Capacitance
Time Constant
Energy Stored in a Capacitor
Magnetic Flux Density

Force on a Moving Charge
Magnetic Flux
Induced EMF
Activity

Binding Energy
Molar Gas Constant
Specific Heat Capacity
Specific Latent Heat

Practical	Photon Energy
N. DWYER	

You are going to use the minimum voltages required for different LEDs to emit light to calculate Plank's constant, h

Equipment List

Power Pack
Voltmeter
Ammeter
Photon Energy Array
Black Plastic Tube
Leads

Task

- Connect the power pack to the Photon Energy Array and ensure that the correct terminals are connected together. Select a voltage of 5V.
- Connect the voltmeter and ammeter to the Photon Energy Array.
- Turn the potential divider dial all the way to the left and select the LED of wavelength 430 nm.
- Calculate the frequency, *f*, of the light it will emit.
- Place the black tube over the LED and view from the other end.
- Turn the potential divider dial until light is only just emitted.
- Record the voltmeter reading.
- Take repeat readings and calculate the mean voltage, *V*, for that LED.
- Repeat this for LEDs of wavelengths 505, 560, 615, 655, 875 and 950 nm.
- Display your results for each LED in a table including a column of *eV*, where *e* is the charge of an electron and *V* is the mean voltage.
- Plot a graph of *eV* on the y-axis against *f* on the x-axis.
- Draw a line of best fit for your data.

After the Experiment

What was the precision of the voltmeter?

Use the precision to calculate the uncertainty in your first reading for the voltage of the LED with wavelength 505.

What is the percentage uncertainty?

Calculate the uncertainty in your value of the mean voltage for this LED.

What is the percentage uncertainty?

Use the precision to calculate the uncertainty in your first reading for the voltage of the LED with wavelength 605.

What is the percentage uncertainty?

Calculate the uncertainty in your value of the mean voltage for this LED.

What is the percentage uncertainty?

Use your graph to comment on the reliability of your results.

Calculate the gradient of your line of best fit.

What is the difference between your value and the accepted value of 6.63×10^{-34}?

Calculate the percentage difference between your gradient and the accepted value.

Theory states that the line will have an equation of , extrapolate your line of best fit so it cuts the y axis, does your graph support the theory? Why / why not?

What do you think was the largest source of error in the experiment?

Explain your answer.

What is the name give to this type of error?

Analysis	Quarks, Hadrons and Leptons
N. DWYER	

You are going to use data on the fundamental particles to find the theoretical masses of some Hadrons.

Experimental Data

Particle	Mass (MeV)			Mean Mass (MeV)	Uncertainty in Mass	Percentage Uncertainty in Mean
u	4.6	5.1	5.3			
d	7	9	8			
s	172	153	155			
c	1617	1442	1441			
b	4126	4432	4192			
t	195000	174000	171000			
e	0.58	0.45	0.50			
μ	104.9	105.4	106.8			
τ	1823	1854	1654			

Analysis

Calculate the mean masses for each of the particles.
Calculate the uncertainty in the mass reading for each particle. (This is equal to half the range of the values).
What is this as a percentage of the mean? (Divide the uncertainty by the mean value then multiply by 100).
Which has the lowest percentage uncertainty in the mean value?
How can we describe this value?

What is the quark composition of a proton?
Use the mean values to calculate the theoretical mass of a proton.
What is the percentage uncertainty in this value? (You should add the percentage uncertainties of the quarks used).
The actual rest mass of a proton is 938.3 MeV. What is the difference between this and your theoretical value?
What is the quark composition of a neutron?
Use the mean values to calculate the theoretical mass of a neutron.
What is the percentage uncertainty in this value?
The actual rest mass of a neutron is 939.6 MeV. What is the difference between this and your theoretical value?

What is the quark composition of a neutral pion?
Use the mean values to calculate the theoretical mass of a neutral pion.
What is the percentage uncertainty in this value?
The actual rest mass of a $\pi^0$is 135.0 MeV. What is the difference between this and your theoretical value?
What is the quark composition of a positive pion?
Use the mean values to calculate the theoretical mass of a positive pion.
What is the percentage uncertainty in this value?

The actual rest mass of a π^+ is 139.6 MeV. What is the difference between this and your theoretical value?

What is the quark composition of a positive kaon?
Use the mean values to calculate the theoretical mass of a positive kaon.
What is the percentage uncertainty in this value?
The actual rest mass of a K^+ is 493.7 MeV. What is the difference between this and your theoretical value?
What is the quark composition of a neutral kaon?
Use the mean values to calculate the theoretical mass of a neutral kaon.
What is the percentage uncertainty in this value?
The actual rest mass of a K^0 is 497.7 MeV. What is the difference between this and your theoretical value?

Analysis	The Threshold Frequency
N. DWYER	

The Threshold Frequency

You are going to analyse data from an experiment investigating the photoelectric effect. Using the wavelengths of the photons used and the speeds of the emerging electrons you will determine the threshold frequency of the metal.

Experimental Data

Here are the measured speeds of the emerging photoelectrons from the surface of the metal.

The Planck Constant = 6.63×10^{-34} Js   Electron Rest Mass = 9.11×10^{-31} kg

Wavelength, λ (nm)	**Speed of Photoelectrons ($\times 10^5$ m/s)**			
300	8.55	8.56	8.53	8.56
200	12.07	12.07	12.09	12.08
150	14.77	14.82	19.22	14.78
120	17.05	17.09	17.06	17.06
100	19.10	19.07	19.07	19.08

Wavelength, λ (nm)	**Frequency, f ($\times 10^{15}$ Hz)**	**Mean Speed, v ($\times 10^5$ m/s)**	**Mean E_K ($\times 10^{-19}$ J)**
300			
200			
150			
120			
100			

Analysis

What were the dependent and independent variables in this investigation?

Use to calculate the frequency of the photons for each wavelength.
Calculate the mean speed of the electrons given out for each wavelength.

Use to calculate the mean kinetic energy (E_K) of the emerging photoelectrons

Plot a graph of kinetic energy (on the y-axis) against the frequency (on the x-axis).
Draw a line of best fit and extrapolate this to so it cuts the x-axis.
Calculate the gradient of your line.
Theory states that the gradient should be equal to the Planck constant. What is the difference between you gradient and the accepted value?
What is the percentage difference of your value from the accepted value?

The threshold frequency of the metal can be obtained from your x-intercept of your graph.
What value did you obtain for the threshold frequency?
The accepted value is 0.5 x 10^{15} Hz, what is the difference between your value and the accepted value?
Calculate the percentage difference from the accepted value.

Using either your graph or the equation calculate the work function, ϕ
The accepted value is 2.5x10^{-19} J. What is the difference between your value and the accepted value?
What is the percentage difference of your value from the accepted value?

Calculate the uncertainty in the speed for the data from photons of wavelength 150 nm.
What is this as a percentage of the mean speed?

Analysis	Line Spectra
N. DWYER	

You are going to analyse the frequencies of photons emitted when electrons make transitions between different energy levels in Hydrogen atoms.

The Paschen Series

Transition	**Frequency, f (x 10^{14} Hz)**			**Mean f (x 10^{14} Hz)**	**Wavelength, λ (nm)**	**Energy Difference (eV)**
6 → 3	2.79	2.72	2.71			
5 → 3	2.39	2.28	2.35			
4 → 3	1.68	1.62	1.50			

The Balmer Series

Transition	**Frequency, f (x 10^{14} Hz)**			**Mean f (x 10^{14} Hz)**	**Wavelength, λ (nm)**	**Energy Difference (eV)**
6 → 2	7.27	7.33	7.36			
5 → 2	6.54	7.26	6.93			
4 → 2	6.23	6.17	6.11			
3 → 2	4.51	4.61	4.59			

The Lyman Series

Transition	**Frequency, f (x 10^{15} Hz)**			**Mean f (x 10^{15} Hz)**	**Wavelength, λ (nm)**	**Energy Difference (eV)**
6 → 1	3.35	3.01	3.21			
5 → 1	3.19	3.24	3.05			
4 → 1	3.12	3.16	2.99			
3 → 1	2.77	2.94	3.02			
2 → 1	2.37	2.53	2.48			

Infrared >750 nm, Visible Light 750 – 400 nm, Ultra Violet 10 – 400 nm
Red (625–740), Orange (590–625), Yellow (565–590), Green (520–565), Cyan (500–520), Blue (435–500), Violet (380–435)

For each transition calculate the mean frequency of the photon emitted.

Use the wave speed equation, to calculate the wavelength of the photon.

Using calculate the energy of the photon in Joules. Convert this to electronvolts and record it in the table.

What is the uncertainty in the frequency of the 4 → 3 transition?
Calculate this as a percentage of the mean frequency for this transition.
What is the uncertainty in the frequency of the 5 → 2 transition?
Calculate this as a percentage of the smallest frequency for this transition.
What is the uncertainty in the frequency of the 6 → 1 transition?
Calculate this as a percentage of the largest frequency for this transition.

For each transition state what type of photon from the EM Spectrum is emitted.
For photons in the Visible Light region of the EM Spectrum state which colour the photon would be.

If the ground state (n=1) has an energy of – 13.6 eV draw an energy level diagram for Hydrogen including values for each energy level.

Analysis	de Broglie Wavelength
N. DWYER	

Electrons were accelerated to a range of speed and their de Broglie wavelengths were measured. Use this experimental data to find a value for Planck's constant.

Experimental Data

Here are the measured wavelengths of the electrons travelling at certain velocities.
Electron rest mass = 9.11×10^{-31} kg

Velocity, v (m/s)	**De Broglie Wavelength, λ ($\times 10^{-4}$ m)**			**Mean λ ($\times 10^{-4}$ m)**	$1/\lambda$ (**m^{-1}**)
5	14.63	14.54	14.51		
6	12.01	12.18	12.20		
7	10.39	10.38	10.43		
8	9.09	9.05	9.16		
9	8.29	8.01	7.97		
10	7.31	7.14	7.39		

Analysis

What is the independent variable in this investigation?
What is the dependent variable in this investigation?

What is the precision of the wavelength measurements?
What is the precision of the velocity measurements?
What is the uncertainty in the velocity measurements?
Calculate the percentage uncertainty in the velocity measurement of 8 m/s

Calculate the mean values of the de Broglie wavelength for each velocity.
For each mean value calculate $1 / \lambda$.

Calculate the uncertainty in the measurement of λ when v is 5 m/s.
What is this as a percentage of the mean value?
Calculate the uncertainty in the measurement of λ when v is 7 m/s.
What is this as a percentage of the mean value?
Calculate the uncertainty in the measurement of λ when v is 9 m/s.

What is this as a percentage of the mean value?

Plot a graph of v against $1 / \lambda$ and draw a line of best fit.
Does the line pass through the origin? Should it? Explain your answer.
Calculate the gradient of your line of best fit.

If v and $1 / \lambda$ are linked by the equation , what does the gradient of your line of best fit represent?
Use your gradient to calculate a value of Planck's constant, h.
The accepted value is 6.63×10^{-34}, what is the different between your value and the accepted value?
What is this as a percentage of the accepted value?

Practical	I-V Graphs
N. DWYER	

I-V Graphs

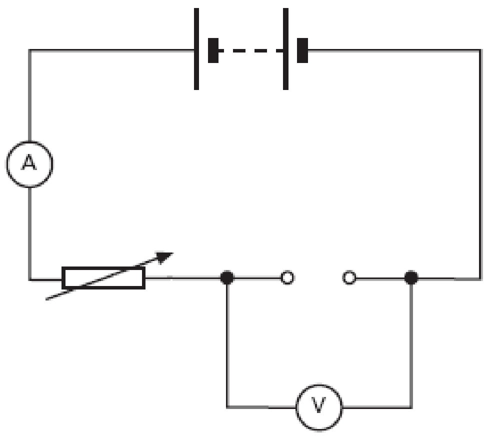
You are going to carry out an investigation to find the I-V graphs of three components.

Equipment List

Battery or Power Pack
Leads with Crocodile Clips
Voltmeter
Ammeter
Multimeter

Variable Resistor
Resistor
Filament Lamp
Diode
Safety Resistor (at least 100Ω)

Task



- Set up the appropriate circuit for the component you are investigating.
- For the diode experiment it is vital to include a safety resistor.
- Change the potential difference (V) across the components from zero to the maximum available from the power supply.
- Measure the current (I) for each p.d.
- Write down the precision of your meters.
- Take repeat reading and calculate a mean value
- Record your results in a table.
- Plot a graph of I (on the y-axis) against V.

After the Experiment

What was the independent variable in your investigation?
What did you use to measure this and what was the precision of this piece of equipment?
What was the dependent variable in your investigation?
What did you use to measure this and what was the precision of this piece of equipment?
If your voltmeter measures a p.d. of 0.20 V when the battery was disconnected, what is the name given to this type of error?
What is the name give to the type of error responsible for the spread of results in your ammeter readings?

RESISTOR

What is the uncertainty in the current for the greatest p.d. value?
Calculate this as a percentage of the mean current at this p.d.
What does the gradient of the I-V graph represent?
What resistance does your graph suggest that the resistor has?
Calculate the distance between the actual value and the value obtained from your graph.
What is this as a percentage of the actual value?

FILAMENT LAMP
At what p.d. did the component stop obeying Ohm's law?
What is the gradient of the line when it did obey Ohm's law?
What resistance does your graph suggest that the lamp has?

DIODE
What feature of your graph shows that the component is a semiconducting diode?
Does the diode appear to obey Ohm's law at any point on the graph?
Calculate the gradient and use this to calculate the resistance of the diode during this period.

Analysis	Ohm's Law
N. DWYER	

A resistor of unknown resistance was connected to a variable power supply. The current through, I, and potential difference across, V, were measured. You will use this information to calculate the resistance, R, of the resistor.

Experimental Data

Potential Difference, V (V)			Current, I (A)		
9.12	9.05	9.07	1.18	1.26	1.24
6.98	7.03	7.06	0.98	0.92	1.01
5.03	4.93	5.02	0.71	0.69	0.65
-4.11	-4.02	-4.04	-0.53	-0.59	-0.53
-5.89	-6.02	-5.98	-0.84	-0.86	-0.78
-8.07	-8.10	-7.92	-1.11	-1.08	-1.14

Mean Potential Difference, V (V)	Mean Current, I (A)	Resistance, R (Ω)

Analysis

Complete the table be calculating the mean values of V and I.
What is the precision of the voltmeter? What is the precision of the ammeter?

What is the uncertainty in the largest positive potential difference?
Calculate this as a percentage of the mean potential difference.
What is the uncertainty in the smallest negative potential difference?
Calculate this as a percentage of the mean potential difference.

What is the uncertainty in the smallest positive current?
Calculate this as a percentage of the mean current.
What is the uncertainty in the largest negative current?
Calculate this as a percentage of the mean current.

Which type of error is responsible for the differences in the potential difference and current measurements?

Plot a graph of I (on the y axis) against V (on the x axis).
Does your line of best fit pass through the origin? Should it? Explain your answer.
What does the gradient of your graph represent?
Calculate the gradient of your line of best fit.
Use the gradient to calculate the resistance, R, of the resistor.
The given value of the resistor is 7.3Ω, what is the difference between your value and the given value?
What is this as a percentage of the accepted value?

Complete the table using the equation to calculate R.
Calculate the mean value of resistance from the table.
What is the uncertainty of the mean resistance?
What is the difference between the accepted value given above and the value you calculated from the table?
Calculate this as a percentage of the accepted value.

You are going to investigate how much light passes through a number of layers of tracing paper using a bright light source and a light dependent resistor.

Equipment List

LDR	Ammeter
Leads	30cm Ruler
Switch	Tracing Paper
Battery/Power Pack	Scissors
Voltmeter	Desk Lamp

Task

- Set up a suitable circuit using the apparatus provided to determine the resistance of the LDR.
- Draw a diagram of your circuit showing your power supply, switch and meters.
- Position the lamp at a distance given by your supervisor so that it fully illuminates the LDR.
- Switch it on and determine the resistance R_0 of the LDR.
- **Do not change the distance between the lamp and the LDR in the remainder of the experiment.**
- Place a small piece of tracing paper over the LDR so that only light that passes through the paper reaches its light sensitive surface. Take readings to determine the new resistance of the LDR.
- Repeat the LDR resistance determination for a range of values of n, where n is the number of layers of tracing paper between the LDR and the lamp.
- Take repeat readings.
- Present all of your measurements in a table.
- For each value of n calculate $R = R_n - R_0$, where R_n is the LDR resistance with n layers of paper.
- Use your results to plot a graph of Ragainst n. Draw a line/curve of best fit.

After the Experiment

What was the independent variable in your investigation?
How many different values did you use for this variable?

Was this enough values? Justify your answer.
What was the dependent variable in your investigation?
How did you calculate this?

What was the precision of the ammeter?
What was the precision of the voltmeter?
Use your raw data to calculate the uncertainty in the current when n = 4.
What is this as a percentage of the mean current?
Use your raw data to calculate the uncertainty in the voltage when n = 4.
What is this as a percentage of the mean voltage?
What is the percentage uncertainty in the resistance calculated from these two values?

What does your graph show? Describe any features and explain any relationships.
Does your graph support the theory that as light intensity increases the resistance of the LDR decreases?
Why/why not?

How could you find the thickness of a single piece of tracing paper?
Explain how your experimental set up and graph could be used as a quality control measurement in tracing paper manufacturing.

Practical	Thermistor Thermometer
N. DWYER	

You are going to calibrate a thermistor to be used as a thermometer and use it to find the temperature of a liquid.

Equipment List

Battery or Power pack	Thermistor
Leads with Crocodile Clips	Calibrated Thermometer
Voltmeter	Beaker
Ammeter	Kettle
Multimeter	Plastic Bag

Task

- Put the thermistor in a waterproof plastic bag and place it into a beaker.
- Write down the precision of the thermometer.
- Pour 100ml boiling hot water into the beaker.
- Stir the water and measure the temperature $T$of the water, the potential difference V and the current I.
- Record your results in a table.
- For every 10 °C drop in temperature measure I and V.
- Write down the precision of the ammeter and voltmeter.
- Calculate the resistance R of the thermistor at each temperature using the equation $V=IR$
- Repeat the experiment twice and determine the average resistance at each temperature.
- Plot a graph of resistance R against temperature T.

After the Experiment

What was the independent variable in your investigation?
How did you measure this?
What was the dependent variable in your investigation?
How did you measure this?

Describe the graph you drew from your results.
Use your graph to comment on the reliability of your results.
How could you improve the reliability of your results?

Ask your supervisor to provide you with a beaker of hot water. Use your thermistor circuit and record the current and voltage of the water and ask your supervisor to measure the temperature using the calibrated thermometer.
Calculate the resistance of the thermistor.
Use your graph to find the temperature of the water.
What is the difference between your value for the temperature and your supervisor's value?
Calculate the percentage difference between your value and your supervisor's value.

For the largest temperature reading use your raw data to calculate the uncertainty in the current reading.
Calculate this as a percentage of the mean current at this temperature.
For the smallest temperature reading use your raw data to calculate the uncertainty in the voltage reading.
Calculate this as a percentage of the mean voltage at this temperature.
For the middle temperature reading use your raw data to calculate the uncertainty in the current reading.
Calculate this as a percentage of the lowest voltage reading at this temperature.
For the middle temperature reading use your raw data to calculate the uncertainty in the voltage reading.
Calculate this as a percentage of the smallest voltage reading at this temperature.
How could you increase the precision of your results?

Practical	Resistivity of Copper
N. DWYER	

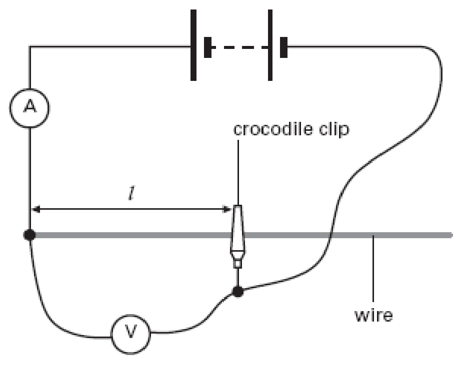
You are going to carry out an experiment to determine the resistivity of a copper.

Equipment List

Battery	Multimeter
Leads with Crocodile Clips	Rulers (30cm and 1m)
Voltmeter	Vernier Callipers
Ammeter	Copper Wire

Task

- Cut a section of copper wire just over 1m in length.
- Measure the diameter of the wire in a number of places along the wire. Record your readings.
- Calculate the cross sectional area of the wire.
- Set up a circuit with the battery, ammeter and copper wire in series. Connect a voltmeter to measure the pd across the wire.
- Adjust the wire so only 1m of the copper wire is in the circuit. Record the current and the potential difference.
- SWITCH OFF OR DISCONNECT THE BATTERY BETWEEN READINGS



- Take repeat readings and calculate the mean values for your readings.
- Repeat this to take readings of current and potential difference for difference lengths of copper wire.
- Calculate the resistance from the mean values.

- Plot a graph of the resistance (on the y-axis) and the length of copper wire (on the x-axis)
- Calculate the gradient of the line. Use this to calculate the resistivity of copper.

After the Experiment

What was the independent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?
What was the dependent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?

Use your raw data to calculate the uncertainty in your largest measurement of the current.
Now calculate the percentage uncertainty in this measurement.
Use your raw data to calculate the uncertainty in the corresponding measurement of the potential difference.
Now calculate the percentage uncertainty in this measurement.
What is the percentage uncertainty in the resistance calculated from these measurements?

Use your graph to comment on the reliability of your results.
How could you increase the reliability of your results?
How could you increase the precision of your results?

If your voltmeter measures a potential difference of 0.20 V when the battery was disconnected, what is the name given to this type of error?
What is the name give to the type of error responsible for the spread of results in your voltmeter readings for 30cm?
Why do you think you were instructed to switch off or disconnect the battery between measurements?

Analysis	Resistivity of Copper
N. DWYER	

Different lengths of copper wire were used to find its resistivity. A potential difference was applied across the wires and the current through them was recorded. The wire had a diameter of 0.9 mm.

Experimental Data

Here is the experimental data collected from the different lengths of copper wire.

Length, l (m)	**p.d., V (mV)**	**Current, I (A)**			**Mean Current, I (A)**	**Resistance, R (Ω)**
1.00	54	2.103	1.978	1.995		
2.00	54	1.021	1.004	1.014		
3.00	54	0.651	0.662	0.712		
4.00	54	0.511	0.514	0.493		
5.00	54	0.395	0.411	0.409		
6.00	54	0.347	0.333	0.334		

Analysis

Calculate the cross-sectional area of the wire using the equation

Calculate the mean value of current for each of the different lengths of wire.
Use the equation   to calculate the resistance of each of the different lengths of wire.

What is the precision of the length measurements?
What is the smallest division on the ruler used to measure it?
What is the precision of the voltmeter used?

Calculate the uncertainty in the current when the wire is 2.00 m long.
What is this as a percentage of the mean current?
What would be the percentage uncertainty in the corresponding value of R?
Calculate the uncertainty in the current when the wire is 4.00 m long.
What is this as a percentage of the mean current?
What would be the percentage uncertainty in the corresponding value of R?
Calculate the uncertainty in the current when the wire is 6.00 m long.
What is this as a percentage of the mean current?
What would be the percentage uncertainty in the corresponding value of R?

Plot a graph of R (y axis) against l and draw a line of best fit.
Does your line of best fit pass through the origin? Should it? Explain your answer.

If the equation linking R and l is   , what does the gradient of your line represent?
Calculate the gradient of your line of best fit.
Use the gradient to find the value of resistivity.

The accepted value of the resistivity of copper at 20 °C is 1.68×10^{-8} Ωm.
What is the difference between this value and the value you obtained from your graph?
Calculate this as a percentage of the accepted value.

Practical	Resistivity of a Metal Wire
N. DWYER	

Resistivity of a Metal Wire

You are going to investigate the variation with length of the resistance of the wire supplied

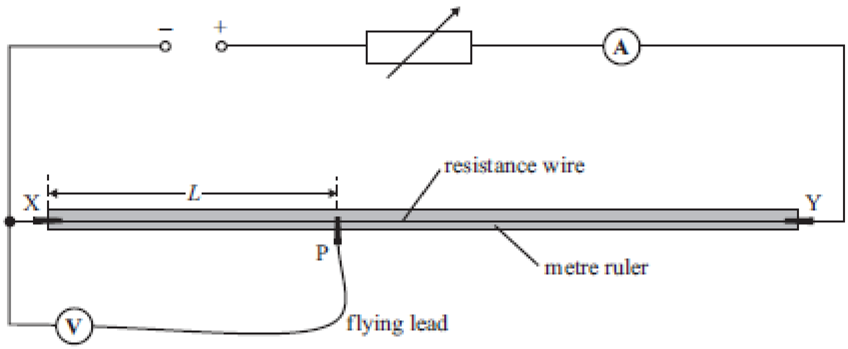
Equipment List

Battery	Multimeter
Leads with Crocodile Clips	Rulers (30cm and 1m)
Voltmeter	Vernier Callipers
Ammeter	Copper Wire

Task

- Complete the circuit as shown in the diagram below: crocodile clips X, Y and P are already in place with leads attached.
- Record the precision of your voltmeter and your ammeter
- Switch on the power supply and adjust the variable resistor if you are using one in your circuit, or the voltage control on the power supply if you do not have a variable resistor, so that the current, I, shown on the ammeter is 0.50 A.
  Always switch off the supply between readings and also ensure that I = 0.50 A before reading the voltmeter
- Observe how the pd, V, between X and P varies for different lengths L of wire between X and P.
- Decide on a range of values for L for which you will measure V.
- Prepare a table to record all of your measurements for L and V and include a column for the resistance, R, of the wire between X and P.

- Carry out your experiment and complete your table.
- Draw a graph to show how R (plotted on the vertical axis) varies with L.



After the Experiment

What was the independent variable in your investigation? What did you use to measure this?
What was the precision of this piece of equipment?
What was the dependent variable in your investigation? What did you use to measure this?
What was the precision of this piece of equipment?

Use your raw data to calculate the uncertainty in your largest measurement of the mean pd, V
Now calculate the percentage uncertainty in this measurement.
What is the uncertainty in your value for the current, I?
Now calculate the percentage uncertainty in this measurement.
What is the percentage uncertainty in the resistance calculated from these measurements?

Use your graph to comment on the reliability of your results.
How could you increase the reliability of your results?
How could you increase the precision of your results?
Calculate the gradient of the graph?
What does the gradient represent?
What value do you get for the resistivity of the wire?

Practical	Series and Parallel Circuits
N. DWYER	

You are going to carry out an experiment to investigate how the theoretical value of resistors in series and parallel differs from values obtained experimentally.

Equipment List

Battery or Power Pack	Ammeter
Leads with Crocodile Clips	Multimeter
Voltmeter	Resistors (of at least 8 different values)

Task

- SWITCH OFF OR DISCONNECT THE BATTERY BETWEEN READINGS.
- Set up a circuit with two resistors in series, a power supply, a voltmeter and an ammeter.
- Draw a diagram of the circuit you used.
- Write down the precision of the instruments used.
- Calculate the theoretical value for the total resistance of the resistors.
- Take readings of the potential difference and the current of the circuit.
- Calculate the total resistance of the resistors
- Repeat the experiment with different values of R_1 and R_2.
- Set up a similar circuit with two resistors in parallel.
- Record all of your results in two tables like the one below.

R_1 (Ω)	R_2 (Ω)	R_{TOTAL} (Ω) theoretical	p.d. V (V)	Current I (A)	R_{TOTAL} (Ω) measured

After the Experiment – Series

Look at the data with the lowest theoretical total resistance. What is the uncertainty in the p.d. reading?
Calculate the percentage uncertainty in this reading.
What is the difference between the actual value and the theoretical value for the total resistance?
Calculate this as a percentage of the theoretical value.

Look at the data with the second highest theoretical total resistance. What is the uncertainty in the current reading?
Calculate the percentage uncertainty in this reading.
What is the difference between the actual value and the theoretical value for the total resistance?
Calculate this as a percentage of the theoretical value.
Which set of data has a smaller percentage difference?
What word can we use this to describe this result?

After the Experiment – Parallel

Look at the data with the second lowest theoretical total resistance. What is the uncertainty in the p.d. reading?
Calculate the percentage uncertainty in this reading.
What is the difference between the actual value and the theoretical value for the total resistance?
Calculate this as a percentage of the theoretical value.

Look at the data with the highest theoretical total resistance. What is the uncertainty in the current reading?
Calculate the percentage uncertainty in this reading.
What is the difference between the actual value and the theoretical value for the total resistance?
Calculate this as a percentage of the theoretical value.
What do you think is responsible for the difference between the theoretical and actual values?

Practical	EMF and Internal Resistance
N. DWYER	

You are going to carry out an experiment to investigate the relationship between the terminal potential difference across and the current through a cell or battery when connected to a range of different value resistors.

Equipment List

Battery
Leads with Crocodile Clips
Voltmeter
Ammeter
Multimeter
Resistors (of 8 different values)

Task

- SWITCH OFF OR DISCONNECT THE BATTERY BETWEEN READINGS
- Set up a circuit with the battery, ammeter and a resistor in series. Connect a voltmeter to measure the pd across the cell terminals.
- Write down the precision of the instruments used.
- For each resistor, record the current and terminal pd values in a suitable table. Include the resistor value in the table. Take readings for the eight different resistors provided.

- Take repeat readings
- Draw a circuit diagram of the circuit you used.
- Plot a graph of the terminal pd (on the y-axis) and the current (on the x-axis) and draw a line of best fit.
- Calculate the gradient of the line and the y intercept.

After the Experiment

What was the independent variable in your investigation?
How did you vary this?
What did you use to measure this?
What was the precision of this piece of equipment?

What was the dependent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?

Use the precision of your equipment to calculate the percentage uncertainty of your smallest measurement of the current.
Use the precision of your equipment to calculate the percentage uncertainty of your smallest measurement of the potential difference.
Which is the greater source of uncertainty? Why?

Use your raw data to calculate the uncertainty in your largest measurement of the current.
Now calculate the percentage uncertainty in this measurement.
Use your raw data to calculate the uncertainty in your largest measurement of the potential difference.
Now calculate the percentage uncertainty in this measurement.

Use your graph to comment on the reliability of your results.
How could you increase the reliability of your results?
How could you increase the precision of your results?

Why do you think you were instructed to switch off or disconnect the battery between measurements?

Analysis	EMF and Internal Resistance
N. DWYER	

A battery was connected to a resistor, the current was measured through the circuit and the potential difference was measured at the terminals of the battery. By varying the resistor value it is possible to find the EMF and internal resistance of the battery.

Experimental Data

Here is the experimental data collected from using different external resistors.

Resistance, R **(Ω)**	**Terminal p.d.,** V **(V)**			**Current** I **(A)**			**Mean p.d.,** V **(V)**	**Mean Current,** I **(A)**
1	1.23	1.18	1.22	1.07	1.14	1.09		
1.5	1.26	1.35	1.26	0.84	0.76	0.84		
2.2	1.33	1.34	1.31	0.57	0.55	0.59		
3.3	1.38	1.37	1.38	0.39	0.43	0.41		

4.7	1.39	1.40	1.40	0.32	0.29	0.29		
6.8	1.42	1.42	1.41	0.21	0.21	0.22		
10	1.43	1.45	1.44	0.14	0.14	0.14		
22	1.46	1.45	1.46	0.07	0.08	0.07		

Analysis

Draw the circuit used in this investigation.
Calculate the mean p.d. and current for each of the resistance values.
What is the precision of the voltmeter and ammeter?

What is the independent variable in this investigation?
What is the dependent variable in this investigation?

Calculate the uncertainty in the largest mean value of p.d.
What is this as a percentage of the mean?
Calculate the uncertainty in the p.d. when the resistance was 3.3Ω
What is this as a percentage of the mean?
Calculate the uncertainty in the smallest mean value of current.
What is this as a percentage of the mean?
Calculate the uncertainty in the current when the resistance was 6.8Ω
What is this as a percentage of the mean?

Plot a graph of V against I (on the x axis) and draw a line of best fit.
If V and I are connected by the equation , what does the gradient of the line represent?
Calculate the gradient of your line of best fit.
What does the y-intercept of your line represent?
Write down the value of the y-intercept from your graph.
If the internal resistance was increased what effect would this have one your graph?

Practical	Potential Dividers
N. DWYER	

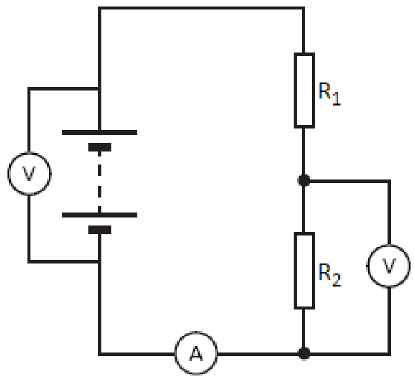
You are going to carry out an experiment to investigate the relationship between the value of first resistor and the potential difference across the second resistor.

Equipment List

Battery or Power Pack
Leads with Crocodile Clips
Voltmeter x2
Ammeter
Multimeter
Resistors (of at least 8 different values)

Task

- SWITCH OFF OR DISCONNECT THE BATTERY BETWEEN READINGS.
- Set up a circuit as shown in the diagram with R_1 = 10 kΩ and R_2 = 50 kΩ.
- Record the p.d. across the battery (V_{IN}).
- Record the p.d. across R_2 (V_{OUT}).
- Write down the precision of the instruments used.
- Keep R_2 the same but replace R_1 with resistors of other values.
- For each R_1 record the V_{OUT} and take repeat readings.



- For each value of R_1 calculate R_1+R_2 and
- Record all of your results in one table.

- Plot a graph of V_{OUT}(on the y-axis) against and draw a line of best fit.

After the Experiment

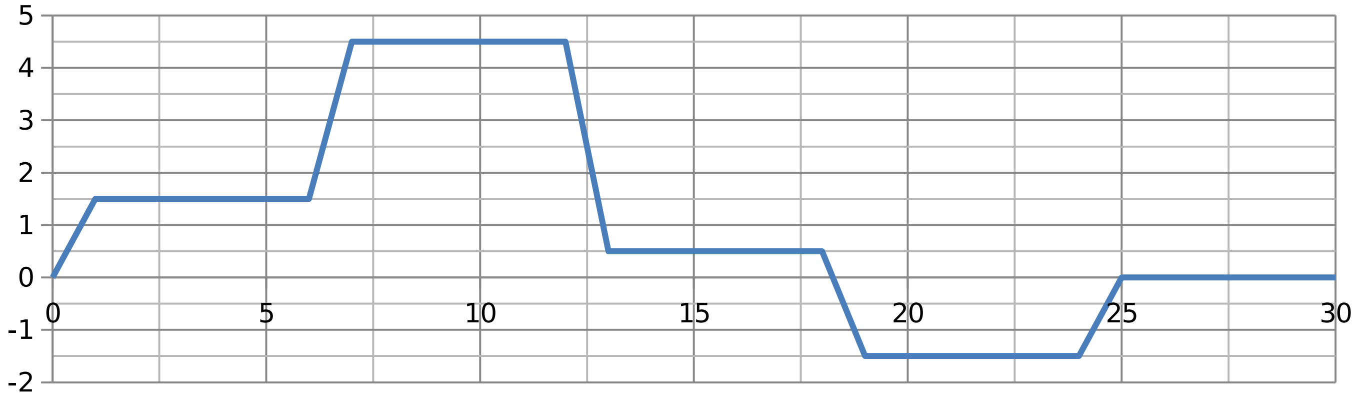
What assumption did we make in this investigation?
What type of error is responsible for the spread in values or V_{OUT} for each value of R_1?
If the voltmeter measured a p.d. of 0.20 V when the battery was disconnected, what is the name given to this type of error?
How many difference values of R_1 did you use?
Explain why this was or wasn't enough values.
What is the uncertainty in V_{OUT} for the largest value of R_1?
Calculate this as a percentage of the mean value of V_{OUT}.

The relationship that links the V_{OUT} with the values of R_1 and R_2 is .
Use this to find the equation of your line of best fit and state what the gradient of the line of best represents.
Does your graph support this equation? Explain your answer.
Calculate the theoretical value of the gradient.
Calculate the gradient of your line of best fit from the graph.
What is the difference between the theoretical value for the gradient and the value obtained from the graph?
Calculate this as percentage of the theoretical value.

Use your graph to comment on the reliability of your results.
How could you increase the reliability of your results?
How could you increase the precision of your results?
Why do you think you were instructed to switch off or disconnect the battery between measurements?

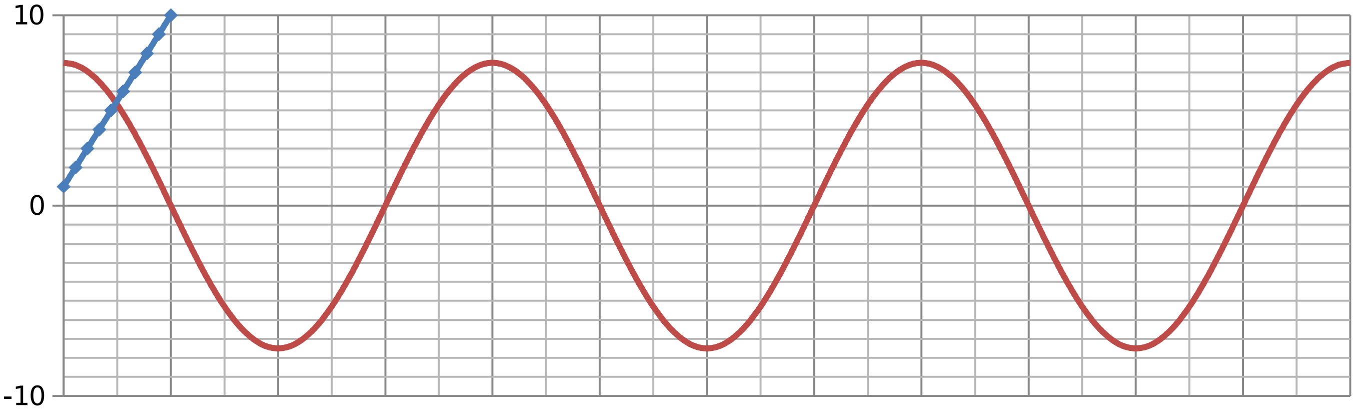
Analysis	Oscilloscope Traces
N. DWYER	

An oscilloscope was used to determine the overall potential difference of five batteries which were added to a circuit one at a time. The volts/div is set at 1V and the time base is set at 2 seconds.

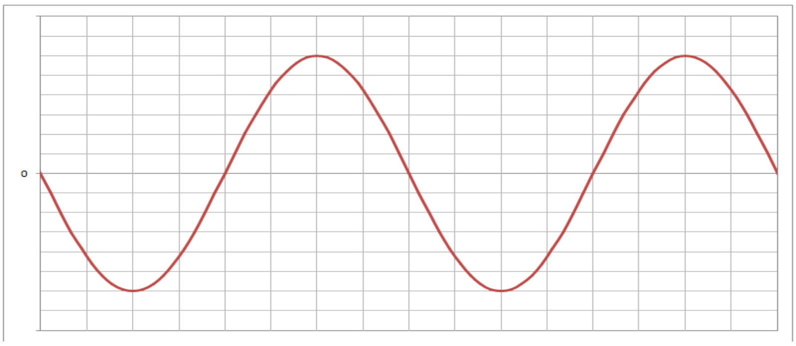


Write down the voltages of the five batteries, how long they are in the circuit before the next one is added and the direction it is placed in.

Here is the oscilloscope traces for the potential difference of an alternating supply. The volts/div is set at 2V and the time base is set at 6 ms.



What is the peak voltage, peak to peak voltage and the time period?How long does the whole trace represent?

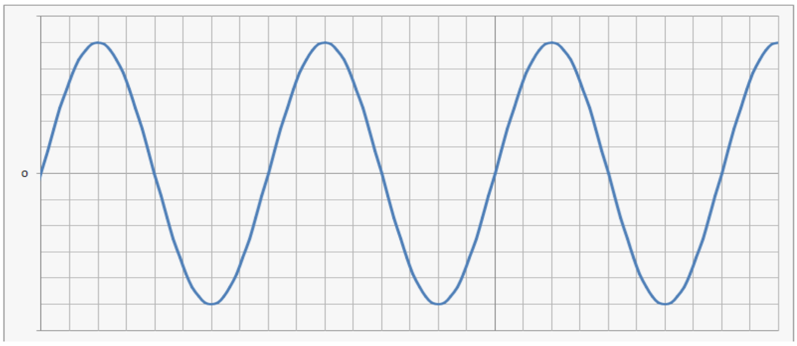


The volts/div is set at 4V and the time base is set at 0.5ms.

What is the peak voltage, peak to peak voltage and the time period?How long does the whole trace represent?

The volts/div is set at 1.5V and the time base is set at 0.5 s.

What is the peak voltage, peak to peak voltage and the time period?How long does the whole trace represent?



Practical	Resolving Forces to find Weight
N. DWYER	

Resolving Forces to find Weight

You are going to carry out an experiment using two force meters and Pythagoras to find the weight and mass of a can containing and unknown amount of water.

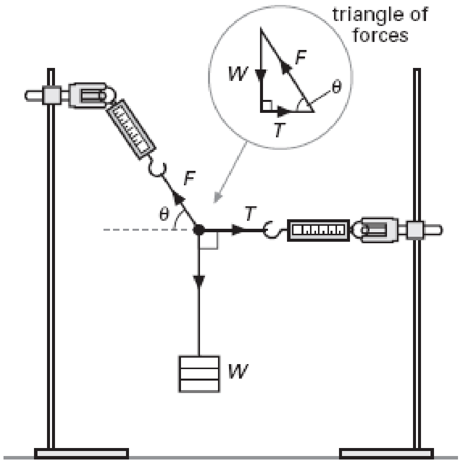
Equipment List

Clamp stand (x2)
Boss and Clamp (x2)
Force meter, 10N (x2)
Protractor

String
Can of unknown mass
Paper clip
Rulers (1m and 30cm)

Task

- Cut a length of string approximately 0.60 m and tie a loop at each end and one in the middle.
- Set up the right clamp stand with the force meter attached to it approximately 0.05 m from the top of the desk.
- Place the left clamp stand between 0.60 and 1.00 m away from the right clamp stand and attach the string between the force meters.
- Attach the can of unknown mass to the middle of the string.
- Raise the force meter on the left until the right force meter is perpendicular to the desk top.
- Measure the angle θ with a protractor and state its precision.
- Measure the tensions *T* and *F* from the force meters.



- Repeat the experiment for different values of θ and record your results in a table.
- For each value of θ construct a triangle of forces and determine the weight, W, of the can.
- From each value of the weight, W, calculate the mass, m of the can.
- Use each force meter to find the average weight of the can and from this find the mass.

After the Experiment

In your investigation what were the independent and dependent variables?
What is the uncertainty in your measurements of the angle θ?
For the smallest value of θ calculate the percentage uncertainty.
How could you increase the reliability of your results?
How could you increase the precision of your measurements for the angle θ and for the forces *T* and *F*?

Ask your supervisor to use a calibrated electronic scale to measure the mass of the can.
Calculate the average value of the mass from the different values of θ that you used.
What is the difference between your value and your supervisor's?
Calculate this as a percentage of your supervisor's value.
What is the difference between your value and the value you calculated at the end of the investigation?

Choose a set of results for any value of θ and calculate $F \cos\theta$.
This value should be equal to the corresponding value of *T* when the system in in equilibrium.
What is the difference between *T* and $F \cos\theta$?
Calculate this as a percentage of *T*.
For the same set of results calculate $F \sin\theta$.
This value should be equal to the weight of the can when the system is in equilibrium.
What is the difference between $F \sin\theta$ and the actual weight of the can? What could have caused this difference?

Practical	Moments
N. DWYER	

You are going to carry out an experiment to investigate the effect that position of mass suspension has on the dip of a ruler.

Equipment List

Wooden metre ruler (x2)	Masses (100g x 10)
G Clamp	Mass hanger
Masses (50g x 1)	Rubber band

Task

- Using the G clamp attach one of the rulers to your desk so that 8cm rests on the surface and the remainder stick out unsupported. The point where the ruler first protrudes from the desk shall be called the pivot.
- Measure the height of the free end of the ruler from the floor. Take repeat readings and record this result.
- Set up the masses and hanger so that they have a combined mass of 500g.
- Use the rubber band to attach the mass hanger to the ruler.
- Position it at various distances from the pivot.
- For each distance from the pivot measure the height of the free end of the ruler and use it to calculate the dip of the ruler.
- Take repeat readings and record your results in a table.
- Plot a graph of distance from pivot (on the x axis) against the dip of the ruler.
- Draw a line or curve of best fit.
- Now position the 500g hanger at a distance of 10cm from the pivot.
- Calculate the moment and measure the dip.
- Repeat this for various masses and distances from the pivot but applying the same moment each time.
- Record your results for this part of the investigation in a separate table.

After the Experiment

In the first part of the investigation what was the independent variable?
What was the dependent variable and how did you measure it?
What was the precision of the instrument you used?

What is the uncertainty in the dip measurement for your greatest distance from the pivot?
Calculate this as a percentage of the mean dip for this distance.
What is the uncertainty in the dip measurement for your second smallest distance from the pivot?
Calculate this as a percentage of the largest dip measured for this distance.
What is the uncertainty in the dip measurement for the middle value for the distance from the pivot?
Calculate this as a percentage of the smallest dip measured for this distance.

Explain the relationship your graph suggest between the distance from the pivot and the dip caused in the ruler.
How could you increase the reliability of your results?
How could you increase the precision of your results?

What conclusion can you make from the second part of the investigation?
When calculating the force applied what value did you use for g?
Using the correct scientific terminology explain why it is better to use a value of 9.81 rather than 10.
What results would suggest that the dip is dependent on the moment regardless of the distance from the pivot?
What results would suggest the opposite?

Practical	Rolling Down a Ramp
N. DWYER	

You are going to carry out an experiment to investigate the acceleration due to gravity using a section of dowel rolling down a ramp which in inclined at an angle of θ to the bench.

Equipment List

Ramp with support and feet
Protractor
Section of dowel
Stop clock
Rulers (30cm and 1m)

Task

- Set up the ramp by attaching one end to the lowest part of the support.
- Measure the angle the ramp makes with the desk.
- State the precision of the protractor.
- Measure the time, t, that the cylinder takes to roll different distances, s, down the ramp.
- Take repeat readings for each distance you choose.
- Present all your measurements in a table.
- For each value of s, calculate t^2 and include these values in your table.
- Plot a graph of t^2 (on the y-axis) against s.
- State the precision of the stop clock that you used in this experiment.

After the Experiment

What was the independent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?
What was the dependent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?

Suggest two reasons why repeat timings at each distance would be expected to spread about a mean value.
Use the spread of your results to calculate the uncertainty in your measurement of t for your:

Largest value of s.
Smallest value of s.
Middle value of s.

Using the *suvat* equations calculate the value of a for your middle value of s.
Calculate the value of $a \sin \theta$.
If this value should be the acceleration due to gravity, 9.81, calculate the difference of your value from the accepted.
What is the percentage difference of your value from the accepted?

Use your graph to comment on the reliability of your results.
Calculate the gradient of your graph.

Theory states that the equation for the line is: , does your graph support this theory?
Use your value for the gradient of the line to calculate the value of a.
What is the difference of this value from your value of a from above?

A student predicts that a hollow cylinder will roll more slowly down a slope than a solid cylinder of the same radius. Describe an experiment to test this theory.

Practical	Acceleration Due to Gravity
N. DWYER	

You are going to carry out an experiment to find the acceleration due to gravity of a falling ball. You will then compare this to the theoretical value.

Equipment List

Table tennis ball
Tennis ball
Ball of screwed up paper
Tape measure
Stop clock
Post-it notes or other sticky markers

Task

- Use the taper measure to mark heights between 3 and 5 metres from the floor.
- Time how long it takes for the table tennis ball to reach the ground when released from rest at 3 metres.
- Take repeat readings and calculate the mean time taken, t.
- Record your results in a table and including a column of t^2.
- Repeat this for the different heights you have chosen between 3 and 5 metres from the floor.
- Plot a graph of distance travelled s (y axis) against t^2.
- Draw a line of best fit and calculate the gradient.
- Repeat the whole procedure for the tennis ball and the paper ball.

After the Experiment

What was the independent variable in your investigation?
What did you use to measure this and what was the precision of this piece of equipment?
How many different values for this variable did you use? Was this enough? Explain your answer.

Table tennis ball

What was the uncertainty in value of t when released from a height of 5 metres?
Calculate this as a percentage of the mean value of t.
What does the gradient of each graph represent?
Use your gradient of your graph to write down the value for the acceleration.
What is the difference between this value and the accepted value of 9.81 m/s^2?
Calculate this as a percentage of the accepted value.

Tennis ball

What was the uncertainty in value of t when released from a height of 5 metres?
Calculate this as a percentage of the mean value of t.
Use your gradient of your graph to write down the value for the acceleration.
What is the difference between this value and the accepted value of 9.81 m/s^2?
Calculate this as a percentage of the accepted value.

Paper ball

What was the uncertainty in value of t when released from a height of 5 metres?
Calculate this as a percentage of the mean value of t.
Use your gradient of your graph to write down the value for the acceleration.
What is the difference between this value and the accepted value of 9.81 m/s^2?
Calculate this as a percentage of the accepted value.

What type of error is responsible for the spread of results for each measurement of time and how did it arise?
Which of the balls was affected most by air resistance?
How could you use light gates and a data logger to improve your results?
How would this improve your results?

You are going to carry out an experiment to investigate how quickly different sized objects reach terminal velocity.

Equipment List

Bun Cases (various sizes)
Stop Clock
Tape Measure
Rulers (30cm and 1m)
Clamp Stand
Boss and Clamp

Task

- Choose a bun case and measure its diameter.
- Drop the bun case from a height of 2.5 m and time how long it takes for it to reach terminal velocity.
- Take repeat readings.
- Repeat the investigation with bun cases of different diameters.
- Record your results in a table.
- Clamp the meter ruler vertically and position it at the end of the workbench.
- Adjust its height so that the when a bun case is released from a height of 2.5 m it will reach terminal velocity before passing the ruler.
- Drop the bun case from a height of 2.5 m again and time how long it takes to pass the meter ruler.
- Take repeat readings.
- Calculate the mean terminal velocity of the bun case as it passes the ruler.
- Repeat the investigation with bun cases of different diameters.
- Record your results in a table.
- Plot a graph of bun case diameter (on the x axis) against time taken to reach terminal velocity.
- Plot a graph of bun case diameter (x axis) against terminal velocity.
- Draw a line of best fit for each graph.

After the Experiment

What was the independent variable in your investigation?
What did you use to measure this and what was the precision of this piece of equipment?

What type of error is responsible for the spread of results for the time taken to reach terminal velocity?
Explain how this arose.
For the largest bun case diameter calculate the uncertainty in the time taken.
What is this as a percentage of the mean time taken?
What does your first graph tell you about the connection between the two variables?
What does the second graph tell you about the connection between the two variables?
If you have drawn a straight line of best fit calculate its gradient. If you have drawn a curve of best fit draw a tangent to the curve when the x axis value is the middle of the scale then calculate its gradient.
What is the uncertainty in the terminal velocity of the smallest bun case?
Calculate this as a percentage of the mean terminal velocity.
What is the uncertainty in the terminal velocity of the largest bun case?
Calculate this as a percentage of the smallest terminal velocity.
Choose the data from any other bun case size. What is the uncertainty in the terminal velocity?
Calculate this as a percentage of the largest terminal velocity.
How can we describe the value with the lowest percentage uncertainty?

Describe and explain how the use of a motion sensor or light gate could lead to better results.

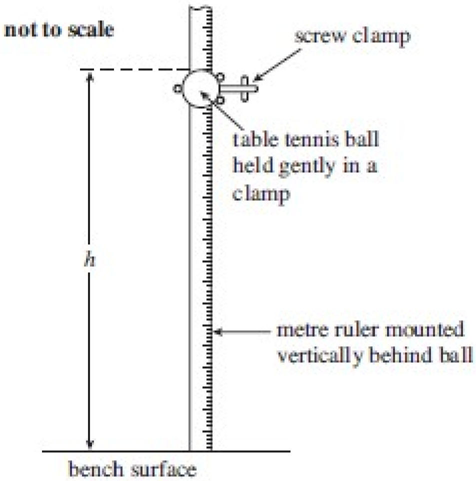
Practical	Bouncing Ball
N. DWYER	

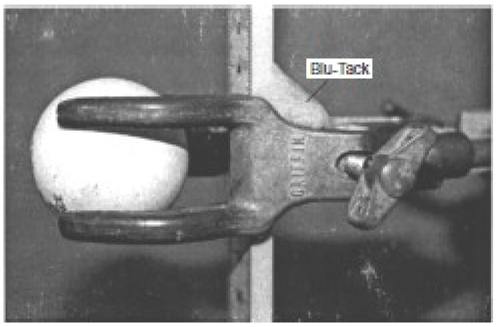
You are going to investigate how the height from which a table tennis ball is dropped affects how high it bounces.

Equipment List

Table Tennis Ball
Ruler (1m)
Blu-Tack
Clamp

Task





- Use the ruler to measure the diameter, d, of the table tennis ball and record this result.
- Give an estimate of the uncertainty in this measurement
- Set up the apparatus as shown. The metre ruler should be held vertically in place at the back of the open clamp by a piece of Blu-Tack with another piece of Blu-Tack securing it to the bench. The table tennis ball should be gently clamped into position in front of the ruler
- Open the clamp and observe the motion of the ball as it bounces on the bench
- Decide on a range of heights, h, measured to the top of the ball, from which you will release the ball so that you can measure the height, s, of its first bounce, also measured to the top of the ball
- Prepare a single table for recording all of your measurements, including repeat readings for s
- Carry out your experiment and complete your table
- Draw a graph to show how s (plotted on the vertical axis) varies with h.

After the Experiment

In your investigation what was independent variable?
What was the dependent variable?
Describe the relationship (if there is one) between s and h.
What is the uncertainty in your measurement of h?
Calculate the percentage uncertainty in your largest value of h.
Calculate the percentage uncertainty in your smallest value of h.
Explain the source of error responsible for the variations in your measurements of s
How could you have made your measurements less precise?

Use data from your table to estimate the uncertainty in your largest mean value of s.
Estimate the percentage uncertainty in your largest mean value of s.
State and explain your estimate for the uncertainty in your measurement of the diameter, d, of the table tennis ball.

The loss in gravitational potential energy, ΔE_P, of a body falling to the Earth's surface is given by where mg is the weight of the ball and x is the vertical distance through which its centre of mass falls.

In your experiment $x = h - d$. Calculate x for your smallest value of h.

Using your uncertainty in s and d, estimate the uncertainty in your value for x.

Calculate ΔE_P for your smallest value of h. mg =0.026 +-0.001N

Determine the percentage uncertainty in ΔE_P.

Practical	Work Done
N. DWYER	

You are going to carry out an experiment to investigate the work done when a mass is pulled up an inclined plane.

Equipment List

200g mass with hanger
Forcemeter
Inclined plane
Materials to cover plane
Rulers (1m and 30cm)
Protractor

Task

- Use the protractor to set the plane to an incline of 20°.
- Measure the height of the plane and state the precision of your reading.
- Take several measurements of the length, s, of the plane and calculate the mean value.
- Use the forcemeter to drag the 200g mass across the table and then up the plane.
- Record the force used to pull the mass up the plane.
- Take repeat readings and calculate the mean force applied, F.
- For this angle calculate the work done using .
- Calculate the gain in gravitational potential energy using .
- Calculate the difference in the work done and the gravitational potential energy.
- Repeat this for other angles of incline.
- Plot a graph on angle of incline (x axis) against difference between W and E.
- Draw a line of best fir for your graph.
- Repeat the investigation with different materials covering the plane.

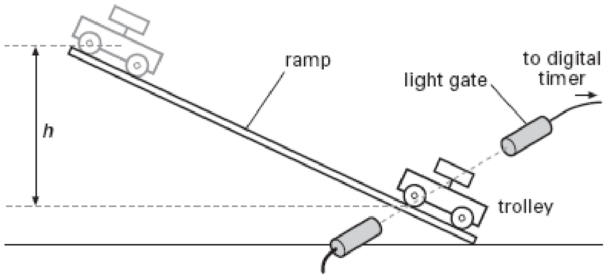
After the Experiment

What was the independent variable in the investigation?
How many different values did you use for this? Was this enough? Explain your answer.
What was the precision of the instrument you used to measure it?
What was the dependent variable in the investigation?
What is the uncertainty in your measurements of the height?
Calculate the percentage uncertainty of your largest height measurement.
Calculate the percentage uncertainty of your smallest height measurement.
What word describes the value with the smaller percentage uncertainty?

What is the uncertainty in the force for the largest angle on incline?
Calculate this as a percentage of the mean value for the force
What is the uncertainty in the force for the second largest angle of incline?
Calculate this as a percentage of the smallest value of force at this angle.
What is the uncertainty in the force for the middle value for the angle of incline?
Calculate this as a percentage of the largest value of force at this angle.
Which type of error is responsible for the differences in the force applied to pull the mass up the incline?

There was a difference between the gravitational potential energy gained and the work done.
What was responsible for this difference? Where did the energy go?
If you carried out the investigation for other materials how did they compare to each other?
What trend does your graph suggest about the relationship between the angle of incline and the difference?
Use your graph to comment on the reliability of your results.
How could you increase the reliability of your results?

You will investigate the transfer of gravitational potential energy to kinetic energy for a trolley rolling down a ramp. The trolley had a piece of card 10 cm long attached to the top. The digital timer measures the time taken for the card to completely cut through the light gate. The trolley has a mass of 250g.
Here is the experimental data obtained.



Experimental Data

Height, h (m)	Time Taken, t (s)			Velocity, v (m/s)		
	t_1	t_2	t_3	v_1	v_2	v_3
0.1	0.16	0.15	0.16			
0.2	0.10	0.11	0.12			
0.3	0.10	0.09	0.09			
0.4	0.06	0.09	0.08			
0.5	0.07	0.07	0.07			

Height, h (m)	Mean Velocity, v (m/s)	E_K (J)	E_P (J)	$E_P - E_K$ (J)
0.1				
0.2				
0.3				
0.4				
0.5				

Analysis

For each measurement of time calculate the velocity of the trolley.
Calculate the mean value of the velocity for each height that the trolley is released from.
What is the uncertainty in the velocity for a height of 0.2 m?
Calculate this as a percentage of the mean velocity.
What is the uncertainty in the velocity for a height of 0.3 m?
Calculate this as a percentage of the smallest velocity at this height.
What is the uncertainty in the velocity for a height of 0.4 m?
Calculate this as a percentage of the smallest velocity at this height.
Which type of error is responsible for the differences in the time measurements?

Calculate the kinetic energy the trolley has gained as it passes through the light gate.
What is the percentage uncertainty in the kinetic energy for a height of 0.2 m?
What is the percentage uncertainty in the kinetic energy for a height of 0.3 m?
What is the percentage uncertainty in the kinetic energy for a height of 0.4 m?
Calculate the gravitational potential energy that the trolley has lost as it passes through the light gate.

Plot a graph of kinetic energy gained against gravitational potential energy lost.
Draw a line of best fit and calculate the gradient of this line.
Explain what a gradient equal to 1 would mean and explain why the gradient will not be equal to 1.
Calculate the difference in kinetic and gravitational potential energy.

You are going to carry out an experiment to determine the total spring constant when two springs are connected in series and in then in parallel.

Equipment List

Springs (2)
Rulers (30cm and 1m)
Clamp Stand, Boss and Clamp
Masses (10 x 50g)

Task

- Measure the lengths of spring A and spring B. Record your readings.
- Suspend spring A from the clamp attached to the clamp stand. Attach a 50g mass to the bottom of the spring.
- Record the extension of the spring for 50g. Repeat with increasing mass up to 500g.
- Draw a table to include columns for mass, force applied and extension.
- Plot a graph of force applied (on the y-axis) against extension (on the x-axis). This will be graph 1
- Calculate the gradient. This is the spring constant for spring A.
- Repeat this for spring B.
- Now that we have the spring constants of spring A and B you will now find the total spring constant when they are connected in series and in parallel.
- Repeat the above procedure but with the springs connected in series.
- Plot a graph of force applied against extension for springs in series.
- Repeat the above procedure but with the springs connected in parallel.
- Plot a graph of force applied against extension for springs in parallel.

After the Experiment

What were the dependent and independent variables in your investigation?

Look at your first graph, are the results reliable? Why?
Look at your second graph, are the results reliable? Why?
How could you have increased the reliability of your results?
How could you have increased the precision of your measurements for the extension of the springs?

For two springs in series the total spring constant, k_T is given by: .
Calculate this value from your gradients of graphs 1 and 2. This is the accepted value.
Calculate this value from the gradient of the graph for springs in series.
What is the difference between this value and the accepted value?
Calculate the percentage difference from the accepted value.

For two springs in parallel the total spring constant, k_T is given by:
Calculate this value from your gradients of graphs 1 and 2. This is the accepted value.
Calculate this value from the gradient of the graph for springs in series.
What is the difference between this value and the accepted value?
Calculate the percentage difference from the accepted value.

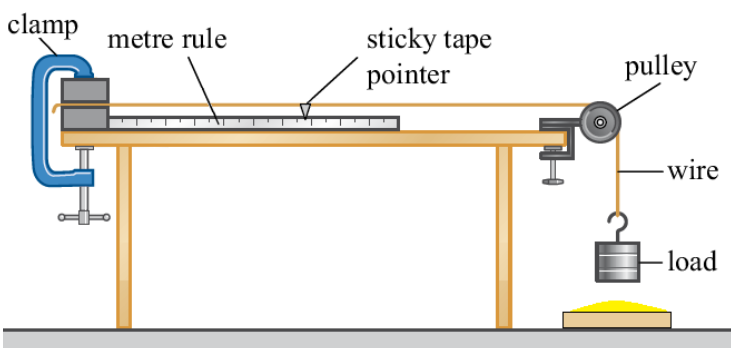
Which is more reliable, your value for the springs in series or parallel? Explain your answer.

Practical	Finding the Young Modulus

You are going to carry out an experiment to determine the Young Modulus for copper.

Equipment List

G Clamp
Two small wooden blocks
Bench Pulley
Metre Ruler
2.5m Copper Wire
Mircometer Screw Gauge
Masses (10 x 100g) with Hanger
Goggles
Sand Tray
Sellotape



Task

- Set up the equipment as shown in the diagram.
- Position the marker 30cm from the pulley.
- Measure the length, l, of the wire from the wooden block to the marker.
- Measure the diameter of the wire in several places and calculate the mean radius, r, of the wire.
- Calculate the cross-sectional area, A, of the wire using the equation .
- Add a 100g mass to the hanger, measure the extension, e, of the wire, the mean radius and calculate the area.
- Calculate the tensile force using the equation where g = 9.81
- Repeat this until 1000g are on the hanger.
- Record the results in a table:

F **(N)**	l **(m)**	e **(m)**	r **(m)**	A **(m²)**	**Stress,** σ **(Pa)**	**Strain,** ε

- Calculate the stress for each force using the equation and the strain using
- Plot a graph of tensile stress (y axis) against tensile strain (x axis).

After the Experiment

What was the independent variable in the investigation?
How many values of this variable did you use?
Was this enough? Explain your answer.
What is the precision of your length measurements?
What is the precision of your diameter measurements?
If the percentage uncertainty in the radius was 5% what would be the percentage uncertainty in the area?

Calculate the gradient of the line of best fit of your graph. The gradient is equal to the Young modulus.
The accepted value for the Young modulus is 119 GPa ± 7.56%. What are the upper and lower limits of the value?
What is the difference between your value and the accepted value of 119 GPa?
Calculate this as a percentage of the accepted value.

Use your graph to comment on the reliability of your results.
How could you improve the reliability of your results?

How could you increase the precision of your results?
Explain why the results cannot be used when the copper is extended beyond the elastic limit.

Analysis	Finding the Young Modulus
N. DWYER	

The load applied to a wire was varied and the length was recorded. You will use the data to find the spring constant and the Young modulus of the wire. The wire has a length of 1.600 m and diameter of 3.2 x 10^{-4} m.

Experimental Data

Here are the lengths of the wire when different loads are applied.

Load, F (N)	**Length, l (m)**	**Extension, e (m)**	**Stress, σ (Pa)**	**Strain, ε**
2.0	1601.2			
3.0	1601.8			
4.0	1602.4			
5.0	1603.0			
6.0	1603.6			
7.0	1604.2			
8.0	1604.8			
9.0	1605.7			
10.0	1607.0			
11.0	1609.0			

Analysis

What is the independent variable in this investigation?
What is the dependent variable in this investigation?
What is the precision of the load measurements?
What is the precision of the length measurements?

Calculate the uncertainty in the length measurement when the load is 7.0 N.
What is this as a percentage of the measurement?
Calculate the uncertainty in the load measurement when the length is 1602.4.
What is this as a percentage of the measurement?

Calculate the change in length (extension) for each load.

Calculate the cross-sectional area of the wire using .

Calculate the stress for each force using the equation and the strain using .

Plot a graph of F against e (x axis) and draw a line of best fit.
Does the line pass through the origin? Should it? Explain your answer.

If F and e are connected by the equation what does the gradient represent?
Use the gradient to find the spring constant.

F and e are also linked by the equation , in this case what does the gradient of your line represent?
Use the gradient to calculate the Young Modulus of the wire.
The accepted value of the Young Modulus is 3.35 x 10^{10}, what is the difference between this value and yours?

Calculate this as a percentage of the actual value.

Practical	Loading and Unloading
N. DWYER	

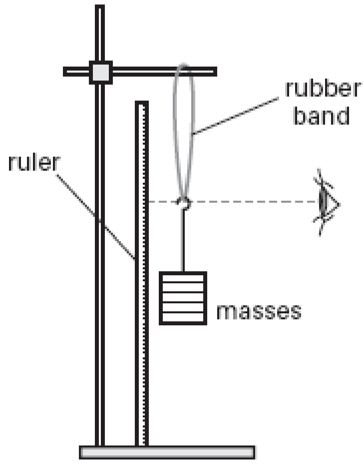
In this experiment you will determine the force-extension graph for a rubber sample as it is loaded and unloaded.

Equipment List

RubberBand
Ruler (30cm)
Clamp Stand

Boss and Clamp
Masses (100g x 10)
Mass Hanger

Task



- Hang the rubber band from the clamp.
- Attach the mass hanger (100g) to the bottom of the rubber band and determine the extension this causes.
- Add a 100g mass to the mass hanger ensuring the tension in the band is not allowed to decrease. Record the extension.
- Continue to add the masses and record the extension up to 1000g.
- Remove the masses one at a time and determine the extension as the tensile force is reduced.
- Repeat the experiment twice more.
- Record all your results in a table.
- Calculate the mean values of the extension for the different masses both loading and unloading.
- Plot a graph of Force (on the y-axis) against extension.

After the Experiment

What was the independent variable in your investigation?
What was the dependent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?

What is the uncertainty in the extension when the load is 400g (loading)?
Calculate this as a percentage of the mean extension.
What is the uncertainty in the extension when the load is 400g (unloading)?
Calculate this as a percentage of the mean extension.
Which is the greater source of uncertainty?
How can you describe the lower source of uncertainty?
What is the uncertainty in the extension when the load is 700g (loading)?
Calculate this as a percentage of the lowest extension reading with this load.
What is the uncertainty in the extension when the load is 700g (unloading)?
Calculate this as a percentage of the greatest extension reading with this load.

Does the rubber band obey Hooke’s Law?
Justify your answer.
If your graph suggests a ‘loop’ rather than a straight line what is the significance of the area of the loop between the loading and unloading sections of the graph?

Explain what would happen to the results of the repeat experiment if the rubber band had extended beyond the elastic limit during the first run.
How could you increase the precision of your results?
How could you increase the reliability of your results?

Practical	The Speed of Waves in Water
N. DWYER	

You are going to carry out an experiment to determine the speed of a wave as it crosses a shallow tray of water

Equipment List

Standard tray
Stop clock
Rulers (30cm and 1m)

Task

- Fill the tray with water to a depth of about 1cm.
- Measure the depth of water in a number of places and also the length of the tray. Record your readings.
- You are going to time the wave travelling backwards and forwards across the surface of the water.
- Draw a table to include columns for distance travelled and time taken, and include columns for repeat readings.
- Raise one end of the tray about 1cm and allow to drop so that a ripple is sent across the surface of the water and is reflected backwards and forwards by the ends of the tray.
- Time how long the wave takes to cross the tray once.
- Time how long the wave takes to cross the tray twice (ie, there and beck).
- Take further times for 3, 4, 5, 6 etc more crossings until the wave is too faint to see, up to a maximum of eight crossings.
- Take repeat readings for each distance.
- Plot a graph of distance travelled (by the wave) on the y-axis against time on the x-axis. Use it to determine the average speed on the wave.

After the Experiment

What was the independent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?

What was the dependent variable in your investigation?
What did you use to measure this?
What was the precision of this piece of equipment?

Use the precision of your equipment to calculate the percentage uncertainty of your smallest measurement of the time taken.
Use the precision of your equipment to calculate the percentage uncertainty of your largest measurement of the time taken.
Use your raw data to calculate the uncertainty in your smallest measurement of the time taken.
Now calculate the percentage uncertainty in this measurement.
Use your raw data to calculate the uncertainty in your largest measurement of the time taken.
Now calculate the percentage uncertainty in this measurement.

What caused the spread in your measurements of the depth of the water?

Use your graph to comment on the reliability of your results.
How could you increase the reliability of your results?
How could you increase the precision of your results?

Analysis	Electromagnetic Speed
N. DWYER	

The frequencies of different coloured light were recorded. Knowing the wavelengths you will analyse the data below to find the speed of light in a vacuum, c.

Experimental Data

Here are the frequencies recorded for light of seven different colours.

Light Colour	Wavelength, λ (nm)	$1/\lambda$ (m^{-1})	Frequency, f ($\times 10^{14}$ Hz)			Mean Frequency, f ($\times 10^{14}$ Hz)
Violet	415		7.22	7.21	7.26	
Blue	463		6.41	6.50	6.53	
Cyan	489		6.15	6.16	6.09	
Green	532		5.61	5.70	5.61	
Yellow	580		5.11	5.24	5.16	
Orange	608		4.98	4.89	4.91	
Red	685		4.38	4.38	4.38	

Analysis

Calculate the mean frequency of each coloured light.

Calculate the uncertainty in the frequency of blue light.
What is this as a percentage of the mean frequency?
Calculate the uncertainty in the frequency of blue light.
What is this as a percentage of the mean frequency?
Calculate the uncertainty in the frequency of red light.
What is this as a percentage of the mean frequency?

What is the precision of the wavelength measurements?
Calculate the percentage uncertainty in the value of wavelength for cyan light.
Calculate the percentage uncertainty in the value of wavelength for yellow light.
Calculate the value of $1/\lambda$ for each coloured light. Ensure your units are per metre (m^{-1}).

Plot a graph of f (on the y axis) against (on the x axis).
Calculate the gradient of your line of best fit.
The gradient should be equal to c, 3×10^8. What is the difference between your gradient and the accepted value?
Calculate the percentage difference from the accepted value.
Does your line pass through the origin? Should it?

Use these calculations and your graph to comment on the reliability, precision and accuracy of the experiment.

Use the equation to calculate the value of c for each coloured light.
Calculate your mean value for the wave speed c.
What is the uncertainty in the wave speed?
Calculate the percentage difference between your mean value and the accepted value.

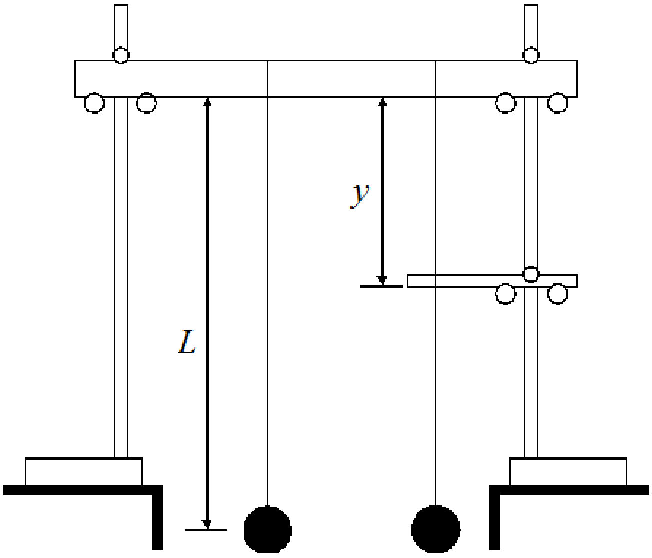
Practical	Phase Difference of Pendulums
N. DWYER	

You are going to carry out an experiment to investigate how the time between two pendulum moving in phase depends on their relative lengths.

Equipment List

Pendulum bob (x2)
String (2 x 1.5m)
Rulers (1m)
Clamp Stands, Bosses and Clamps
Stop clock
Plasticine

Task



- Clamp a ruler between two clamp stands and suspend two pendulums of equal length approximately 1.00 m.
- Attach a second clamp to one of the clamp stands so that it obstructs the swing of the second pendulum.
- Set the initial value of y to by 0.20m.
- Measure the lengths L and y and state the precision of your readings.
- Displace and release the pendulums so they oscillate with a small amplitude parallel to the edge of the bench.
- Start the timer when the two pendulum motions are seen to be exactly in phase.
- Measure and record the time until the pendulums are next seen to be in phase, T.
- Repeat this reading three times.
- Measure and record further values of T which correspond to four larger values of y.

- Record your results in a table with a column .

After the Experiment

What were the dependent and independent variables in your investigation?
Look at your graph, are the results reliable? Why?
Other than taking repeat readings how else could you increase the reliability of your experiment?

Plot a graph of (on the y-axis) against (on the x-axis)
Draw a line of best fit for your graph.
Calculate the gradient of this line.

Calculate the uncertainty in the measurement for the value of T when y has a value of 0.20 m.
Calculate this as a percentage uncertainty of the mean value of T for this value of y.
Calculate the uncertainty in the measurement for the value of T for your largest value of y.
Calculate this as a percentage uncertainty of the mean value of T for this value of y.

A student suggests that in order to extend the investigation additional measurements of T should be made using values of y that were much smaller than 0.20 m and much bigger than 0.90 m. Discuss briefly whether you think that such additional readings would improve the quality of the evidence obtained for the experiment.

Analysis	Sound Waves in a Column of Air
N. DWYER	

A speaker was attached to the top of an open ended glass cylinder. The other end was placed in a trough of water so that the column of air between the speaker and the water is 15 cm. The speaker is attached to a signal generator which is adjusted until each harmonic is heard

Experimental Data

Here are the frequencies recorded for the first five harmonics.

Harmonic	**Frequency, f (Hz)**			**Wavelength, λ (m)**
First	1134	1131	1125	
Second	2288	2282	2291	
Third	3387	3407	3406	
Forth	4838	4841	4850	
Fifth	5639	5666	5645	

Harmonic	**Mean Frequency, f (Hz)**	**Wavelength, λ (m)**	**(m^{-1})**	**Wave Speed, v (m/s)**
First				
Second				
Third				
Forth				
Fifth				

Analysis

Calculate the mean frequency for each harmonic.
Calculate the uncertainty in the frequency of the first harmonic.
What is this as a percentage of the mean frequency?
Calculate the uncertainty in the frequency of the third harmonic.
What is this as a percentage of the mean frequency?
Calculate the uncertainty in the frequency of the fifth harmonic.

What is this as a percentage of the mean frequency?

Calculate the wavelength of the standing wave for each harmonic.

Complete the column in the table labelled .

Plot a graph of f on the y axis against on the x axis.
Draw a line of best fit and calculate the gradient.
Calculate the percentage difference between the gradient and the accepted value of 343 m/s.

Use the equation to complete the last column of the table.
Calculate your mean value for the wave speed v.
What is the uncertainty in the wave speed?
Calculate the percentage difference between your mean value and the accepted value.

Is the gradient value or the table value of v more accurate?
What type of error is responsible for the spread of frequencies for each harmonic?

Practical	Finding the Refractive Index
N. DWYER	

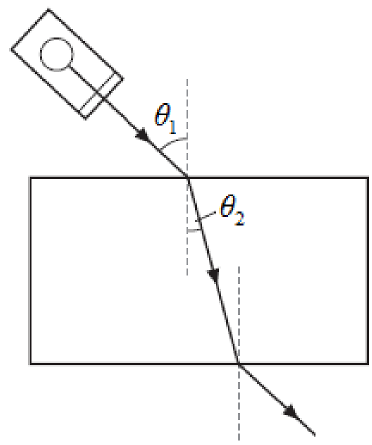
Finding the Refractive Index

You are going to carry out an experiment to determine the refractive index of a Perspex block.

Equipment List

Power Pack	A4 White Paper x 3
Ray Box	Red Filter
Perspex Block	Ruler
Protractor	Sharp Pencil

Task



- Place the block on the paper and draw around its outline.
- Set up the apparatus so that a narrow beam of coloured light passes through the block.
- Draw the path of the beam through the block as shown in the diagram.
- Using a protractor, measure the angle of incidence, θ_1, and the angle of refraction, θ_2, at the first surface.
- Take a set of readings for various values of the angle of incidence within the range 20° to 60°.
- Using the other two sheets of paper, repeat the measurements for the same angles of incidence.
- Tabulate all your results in a single table.
- Record the precision of your protractor.
- Calculate $\sin\theta_1$ and $\sin\theta_2$ for each angle of incidence and include these values in your table.
- Plot $\sin\theta_1$ on the y axis against $\sin\theta_2$ and draw a straight line of best fit.

After the Experiment

What is the uncertainty in your measurements of the independent variable?
How many values did you use for the independent variable?
Was this enough values? Explain your answer.
What would increasing the number of values used do to your results?
What is the uncertainty in the value of θ_2 when θ_1 = 60°?
Calculate this as a percentage of the mean value of θ_2 at this value of θ_1.

What is the uncertainty in the value of θ_2 when θ_1 = 20°?
Calculate this as a percentage of your smallest value of θ_2.

Use your graph to comment on the reliability of your results.
Calculate the gradient of the line of best fit.

The refractive indices of material 1 and 2 are linked by the equation .
Rearrange this to show the equation of your line of best fit.
If material 1 is air (n_1 = 1) what does the gradient represent?
Use your gradient to find the refractive index of Perspex.
What is the difference between your value and the accepted value of 1.48?
Calculate this as a percentage of the accepted value.
What does this percentage tell you about your results?
Using a sharp pencil rather than a blunt pencil did what to your results?
Give some of the advantages of using a laser instead of a filament bulb.

Analysis
N. DWYER

Finding the Refractive Index

You are going to use experimental data on light being shone through a Perspex block to find its refractive index.
The incident angle is measured from the normal in the Perspex block and the refracted angle is measured from the normal out of the block in the air.

Experimental Data

The protractor used to measure the incident and refracted angle had a precision of 0.5°

Incident Angle, θ_1 (°)	**Refracted Angle,** θ_2 (°)			**Mean Refracted Angle,** θ_2 (°)	**Sin θ_1**	**Sin θ_2**
5.0	7.0	7.5	7.5			
10.0	14.5	15.5	15.0			
15.0	22.0	23.0	23.0			
20.0	31.0	30.0	31.0			
25.0	38.0	39.0	39.5			
30.0	47.5	47.5	47.5			
35.0	57.5	57.5	58.5			
40.0	71.5	71.5	73.0			

Analysis

Calculate the mean values for the refracted angle for each incident angle.
What type of error is responsible for the variation in readings for the refracted angle?
Calculate the uncertainty in the mean refracted angle for an incident angle of 15°.
What is this as a percentage of the mean refracted angle?
Calculate the uncertainty in the mean refracted angle for an incident angle of 30°.
What is this as a percentage of the mean refracted angle?
Which measurement is more precise?

Complete the columns labelled sin $\theta_1$and sin θ_2 and state your values to 3 decimal places.
Plot a graph of sin θ_1 on the y axis and sin θ_2 on the x axis.
Draw a line of best fit for the graph.

The equation for the line is , what does the gradient represent?
Calculate the gradient of your line.
What value for the refractive index, n, does your graph produce?

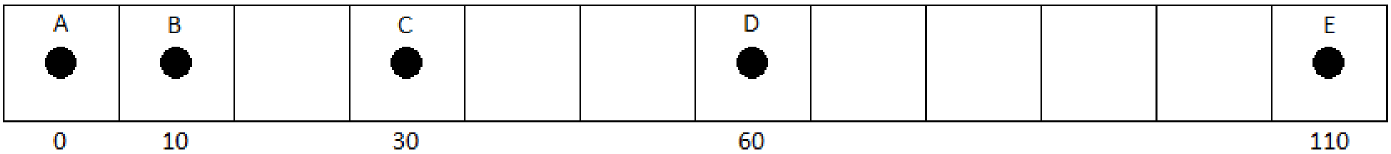
The accepted refractive index of Perspex is 1.48.
What is the difference between your value for the refractive index and the accepted value?
Work out this out as a percentage of the accepted value.

Use the equation to calculate the critical angle of Perspex.
The accepted critical angle is 42.5°.
What is the difference between your value for the critical angle and the accepted value?
Calculate this as a percentage of the accepted value.

How could you prove that this was the critical angle? Describe how you would go about doing this.

Analysis	# Interference of Sound
N. DWYER	

Five speakers are set into a box in the formation as shown in the diagram below. By measuring the separation of the loud interference fringes at different distance from the speaker box it is possible to deduce which speakers are emitting a sound of wavelength (λ) 0.17 m.



Values in cm

Experimental Data

Here are the separations of the fringes at different distances from the speaker box.

Distance to Speaker, D **(m)**	**Fringe Separation,** w **(m)**			**Mean** w **(m)**		**Speaker Separation,** s **(m)**
1.00	0.20	0.21	0.21			
1.50	0.33	0.33	0.29			
2.00	0.41	0.47	0.42			
2.50	0.52	0.56	0.51			
3.00	0.63	0.66	6.63			
3.50	0.77	0.72	0.73			
4.00	0.89	0.84	0.82			
4.50	0.91	0.98	0.99			

Analysis

In this experiment what were the independent and dependent variables?
What was the precision in the wavelength value and distances from the speaker?

Calculate the mean values of the fringe separation for each distance to the speaker.
What is the uncertainty in the fringe separation for a distance of 2.00m?
Calculate this as a percentage of the mean.

What is the uncertainty in the fringe separation for a distance of 3.50m?
Calculate this as a percentage of the largest value at this distance.
What is the uncertainty in the fringe separation for a distance of 4.50m?
Calculate this as a percentage of the smallest value at this distance.
What is the name given to the error responsible for the spread in the fringe separations?

Use the equation to calculate the speaker separation for each distance to the speaker.
What is a percentage uncertainty in the value of s for when D = 2.50m?
Calculate the mean value of the speaker separation.

Either: plot a graph of D on the y axis against w on the x axis and use your gradient to calculate s.

or plot a graph of D against and your gradient will equal s. A column has been left for

the values of .

Does your graph support the value of s obtained from the table?
Which speakers does this suggest are emitting the sound?

Practical	Laser Diffraction
N. DWYER	

You are going to carry out an experiment to determine the wavelength of light emitted from a laser then use this value to calculate the slit separation of a diffraction grating.

Equipment List

Laser
Rulers (30cm and 1m)
Tape Measure (at least 5m)

Diffraction Gratings (300 lines per mm and Course 3)

Task 1

- Aim the laser at a screen/wall approximately 4 metres away.
- Place the 300lines per mm grating approximately 5cm in front of the laser.
- Measure the distance from the grating to the screen/wall. State the precision of your instrument.
- Measure the distance from the central spot to the first order bright spot to the right and to the left.
- State the precision of your instrument.
- Repeat this for the second, third and forth order maxima.
- Record your results in a table including columns for $\sin\theta$ and wavelength (λ).

Task 2

- Keeping the laser in the same position, replace the grating with the course grating.
- Measure the distance from the grating to the screen/wall. State the precision of your instrument.
- Measure the distance from the central spot to the first order bright spot to the right and to the left.
- State the precision of your instrument.
- Repeat this for the second, third and forth order maxima.
- Record your results in a table including columns for $\sin\theta$ and wavelength (λ).

After the Experiment 1

For each order maxima calculate the value of $\sin\theta$ by dividing the distance from the central maxima by the distance to the screen.
If there are 300 lines per mm calculate the slit separation d.

Using the equation calculate the value of λ for each maxima (n).
Calculate the mean value of λ. What is the uncertainty in this value?What is this as a percentage of the mean?
If the accepted value is 660 nm what is the difference of your value from the accepted value?
Calculate this as a percentage of the accepted value.
Plot a graph of $\sin\theta$on the y-axis against n on the x-axis.
Draw a line of best fit and calculate the gradient of this line.
Use the gradient to calculate the value of λ.
Look at your data for the first order maxima

After the Experiment 2

For each order maxima calculate the value of $\sin\theta$ by dividing the distance from the central maxima by the distance to the screen.

Using the equation calculate the value of $d$for each order maxima (n).
Calculate the mean value of d. What is the uncertainty in this value? What is this as a percentage of the mean?
Plot a graph of $\sin\theta$on the y-axis against n on the x-axis.
Draw a line of best fit and calculate the gradient of this line.
Use the gradient to calculate the value of d.

Analysis	Braking Force
N. DWYER	

You are going to use information from the Highway Code to calculate the braking force exerted on a car performing an emergency stop.

Experimental Data

Here are the braking distances for vehicles travelling at different speeds.

Speed (mph)	**Speed (km/h)**	**Initial Speed,** v **(m/s)**	**Braking distance,** s **(m)**	**Time taken,** t **(s)**		**Braking Force,** F **(N)**
20			6			
30			14			
40			24			
50			38			
60			55			
70			75			

Analysis

Convert the speeds from miles per hour to kilometres per hour using the conversion 1mile = 1.6km.

Convert the speeds from kilometres per hour to metres per second.

Use the equation to complete the column for the time taken to stop.

If a car has a mass (m) of 950 kg calculate the quantity $m\Delta v$ for each of the initial speeds.
Write your values in the empty column of the table including a heading and appropriate units.

Plot a graph of $m\Delta v$ on the y axis against t on the x axis.
Draw a line of best fit for the points.
The gradient of the line of best fit is equal to the Braking Force (F) of the car. Calculate this value.

Use the equation to complete the last column of the table.
Calculate the mean braking force on the car from the table.
What is the difference between this value and the gradient of your graph?
Calculate this as a percentage of the gradient.

What is the uncertainty in the braking force from the table?
Calculate this as a percentage of the mean braking force you obtained from the table.
Does the gradient fall within the uncertainty?

The Highway Code states that these are the average braking distances, what might cause a variation in the braking distances?
The Highway Code also gives the overall stopping distances which are larger than the braking distances, why?
Why didn’t we use the overall stopping distances?
Describe the forces acting upon the car before the brakes are applied.

Analysis
N. DWYER

Impulse

A device for firing toy cars was used to investigate the concept of impulse. The firing force could be adjusted and the velocity of a car of unknown mass was recorded.

Experimental Data

Here are the velocities the car travelled at after the force was applied for 0.07 seconds.

Force, F **(N)**	**Velocity,** v **(m/s)**			**Mean Velocity,** v **(m/s)**	**Mass,** m **(kg)**
0.5	0.27	0.28	0.28		
1.5	0.88	0.83	0.81		
2.5	1.47	1.37	1.36		
3.5	2.03	1.94	1.92		
4.5	2.52	2.52	2.52		
5.5	2.98	3.17	3.09		
6.5	3.75	3.58	3.59		

Analysis

Calculate the mean velocity for each of the forces.
What is the uncertainty in the measurement of v when F is 1.5?
Calculate this as a percentage of the mean v.
What is the uncertainty in the measurement of v when F is 2.5?

Calculate this as a percentage of the mean v.
What is the uncertainty in the measurement of v when F is 4.5?
Calculate this as a percentage of the mean v.
Which type of error is responsible for the variation in value of v?

Plot a graph of F against v (on the x axis) and draw a line of best fit.
Does your line of best fit pass through the origin? Should it? Explain your answer.
If F and v are connected by the equation , what does the gradient of your line represent?
Calculate the gradient of your line of best fit.
Use the gradient to calculate the mass of the toy car.

Use the above equation to calculate a value of m for each value of F, write these values in the table above.
Calculate the mean value of m from the table.
What is the uncertainty in this value?

The mass of the toy was measured to be 125g.
Calculate the difference between the actual value and the gradient answer.
What is this as a percentage of the actual answer?
Calculate the difference between the actual value and the table answer.
What is this as a percentage of the actual answer?
Which word describes the answer that is closer to the true answer?

If the velocity was calculated by measuring how far the toy car moved in 1 second, how could you increase the precision of the value of velocity?

Practical	# Circular Motion
N. DWYER	

You are going to carry out an experiment to investigate the relationship between the centripetal force and the mass of a bung on a string system. You will then use your data to calculate the mass of the bung.

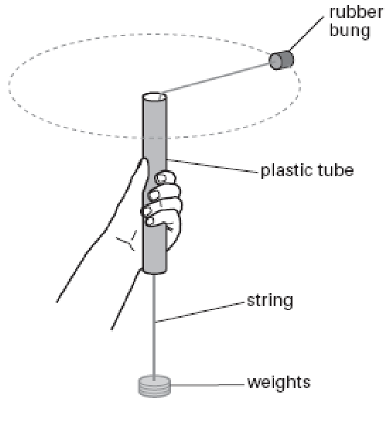
Equipment List

Plastic tube
String (1.0m)
Rubber bung with hole
Rulers (30cm and 1m)

Stop clock
Masses (4 x 100g, 1 x 50g)
Digital balance

Task

- Tie one end of the string to the rubber bung and make a mark on the string at a distance of 45cm from the bung.
- Thread the string through the plastic tube and attach 150g to the other end of the string.
- Whirl the rubber bung in a horizontal circle as shown in the diagram.
- Adjust the speed of the bung so that the radius *r* of the circle is equal to 45cm.
- Measure the time *t* for 20 revolutions of the bung.Take repeat readings and calculate a mean value.
- Calculate the centripetal force using



- Calculate the speed *v* of the bung using

- Repeat the experiment for masses equal to 200, 250, 300, 350, 400 and 450g.
- Plot a graph of *F* on the y-axis against v^2. Draw a line of best fit and calculate the gradient.
- Use the digital balance to find the mass of the bung. Record this measurement as the 'actual mass'.

After the Experiment

What were the dependent and independent variables in your investigation?
What is the uncertainty in your value for the radius? Calculate the percentage uncertainty in your reading.

What is the uncertainty in your mean value of the *t* when the mass was 200g?
Calculate the percentage uncertainty in the mean value.
Use the mean value of *t* to calculate the time taken for a single revolution.
What is the uncertainty of this value?

What is the uncertainty in your mean value of the *t* when the mass was 300g?
Calculate the percentage uncertainty in the mean value.
Use the mean value of *t* to calculate the time taken for a single revolution.
What is the uncertainty of this value?
Which of the two produced a more precise value?

Using the results you obtained for a mass of 300g calculate the percentage uncertainty in the value of v.
What would be the percentage uncertainty in the corresponding value of v^2?

The equation of your line of best fit is given by . Use your value of the gradient to calculate m.
What is the difference between your value and the actual mass?
Calculate the percentage difference of your value from the actual mass.

Practical	Finding g with a Simple Pendulum
N. DWYER	

You are going to carry out an experiment to investigate the relationship between the time period of a pendulum, its length and the gravitational field strength, g.

Equipment List

Pendulum bob	Clamp Stand, Boss and Clamp
String (1.5m)	Stop clock
Rulers (30cm and 1m)	Plasticine

Task

- Suspend the pendulum bob from the clamp attached to the clamp stand so that the pendulum length is 0.30m.
- Write down the precision of the ruler.
- Displace the pendulum by less than 10° from the vertical to set it in simple harmonic motion.
- Measure the time taken for the pendulum to complete 10 swings. Record this in a table along with the time period for 1 swing.

- Write down the precision of the stop clock.
- Repeat this experiment twice more and take an average for the time taken for 1 swing, T.
- Include a column in your table of T^2, where T is the time period of 1 swing.
- Obtain mean values of T for pendulums of length: 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0m.
- Include a column labelled g.
- Plot a graph of time period squared, T^2 (on the y-axis) against pendulum length, l (on the x-axis).
- Plot a line of best fit and calculate its gradient.

After the Experiment

What were the dependent and independent variables in your investigation?
Why do you think you were asked to displace the pendulum by less than 10°?
Look at your graph, are the results reliable? Why?
Other than taking repeat readings how else could you increase the reliability of your experiment?

Use the value of l and T^2 for each value of l to fill in the column you labelled g.
Calculate the mean value of g from this column.
What is the difference between your value and the accepted value of 9.81?
Calculate the percentage difference of your value from the accepted value.

The equation of your line of best fit is given by . Use your value of the gradient to calculate g.
What is the difference between your value and the accepted value of 9.81?
Calculate the percentage difference of your value from the accepted value.
Which of your two values of g is more accurate?

Look at the column labelled g and the largest value.
Use your raw data to calculate the uncertainty in the mean value of T.
Now calculate the percentage uncertainty in this measurement.
What is the percentage uncertainty in the corresponding value of T^2?
Use the precision of your equipment to calculate the percentage uncertainty in your measurement of the corresponding length.

If calculate the overall uncertainty in this value of g.

Practical	Finding k with a Mass and Spring
N. DWYER	

You are going to carry out an experiment to investigate the relationship between the time period of a mass and spring system, the mass applied and the spring constant, k.

Equipment List

Spring
Masses (10 x 50g)
Ruler (30cm)
Clamp Stand, Boss and Clamp
Stop clock
Plasticine

Task

Part 1

- Measure the length of the spring.
- Suspend the spring from the clamp attached to the clamp stand. Attach a 50g mass to the bottom of the spring.
- Record the extension of the spring for 50g. Repeat with increasing mass up to 500g.
- Draw a table to include columns for mass, force applied and extension.
- Plot a graph of force applied (on the y-axis) against extension (on the x-axis).
- Calculate the gradient. This is the spring constant for the spring and will be called the accepted value.

Part 2

- Hang a 50g mass from the spring. Displace the mass to set it into simple harmonic motion.
- Measure the time taken for the pendulum to complete 10 cycles. Record this in a table along with the time period for 1 cycle.
- Write down the precision of the stop clock.
- Repeat this experiment twice more and take an average for the time taken for 1 cycle, T.
- Include a column in your table of T^2, where T is the time period of 1 cycle.
- Obtain mean values of T for masses: 100, 150, 200, 250, 300, 350, 400, 450 and 500g
- Include a column labelled k.
- Plot a graph of time period squared, T^2 (on the y-axis) against mass, m (on the x-axis).
- Plot a line of best fit and calculate its gradient.

After the Experiment

Use the value of m and T^2 for each value of m to fill in the column you labelled k.

Calculate the mean value of k from this column.

What is the difference between the mean value from the table and the accepted value?

Calculate the percentage difference of the mean value from the accepted value.

The equation of your line of best fit is given by . Use your value of the gradient to calculate k.

What is the difference between the gradient and the accepted value?

Calculate the percentage difference of the gradient from the accepted value.

Which of your two values of k is more accurate?

What were the dependent and independent variables in Part 2 of your investigation?
Use your graph to comment on the reliability of your results.
How could you have increased the reliability of your results?
How could you have increased the precision of your results?
Calculate the percentage uncertainty in your largest time measurement. What is the percentage uncertainty in the corresponding T^2 value?

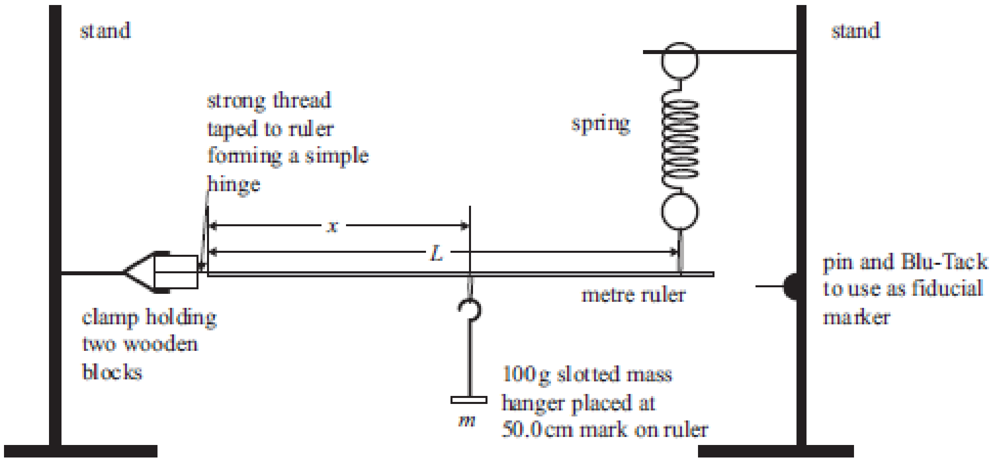
Practical	SHM Oscillations of a Spring
N. DWYER	

You are going to investigate how the time period of the oscillations of a ruler, which is supported by a spring, varies when different masses are suspended from the ruler

Equipment List

Spring	Clamp Stand, Boss and Clamp (x2)
Masses (10 x 50g) with hanger	Stop clock
Ruler (1m)	Blu-Tack and Pin
Clamping blocks	Spirit level

Task



- Set up the apparatus as shown in **Figure 1**. The threads taped to the ruler should be held firmly between the two wooden blocks so the ruler is free to pivot about this end. The spring should support the ruler 10.0 cm from its free end.
- Adjust each clamp so that the ruler is horizontal and the spring is vertical.
- The mass, m, should initially be the 100 g slotted mass holder and be supported at
- x = 50.0 cm. Keep both $L$and $x$constant throughout the experiment.
- Depress the free end of the ruler slightly and release it so that it oscillates vertically.
- Take suitable readings to determine the time period, T, of the oscillation.Add a 100 g mass to the mass holder. Adjust the clamp so that the ruler is horizontal and the spring is vertical. Measure the time period of the oscillation. Repeat the procedure up to a total mass of 700 g.
- Record your results in a suitable table.
- Draw a graph to show how T^2 plotted on the vertical axis varies with total mass, m.

After the Experiment

In your investigation what was the dependent variable?
How did you ensure that the ruler was horizontal and the spring was vertical?
Describe and explain two techniques you used to ensure accurate timings.
Describe what your graph suggests about the relationship between T^2 and m.
Evaluate the reliability of your results.
Describe the effect on your graph of using a ruler with greater mass.

Determine the uncertainty in the largest value of T.
What is the percentage uncertainty in the largest value of T?
What is the percentage uncertainty in the corresponding of T^2?
Determine the uncertainty in the smallest value of T.
What is the percentage uncertainty in the smallest value of T?
What is the percentage uncertainty in the corresponding of T^2?

State one likely source of this uncertainty.
State the name given to this type of error.

What does the gradient of your graph represent?
Calculate the gradient of your line.

Practical	V Shaped Pendulum
N. DWYER	

You are going to investigate how the time period of a V-shaped pendulum varies with distance d

Equipment List

Ruler (1m)	Stop Clock
Clamp Stand, Boss and Clamp (x2)	Blu-Tack and Pin
Pendulum Bob	Spirit Level
Thin String or Thread	

Task

- You are provided with a V-shaped pendulum set up as shown in **Figure 1**
- The length s should remain constant throughout the experiment.
- Initially set distance d to 10.0cm
- When the pendulum bob is displaced and released in the direction shown in **Figure 2**, it oscillates with SHM, provided the amplitude is small.
- Make suitable measurements to determine accurately the time period, T, of the oscillations.
- The mounted pin is available as a reference marker (sometimes called a fiducial marker) for use in timing the oscillations.
- Repeat the time measurements for a range of values of distance d
- Use your results to plot a graph of Tagainst d.

Figure 1

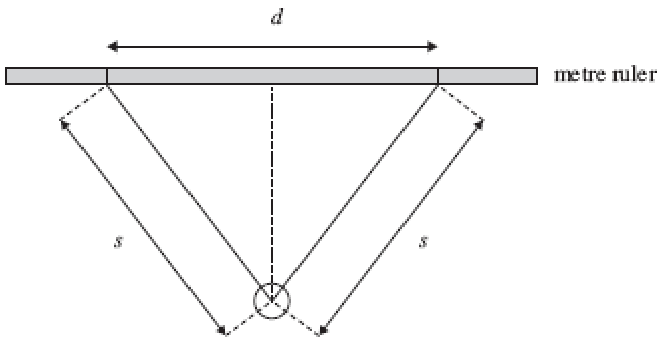
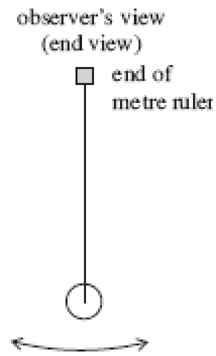


Figure 2



After the Experiment

In your investigation what was the dependent variable?
State and explain the best position to place the reference marker (or fiducial marker) for timing the oscillations.
State and explain one procedure, other than using the fiducial marker, that you used to reduce the uncertainty in the measurement of the time period of the oscillations.

The effective length, $L$of a V-shaped pendulum, is given by: . Theory shows that

the time period, T, of the pendulum is given by: where g is the gravitational field strength.

Show that

By comparing the above equation with the general equation of a straight line, $y = mx + c$, state what should be plotted to obtain a straight graph.
How could a value for g be obtained from this graph?

Calculate the gradient of your graph.
Use your graph to evaluate the reliability of your results.

What is your uncertainty in the measurement of d?
Calculate the percentage uncertainty for your smallest value of d.
Calculate the percentage uncertainty for your largest value of d.

Analysis	Damping
N. DWYER	

A mass and spring system was set up with three masses of 100g and radius 2.5 cm. The oscillator (masses) was displaced by 3 cm, released and the time was measured for the oscillator to come to rest. After this pieces of circular card were inserted between two of the masses and the experiment was carried out again.
You are to analyse the results obtained.

Experimental Data

Radius of card (cm)	Time taken for oscillator to come to rest (s)			Mean time (s)	Area of Oscillator (m^2)	Additional Area (m^2)	% of Undamped time to come to rest
0.0	259	248	254			---	---
6.0	134	131	143				
7.0	116	115	111				
8.0	92	83	83				
9.0	65	68	68				
10.0	58	57	53				

Analysis

Calculate mean value for the time taken for the oscillator to come to rest for each radius of card.
What is the uncertainty in the time taken to stop when the radius is 6 cm?
Calculate this as a percentage of the mean value.
What is the uncertainty in the time taken to stop when the radius is 8 cm?
Calculate this as a percentage of the shortest time measurement at this radius.
What is the uncertainty in the time taken to stop when the radius is 10 cm?
Calculate this as a percentage of the longest time measurement at this radius.
What type of error is responsible for the difference in the value of the time taken to come to rest?

Calculate the area of the oscillator using . Write these values in the column provided.
What is the precision in the radius if card measurements?
Calculate the percentage uncertainty in the 7.0 cm measurement.
What will be the percentage uncertainty in the value of the Area?
Write down the upper and lower limits of the Area.

Plot a graph of Radius of Oscillator (on the y axis) against time taken to come to rest.
Describe the graph you have plotted.
What does your graph suggest about the relationship between the two variables?
Plot a graph of Area of Oscillator (on the y axis) against time taken to come to rest.
Describe the graph you have plotted.
What does your graph suggest about the relationship between these two variables?

Complete the final columns of the table by calculating the additional area each card adds to the oscillator and the time period as a percentage of the undamped time taken to come to rest.
Do you notice any patterns or trends?
Plot a graph of Additional Area (y axis) against percentage of undamped time taken to come to rest.
How are these variables linked?

Theory states that damping will not affect the time period of the SHM system. How could you prove this using the experimental set up described at the top of the page?

Analysis	The Gravitational Constant
N. DWYER	

You are going to use experimental data on the six closest planets to the Sun to determine the gravitational constant G.

Experimental Data

Here is the planetary data for the six closest planets to the Sun

Planet	Radius, r (m)			Surface field strength, g (N kg^{-1})		
Mercury	2.40×10^{6}	2.43×10^{6}	2.44×10^{6}	3.76	3.74	3.78
Venus	6.04×10^{6}	6.11×10^{6}	6.11×10^{6}	8.73	8.80	8.79
Earth	6.36×10^{6}	6.40×10^{6}	6.39×10^{6}	9.85	9.78	9.81
Mars	3.41×10^{6}	3.35×10^{6}	3.38×10^{6}	3.81	3.79	3.79
Jupiter	7.13×10^{7}	7.14×10^{7}	7.14×10^{7}	24.95	24.92	24.83
Saturn	6.10×10^{7}	6.00×10^{7}	6.02×10^{7}	10.40	10.38	10.41

Planet	Mean radius, r (m)	Mass, M (kg)	Mean surface field strength, g (N kg^{-1})	G (N m^{2} kg^{-2})
Mercury		3.30×10^{23}		
Venus		4.87×10^{24}		
Earth		5.98×10^{24}		
Mars		6.42×10^{23}		
Jupiter		1.90×10^{27}		
Saturn		5.67×10^{26}		

Analysis

Calculate the mean values of the radius for each planet
Calculate the mean values of surface field strength for each planet.
What is the name given to the error responsible for the spread in the values of radius and surface field strength?

Calculate the uncertainty in the radius of Mercury.
Calculate the percentage uncertainty in the largest value of the radius of Mercury.
Calculate the uncertainty in the surface field strength of Jupiter.
Calculate the percentage uncertainty in the smallest value of the surface field strength of Jupiter.

Use the equation to complete the last column of the table.
Calculate your mean value for the gravitational constant G.
Calculate the percentage difference of your mean value from the accepted value of 6.67×10^{-11} N m^{2} kg^{-2}.

Calculate the percentage uncertainty in the smallest value of the radius of Earth.
Calculate the percentage uncertainty in the largest value of the surface field strength of Earth.
If the two above values were used to calculate G what would be the percentage uncertainty in your value of G? You may ignore any uncertainty in the measurement of the mass M.

Plot a graph of surface field strength g (on the y-axis) against (on the x-axis).
Calculate the gradient of the line of best fit.
Calculate the difference between the gradient and your mean value of G.
Calculate the percentage difference between the gradient and your mean value of G.
Calculate the difference between the gradient and the accepted value of G.
Calculate the percentage difference between the gradient and the accepted value of G.

Analysis	Gravitational Potential
A. HUDSON	

An experiment was carried out to find the relationship between the distance from the centre of the earth and the gravitational potential. The raw data are shown below:

Experimental Data

Distance, r, from the centre of the Earth to test mass (m)	$1/r$ (m^{-1})	Gravitational potential, V (JKg^{-1})			
		Trial 1	**Trial 2**	**Trial 3**	**Mean**
$6.37 x10^6$		-7.00×10^7	-6.13×10^7	-5.85×10^7	
$8.37 x10^6$		-4.58×10^7	-4.64×10^7	-4.81×10^7	
$1.04 x10^7$		-3.86×10^7	-3.97×10^7	-3.98×10^7	
$1.24 x10^7$		-3.49×10^7	-3.35×10^7	-3.00×10^7	
$1.44 x10^7$		-2.64×10^7	-2.82×10^7	-2.51×10^7	
$1.64 x10^7$		-2.47×10^7	-2.64×10^7	-2.71×10^7	
$1.84 x10^7$		-2.31×10^7	-2.26×10^7	-2.08×10^7	
$2.04 x10^7$		-1.84×10^7	-1.93×10^7	-2.19×10^7	
$2.24 x10^7$		-2.01×10^7	-1.60×10^7	-1.99×10^7	

Analysis

Calculate the mean gravitational potential for each distance and the values for $1/r$.

What error is responsible for the spread in the values of gravitational potential?

Calculate the uncertainty in the measurement of gravitational potential for the largest distance measured.

Calculate the percentage uncertainty in this measurement of gravitational potential.

Calculate the uncertainty in the measurement of gravitational potential for the smallest distance measured.

Calculate the percentage uncertainty in this measurement of gravitational potential.

Plot a graph of gravitational potential (y-axis) against distance from the centre of the earth (x-axis).

Describe any pattern or trend shown by your graph.

Use your graph to find the gravitational potential at distances of $1.0x10^7$m from the centre of the earth and $2.0x10^7$m from the centre of the earth.

Calculate the work done in moving a 25kg mass from $1.0x10^7$m from the centre of the earth to $2.0x10^7$m from the centre of the earth.

The gradient of the line at any point on the graph gives the gravitational field strength at that distance from the centre of the planet. Use your graph to calculate the gravitational field strength at a distance of $1.5x10^7$m from the centre of the earth.

Calculate the percentage difference between the value you just worked out and the true value of $-1.78 Nkg^{-1}$.

The mass of the earth is $6.0x10^{24}$kg. Using the precision, calculate the percentage uncertainty in this value.

This value can be used in the equation .

Plot a graph of V (y-axis) against $1/r$ (x-axis).

What does the gradient of this line represent?

Use your graph to calculate a value for the gravitational constant, G.

Calculate the percentage difference between your value of G and the accepted value of $6.67x10^{-11} Nm^2Kg^{-2}$.

Analysis	

N. DWYER

Kepler's Third Law

You are going to use experimental data on the six closest planets to the Sun and Kepler's Third Law to determine the Mass of the Sun M.

Experimental Data

Here is the planetary data for the six closest planets to the Sun

Planet	**Minimum radius of orbit (10^9 m)**	**Maximum radius of orbit (10^9 m)**	**Orbit time, T (days)**		
Mercury	45.9	69.8	88.00	87.92	87.98
Venus	107.3	108.8	224.60	224.80	224.70
Earth	146.9	152.0	364.24	365.27	365.27
Mars	206.4	249.1	687.09	686.89	686.96
Jupiter	740.3	815.5	4331.29	4333.98	4332.86
Saturn	1348.6	1503.0	10759.8	10763.2	10755.5
Uranus	2733.6	3004.2	30675	30689	30688
Neptune	4456.5	4533.6	60194	60145	60210

Planet	**Mean radius, r (m)**	**Mean radius cubed, r^3 (10^{32} m^3)**	**Mean orbit time, T (s)**	**Orbit time squared, T^2 (10^{13} s^2)**
Mercury				
Venus				
Earth				
Mars				
Planet	**Mean radius, r (m)**	**Mean radius cubed, r^3 (10^{35} m^3)**	**Mean orbit time, T (s)**	**Orbit time squared, T^2 (10^{17} s^2)**
Jupiter				
Saturn				
Uranus				
Neptune				

Analysis

Calculate the mean radius of orbit for each of the planets.
Complete the column for the radius of orbit cubed. State your results in the form given in the heading of the column.
Calculate the mean orbit time for each planet in seconds.
Complete the column for the orbit time squared. State your results in the form given in the heading of the column.
Plot a graph of T^2 on the y axis and r^3 on the x axis for the 4 inner planets and a second graph for the 4 outer planets. Draw a line of best fit on each graph.

The equation for your line of best fit is given by where G is the gravitational constant (6.67×10^{-11}).

Calculate the gradient for the 4 inner planets graph.
Use this to calculate M.
What is the difference between this value and the accepted value of 1.99×10^{30}kg?
Work this out as a percentage of the accepted value.
Calculate the gradient for the 4 outer planets graph.
Use this to calculate M.
What is the difference between this value and the accepted value?
Work this out as a percentage of the accepted value.
Which of the graphs gave you a value of closest to the true value?What word describes this?

Electric Potential

You are going to analyse the data obtained in an investigation into the electric potential at different distances from a Van de Graaff generator whose dome has a diameter of 40 cm.

Experimental Data

Distance from the Van de Graaff (m)	**r (m)**	(m^{-1})	**Electric Potential, V ($J\ C^{-1}$)**			**Mean V ($J\ C^{-1}$)**
0.30			62300	61500	61300	
0.80			36300	36100	35300	
1.30			25100	25000	26100	
1.80			20300	19200	19300	
2.30			16300	15900	15500	
2.80			13600	13600	13300	
3.30			11400	11600	11800	
3.80			10300	10300	10300	
4.30			9250	9060	9230	
4.80			8190	8370	8310	

Analysis

Calculate the distance from the centre (r) for each distance from the Van de Graaff generator.
What is the precision of the distance measurements?
Calculate $1/r$ for each distance from the Van de Graaff generator.
Calculate the mean electric potential (V) for each distance.
What is the uncertainty in V for a distance of 0.80 m?
Calculate this as a percentage of the mean value of V at this distance.
What is the uncertainty in V for a distance of 1.80 m?
Calculate this as a percentage of the smallest value of V at this distance.
What is the uncertainty in V for a distance of 3.30 m?
Calculate this as a percentage of the largest value of V at this distance.
What is the uncertainty in V for a distance on 4.30 m?
Calculate this as a percentage of the middle value of V at this distance.
What error is responsible for the spread in values of the electric field strength at 2.80 m?

Plot a graph of V against $1/r$ and draw a line of best fit.

If the equation of the line is what does the gradient present?
Use your gradient to calculate the charge, Q, on the Van de Graaff.

Plot a graph of V against r and draw a line of best fit.
Draw a tangent to the line of best fit when r = 2.50 m.
Calculate the gradient of the tangent. This is equal to the electric field strength (E) at that distance from the centre.
Write down your value of E obtained from the graph.

Use the equation to calculate the theoretical value of E when r is 2.50 m.
What is the difference between your value from the graph and the theoretical value?
Calculate this difference as a percentage of the theoretical value.

N. DWYER	Finding ε_0

You are going to analyse the data obtained in an investigation into the electric potential at different distances from a Van de Graaff generator that has a charge of 13 C stored on its surface. This will lead to you finding a value for ε_0.

Experimental Data

Distance from Centre, r (m)	**Electric Field Strength, E (x 10^9 N/C)**			**Mean E (x 10^9 N/C)**	r^2 **(m²)**	$1/r^2$ **(m^{-2})**
2.0	29.47	28.76	29.43			
2.5	19.03	18.45	18.62			
3.0	13.08	12.71	13.18			
3.5	9.49	9.52	9.61			
4.0	7.36	7.29	7.28			
4.5	5.69	5.91	5.71			
5.0	4.66	4.73	4.65			
5.5	3.92	3.81	3.85			
6.0	3.28	3.28	3.19			
6.5	2.82	2.73	2.76			

Analysis

What is the independent variable in this investigation?
What is the dependent variable in this investigation?
What is the precision of the distance measurements?
Calculate the mean values of electric field strength for each value of r.
Calculate the values of r^2 and $1/r^2$.

Calculate the uncertainty in the value of E when r is 2.5 m?
What is this as a percentage of the mean value of E?
Calculate the uncertainty in the value of E when r is 4.0 m?
What is this as a percentage of the mean value of E?
Calculate the uncertainty in the value of E when r is 5.0 m?
What is this as a percentage of the mean value of E?
Calculate the uncertainty in the value of E when r is 6.5 m?
What is this as a percentage of the mean value of E?

Plot a graph of E against $1/r^2$ (on the x axis)
Draw a line of best fit and calculate its gradient.

If the equation linking E and $1/r^2$ is , what does the gradient of your line represent?
Use the gradient to calculate a value of ε_0.
The accepted value of ε_0 is 8.85 x 10^{-12}, what is the difference between your value and the actual value?
Calculate this as a percentage of the actual value?

N. DWYER	Capacitance

You are going to use experimental data to find the capacitance of a capacitor.

Experimental Data

Here is the charge stored on the capacitor when different voltages are applied across it

Voltage, V (V)	**Charge Stored, Q (x 10^{-6} C)**				**Mean Charge Stored, Q (C)**
2.02	9.47	9.53	9.54	9.42	
4.11	19.32	19.32	19.32	19.32	
6.04	28.42	28.37	28.23	28.54	
7.99	37.60	37.41	11.79	37.64	
10.03	47.15	46.92	47.25	47.24	

Analysis

Calculate the mean charge stored by the capacitor at each of the voltages.
What is the precision of the voltage readings?
Calculate the percentage uncertainty in the middle voltage reading.

What is the uncertainty in the charge stored reading when the voltage was 2.02 V.
Calculate this as a percentage of the mean charge stored.
What is the uncertainty in the charge stored reading when the voltage was 4.11 V
Calculate this as a percentage of the mean charge stored.
What is the uncertainty in the charge stored reading when the voltage was 6.04 V.
Calculate this as a percentage of the smallest reading of charge stored at this voltage.
What is the uncertainty in the charge stored reading when the voltage was 7.99 V.
Calculate this as a percentage of the largest reading of charge stored at this voltage.
What is the uncertainty in the charge stored reading when the voltage was 10.03 V.
Calculate this as a percentage of the reading of charge stored closest to the mean value at this voltage.

Plot a graph of mean charge stored, Q on the y axis against voltage, V on the x axis.
Draw a line of best fit for the results.
Calculate the gradient of the line of best fit.

The gradient represents the capacitance of the capacitor, what value did you obtain from the gradient?
The capacitance quoted on the capacitor is 4.7 μF.
What is the difference between your gradient and the quoted value?
Calculate this as a percentage of the quoted value.

You can calculate the capacitance using the equation   .
Use the readings from the 7.99 V run to calculate the capacitance.
What is the percentage uncertainty in this value?
What is the maximum the capacitance could be?
What is the minimum the capacitance could be?
Does the quoted value fall with-in these limits?
How can we describe this?

Practical	Discharging Capacitors
N. DWYER	

You are going to carry out an experiment to determine the capacitance of an unmarked commercial capacitor.

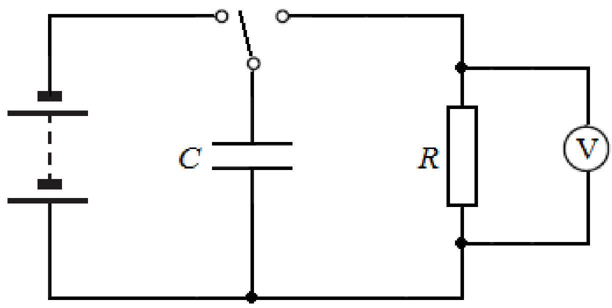
Equipment List

Power pack	Resistors (various values)
Crocodile clips and Leads	Voltmeter
Capacitors (various values)	SPDT switch
Capacitor (unknown value)	Stop clock

Task

Part 1

- Set up a circuit like the one shown in the diagram. The resistor should have a value of 220 kΩ and the capacitor should have a value of 1000 μF.
- Ensure the capacitor is connected with the correct polarity.
- Ensure the Single Pole, Double Throw (SPDT) switch is switched to charge the capacitor from the power pack.
- Set the power pack to a p.d. of 10V and charge the capacitor.
- Flip the SPDT switch to discharge the capacitor through the resistor and start the stop clock.



- Take readings from the voltmeter every 20 seconds.
- Plot a graph of potential difference(y axis) against time.
- Draw a curve of best fit.

Part 2

- Ask your supervisor for an unmarked capacitor and set up a similar circuit as before.
- Discharge the capacitor and determine the time τ taken for the potential difference across the capacitor to decrease to 37% of its initial value.
- Take repeat readings.
- Repeat this measurement for different values of R, both larger and smaller.
- Record your results in a table including a blank column at the end to be used in the analysis.
- Plot a graph τ (y axis) against R and draw a line of best fit.

After the Experiment

Use your first graph to calculate the time constant τ of the capacitor.
Take several readings and clearly label these on your graph.
The theoretical value is 220 seconds. What is the difference between this and your mean value for τ?
Calculate this as a percentage of the theoretical value.

Ask your supervisor for the actual capacitance stated on the capacitor in the second part of the experiment.
The gradient of your line of best fit is equal to C. What is the difference between your gradient and the actual value?
Calculate this as a percentage of the actual value.

In the blank column of your table calculate C for each value of R using the equation .
Calculate the mean value of C from the table.
What is the difference between this value and the actual value?
Calculate this as a percentage of the actual value.
Is the gradient value or the table value more precise?
Explain how using a voltmeter connected to a data logger would improve your experiment.

Analysis	Capacitor Time Constant
N. DWYER	

Capacitor Time Constant

A circuit was set up to initially charge a 470 μF capacitor from a 7.52 V battery and then discharge through a resistor of unknown resistance. You are going to use the data of how the potential difference changes over time to find the resistance of the resistor.

Experimental Data

Here are the potential differences for different times from the start of discharge.

Time, t **(s)**	**Potential Difference,** V **(V)**			**Mean** V **(V)**	V / V_0	$\ln(V / V_0)$
5	5.80	5.78	5.94			
10	4.61	4.48	4.50			
15	3.49	3.48	3.59			
20	2.69	2.74	2.76			
25	2.10	2.15	2.11			
30	1.64	1.63	1.68			
35	1.30	1.23	1.31			
40	1.02	0.98	0.97			
45	0.79	0.78	0.74			
50	0.59	0.59	0.62			

Analysis

Name one control variable on the investigation.
What is the independent variable in this investigation and how was it measured?
What is the dependent variable in this investigation and how was it measured?
What was the precision of the voltmeter?

Calculate the mean values of each potential difference.
Calculate the value of V / V_0 for each time.
Calculate the value of $\ln(V / V_0)$ for each time.
Calculate the uncertainty in the p.d. when discharged for 15 seconds.
What is this as a percentage of the mean p.d. for this time?
Calculate the uncertainty in the p.d. when discharged for 45 seconds.
What is this as a percentage of the mean p.d. for this time?

Plot a graph of $\ln(V / V_0)$ against t (x axis) and draw a line of best fit.

If V and V_0 are connected by the equation what does the gradient of your line of best fit represent?
Calculate the gradient of your line.
Use your gradient to calculate the resistance, R, of the resistor.
The resistance given for the resistor is 42 kΩ, what is the difference between the accepted value and your value?
Work this out as a percentage of the accepted value.

Plot a graph of V against t (x axis).
Use your graph to find the time constant.
Use the time constant to find the resistance, R, of the resistor.
What is the difference between this value of R and the accepted value?
Work this out as a percentage of the accepted value.

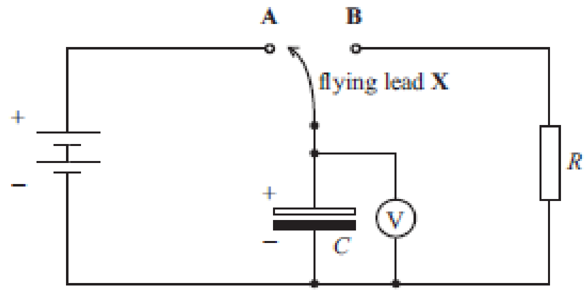
Practical	Capacitor Discharge
N. DWYER	

You are going to investigate the discharge of a capacitor through different resistors

Equipment List

Power pack/Battery	Resistors (various values)
Crocodile Clips and Leads	Voltmeter
Capacitors (470µF)	Stop clock

Task



- Set up the circuit as shown in the diagram. You should ensure that the negative terminal of the supply is connected to the negative terminal of the capacitor. If in doubt, ask your supervisor. You will not lose marks for this safety check.
- Connect the resistor with the least resistance in the circuit as R, and record its value.
- Connect the flying lead to point **A** to charge the capacitor. Record the p.d., V_0 across the capacitor.
- Remove the flying lead from point **A** and connect it to point **B** so that the capacitor discharges through the resistor. Start the stopclock**at the same time** as connecting to point **B**.
- Take measurements to determine the pdV_{10} across the capacitor after the capacitor has discharged for 10 seconds.
- Change the resistor and repeat the charging and discharging process. Record the resistor value, R, the initial pd, V_0, across the capacitor and the pd, V_{10} after 10 seconds. Repeat this process with the remaining resistors.
- Record all your measurements and processed data in a suitable table.

- Draw a graph to show how (plotted in the vertical axis) varies with .

After the Experiment

State the control variable in your experiment
Use your data calculate the uncertainty in your smallest mean pd, V_{10}.
Calculate the percentage uncertainty in your smallest mean pd, V_{10}.
Use your data calculate the uncertainty in your largest mean pd, V_{10}.
Calculate the percentage uncertainty in your largest mean pd, V_{10}.

State and explain two factors that determined the accuracy of the measurement of V_{10}.
State and explain two ways in which a data logger instead of a voltmeter and stopclock, would improve the accuracy in the measurement of V_{10}.

For a capacitor of capacitance C discharging through a resistor of resistance R the potential

difference across the capacitor is given by the equation where V is the pd across the capacitor at time, t, and V_0 is the pd across the capacitor at time $t = 0$. Use this equation to

show that

What does the gradient of your graph represent?

Use your gradient to calculate the capacitance of the capacitor.

Calculate the difference between your value of the capacitance and the given value on the capacitor

What is the percentage difference between your value and the given value?

Analysis	Mass Spectrometer
N. DWYER	

You are going to use experimental data to find the charge to mass ratio of a proton and an electron.

Proton Experimental Data

The magnetic flux density of the field is 1.42T

Radius, r (m)	**Speed, v (x10^5 m/s)**			**Mean speed, v (m/s)**	**v/B (m/sT)**
0.02	18.78	18.71	18.82		
0.04	37.63	37.44	37.58		
0.06	56.35	56.29	56.35		
0.08	75.08	75.13	75.11		
0.10	93.81	93.89	93.88		

Electron Experimental Data

The magnetic flux density of the field is 1.28T

Radius, r (x 10^{-6} m)	**Speed, v (x 10^5 m/s)**			**Mean speed, v (m/s)**	**v/B (m/sT)**
2.0	4.47	4.53	4.53		
4.0	9.03	9.05	8.95		
6.0	13.56	13.46	13.54		
8.0	17.96	17.98	18.12		
10.0	22.52	22.59	22.48		

Proton Analysis

Calculate the mean speed for each radius.

For the smallest radius calculate the uncertainty in the mean speed.

Calculate the percentage uncertainty in the mean speed.

What is the percentage uncertainty in the corresponding value of v/B?

Plot a graph of radius on the y axis against v/B on the x axis.

Draw a line of best fit and calculate the gradient of this line.

The equation for this line is given by , what does the gradient represent?

Use the gradient to calculate the charge to mass ratio for the proton.

What is the difference between your value and the accepted value of 9.58 x 10^7 Ckg^{-1}?

What is this as a percentage of the accepted value?

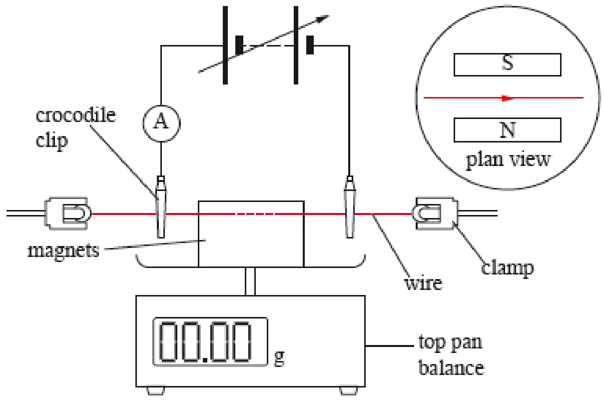
Electron Analysis

Calculate the mean speed for each radius.
For the largest radius calculate the uncertainty in the mean speed.
Calculate the percentage uncertainty in the mean speed.
What is the percentage uncertainty in the corresponding value of v/B?
Plot a graph of radius on the y axis against v/B on the x axis.
Draw a line of best fit and calculate the gradient of this line.
Use the gradient to calculate the charge to mass ratio for the electron.
What is the difference between your value and the accepted value of 1.76 x 10^{11} Ckg^{-1}?
What is this as a percentage of the accepted value?

Analysis	Magnetic Flux Density
N. DWYER	

Magnetic Flux Density

An experiment was conducted to find the magnetic flux density between the poles of a magnet using the apparatus as shown in the diagram. The current-carrying wire experiences an upwards force so the magnet experiences and equal and opposite force. The current flowing through the wire was varied and the reading on the top pan balance recorded. The length of wire in the magnetic field can be taken as 10 cm.



Experimental Data

Current I (A)	Reading on Top Pan Balance m (g)			Mean mass m (g)	Force F (N)	Magnetic Flux Density B (T)
1.0	01.32	01.30	01.37			
2.0	02.72	02.72	02.61			
3.0	04.01	03.91	03.96			
4.0	05.27	05.24	05.29			
5.0	06.62	06.68	06.59			
6.0	07.92	07.99	07.94			

Analysis

What is the independent variable and its precision?
Calculate the mean values of the mass reading for each of the currents.
What is the uncertainty in the mass reading for a current of 1.0 A?
Calculate this as a percentage of the mean.
What is the uncertainty in the mass reading for a current of 4.0 A?
Calculate this as a percentage of the smallest mass reading at this current.
What is the uncertainty in the mass reading for a current of 6.0 A?
Calculate this as a percentage of the largest mass reading at this current.
What type of error is responsible for the variation in the mass readings?

Use the equation to calculate the Force for each of the currents. Take g to be 9.81.

Use the equation to complete the last column of the table.
Use the graph to comment on the reliability of the results.

Calculate your mean value for the magnetic flux density B.

Plot a graph of current (y axis) against Force.
Draw a straight line of best fit and calculate the gradient.
What is the equation of your line of best fit?
Use the gradient to find the value for the magnetic flux density.

Calculate the difference between the value of B from the graph and the value from the table.
Calculate this as a percentage of the table value.

If the reading on the balance was 00.06 when no current flows what type of error would that be?
How would this have effected your mass measurements?

Analysis	Transformers
N. DWYER	

An investigation was carried out on a simple transformer. The primary coil was fixed with 4250 turns but unknown potential difference. The number of turns on the secondary coil was varied and the potential difference measured. With this information it should be possible to find the potential difference of the primary coil.

Experimental Data

Here is the data found when the number of coils on the secondary coil was varied

Turns on the Secondary Coil, N_S	**Potential Difference across the Secondary Coil,** V_S **(V)**				**Mean,** V_S **(V)**
10	7.68	7.43	7.49	7.52	
15	11.08	11.44	11.28	11.34	
25	18.49	18.76	19.06	18.89	
40	29.76	30.63	29.83	30.24	
60	45.92	44.49	44.37	45.64	
85	65.32	63.54	64.51	62.73	
115	88.03	85.48	86.73	87.16	

Analysis

Complete the table by calculating the mean value of V_S for each value of N_S.
Did you ignore any of the values because they were anomalous? Identify them and justify their exclusion.
Which type of error is responsible for the variation of values of V_S when N_S is 115?
How are these errors reduced?
What is the precision of the voltmeter used?

What is the uncertainty in the value of V_S when N_S is 15?
Calculate this as a percentage of the mean value of V_S.
What is the uncertainty in the value of V_S when N_S is 40?
Calculate this as a percentage of the mean value of V_S.
What is the uncertainty in the value of V_S when N_S is 85?
Calculate this as a percentage of the mean value of V_S.

Plot a graph of V_S (on the y axis) against N_S (on the x axis). Draw a line of best fit.
Does your line of best fir pass through the origin? Should it? Explain your answer.

If V_S and N_S are linking by the equation , what does the gradient of your line of best fit represent?

Calculate the gradient of your line of best fit.

Use your gradient to find a value of V_P, the potential across the primary coil.

The potential was measured to be 3200V, what is the difference between this and the value from the gradient?

Calculate this as a percentage of the measured value.

Use this to comment on the accuracy of the investigation.

Identify and explain 2 ways in which a transformer loses energy.

For each way explain how to reduce these losses.

Analysis	The Nuclear Radius Constant
N. DWYER	

You are going to use experimental data on the nuclear radius of ten elements to find the nuclear radius constant r_0.

Experimental Data

Element	A	$A^{1/3}$	Radius (fm)			Mean Radius (fm)	r_0
Helium	4.00		2.09	2.05	2.04		
Beryllium	9.01		2.60	2.65	2.61		
Oxygen	16.00		3.06	3.06	3.09		
Aluminium	26.98		3.56	3.61	3.62		
Calcium	40.08		3.85	3.93	3.92		
Zinc	65.39		4.95	4.95	4.99		
Niobium	92.91		5.54	5.53	5.53		
Tellerium	127.60		6.48	6.54	6.45		
Erbium	167.26		7.29	7.17	7.19		
Uranium	238.03		8.01	8.07	8.09		

Analysis

Calculate the value of $A^{1/3}$ for each of the elements.
Calculate the mean value of the nuclear radius for each element.
What is the name given to the error responsible for the spread in the values of nuclear radius?

Calculate the uncertainty in the radius of each element.
Which has the largest uncertainty?
Calculate the percentage uncertainty in each value of mean radius.
Which has the largest percentage uncertainty?

Use the equation to complete the last column of the table.
Write the appropriate units in the heading of this column.

Calculate the mean value for the nuclear radius constant r_0.

Plot a graph of nuclear radius R (on the y-axis) against the cube root of the number of nucleons $A^{1/3}$ (on the x-axis).
Draw a line of best fit and use it to calculate the gradient.

If the accepted value of r_0 was 1.27 fm ....
Calculate the difference between this value and the value you calculated from the table.
Calculate the percentage difference this gives.
Calculate the difference between this value and the gradient of your graph.
Calculate the percentage difference this gives.

Which of these values is more accurate? Why?

Use your graph to comment on the reliability of the data you were given for this experiment.

What would increasing the number of repeat readings for each radius do to our mean value of radius?
What would keeping the same number of repeats but measuring to radius to a smaller scale (eg. 3 decimal places) do to our mean value of radius?

Practical	Radioactive Decay
N. DWYER	

Radioactive Decay

You are going to carry out an experiment to determine the half-life of a sample of yellow cubes which will represent radioactive nuclei and from this the decay constant.

Equipment List

525 yellow cubes with one side coloured black

The cubes will represent radioactive nuclei. All the cubes with their black side facing up will represent nuclei which have decayed to safety and the cubes with their yellow side facing up will represent nuclei which are still radioactive.

Task

- Count the number of cubes at the start of the experiment. This will be known as the initial number, N_0.
- The decay constant should be ⅙. Using calculate the expected activity, A_E.
- Place the cubes into their container, shake and then pour them onto the desk. Count the cubes which have decayed and place them to one side. Record this value as actual activity, A_A.
- Record the remaining number of radioactive nuclei, N.
- Calculate the expected activity for roll number two.
- Continue until all the nuclei have decayed.
- Record your results in a table which has the following columns:

Number of Rolls t	Expected Activity A_E	Number Remaining N	Actual Activity A_A	Decay Constant λ

After the Experiment

Calculate the difference between the Expected Activity (A_E) and Actual Activity(A_A) for each number of rolls.
Calculate these differences as percentages of the Actual Activity.
Which is the most accurate roll?

Calculate the decay constant for each roll. You should use the number remaining before the roll and the actual activity.
Which is the most accurate?
Calculate the mean value for the decay constant.
What is the uncertainty?
Calculate this as a percentage of the value.

Plot a graph of Actual Activity (A_A) against number of rolls(t).
Take four values from your graph for the half life of the sample. Calculate the mean value for the half-life, $T_{½}$.
What is the uncertainty in your mean?
What is the percentage uncertainty of the mean?

Use the equation to calculate the value of the decay constant. The percentage uncertainty is the same as that in your value for the half-life.

Create a second table with columns for t, N/ N_0 and ln(N/ N_0)
Use your data from the experiment to complete this table.
Plot a graph of ln(N/ N_0) on the y-axis against t on the x-axis and draw a line of best fit.
Calculate the gradient of your line. This is equal to the decay constant.

Is the decay constant calculated from the table, from the half-life or from the last graph the most accurate?

Analysis	Half-Life and the Decay Constant
N. DWYER	

Half-Life and the Decay Constant

A radioactive sample of 7500 nuclei was observed over a period of time and the remaining radioactive nuclei were counted. You are going to use experimental data to find the decay constant and half-life of a radioactive substance. The background radiation was measured to be 11 counts per second.

Experimental Data

Time, t (s)	**Activity, A (Bq)**	**Corrected A (Bq)**	**Number of Nuclei, N**	N / N_0	$\ln (N / N_0)$
5	1371				
10	1124				
15	922				
20	757				
25	622				
30	511				
35	421				
40	346				
45	285				
50	236				

Analysis

Take the background radiation into account to find the corrected activity.
Calculate the number of radioactive nuclei remaining, N, for each time measurement.
Calculate N/N_0 for each time interval.
Calculate $\ln(N/N_0)$ for each time interval.

Plot a graph of N against t (on the x axis) and draw a line of best fit.
Take at least 3 measurements from your graph of the half life.

Use the equation   to find the decay constant λ.

Plot a graph of $\ln(N/N_0)$ against t (on the x axis) and draw a line of best fit.

If $\ln(N/N_0)$ and t are linked by the equation   what does the gradient f your line represent?
Calculate the gradient of your line of best fit.
Use your gradient to calculate the decay constant λ.

The decay constant was given to be 0.04.
Calculate the difference between this value and your value found from the half-life.
What is this as a percentage of the actual value?
Calculate the difference between the actual value and your value found from the gradient.
What is this as a percentage of the actual value?
Which answer is more accurate?

Analysis	# The Inverse Square Law
N. DWYER	

You are going to use experimental data obtained to investigate the inverse square law of γ radiation.

Experimental Data

A G-M tube was placed at various distances from a gamma source. After a set time the reading on the counter was recorded.The background radiation was measured over a minute time period which resulted in a count of 61.

Distance d (m)	**Count**	**Time (s)**	**Count rate (s^{-1})**	**Count**	**Time (s)**	**Count rate (s^{-1})**	**Count**	**Time (s)**	**Count rate (s^{-1})**
0.15	2174	20		4324	40		6612	60	
0.30	566	20		1128	40		1650	60	
0.45	258	20		532	40		774	60	
0.60	166	20		312	40		474	60	
0.75	104	20		196	40		294	60	

Distance d (m)	**Mean count rate C (s^{-1})**	**Corrected count-rate C (s^{-1})**
0.15		
0.30		
0.45		
0.60		

0.75		

Analysis

Calculate the count rate for each trail at every distance from the gamma source.
Calculate the mean count rate at every distance from the gamma source.
What is the uncertainty in the mean count rate at a distance on 0.30m?
Calculate this as a percentage of the mean count rate.
What is the uncertainty of the distance measurement of 0.30m?
Calculate this as a percentage of the actual measurement.
Which of the quantities is the greater source of uncertainty?
What is the background count rate?
Complete the column for the corrected count rate for every distance from the gamma source.
If we did not subtract the background radiation from our readings which type of error would this be?

Plot a graph of: A) against C and B) against d
Draw lines of best fit which continue to cut the axes.
Does either of your graphs support the inverse square law? Explain which features do.

The count rate at point A and B can be compared using the equation:
Use this equation and data from the experiment to calculate the count rate at 0.35m from the gamma source.
Use graph A to calculate the count rate at 0.35m from the gamma source.
Use graph B to calculate the count rate at 0.35m from the gamma source.
If the calculate answer is the actual value which of your graphs gave the most accurate result?

If we had not subtracted the background radiation how would it have affected the gradient of graph A?

Analysis	# Binding Energy
N. DWYER	

Complete this table and plot a graph of binding energy per nucleon (y-axis) against nucleon number (x-axis)

Mass of Proton = 1.00728u Mass of Neutron = 1.00867u 1u = 931.3 MeV

Element	Z	N	A	Mass of separate nucleons (u)	Mass of Nucleus (u)	Mass Defect (u)	Binding Energy (MeV)	BE/A (MeV)
H	1	0	1		1.00728			
He	2	2	4		4.00150			
Li	3	4	7		7.01435			
Be	4	5	9		9.00998			
B	5	6	11		11.00656			
C	6	6	12		11.99670			
N	7	7	14		13.99922			
O	8	8	16		15.99051			
F	9	10	19		18.99345			
Ne	10	10	20		19.98694			
Na	11	12	23		22.98375			
Mg	12	12	24		23.97844			
Al	13	14	27		26.97438			
Si	14	14	28		27.96923			
P	15	16	31		30.96551			
S	16	16	32		31.96327			
Cl	17	18	35		34.95950			
Ar	18	20	38		37.95282			

K	19	20	29		38.95326			
Ca	20	20	40		39.95159			
Sc	21	24	45		44.94437			
Ti	22	25	47		46.93970			
V	23	28	51		50.93135			
Cr	24	28	52		51.92730			
Mn	25	30	55		54.92435			
Fe	26	30	56		55.92060			
Ni	27	30	58		57.91990			
Co	28	32	59		58.91835			
Cu	29	34	63		62.91385			
Zn	30	34	64		63.91260			
Ga	31	38	69		68.90865			
Ge	32	42	74		73.90430			
As	33	42	75		74.90345			
Br	34	44	79		78.89905			
Se	35	46	80		79.89780			
Kr	36	46	82		81.89370			
Rb	37	48	85		84.89135			
Sr	38	50	88		87.88470			
Y	39	50	89		88.88395			
Zr	40	50	90		89.88230			
Nb	41	52	93		92.88345			
Mo	42	56	98		97.88240			

Analysis	$E=mc^2$
N. DWYER	

You are going to use experimental data and Einstein's mass-energy equation to calculate the speed of light.

Experimental Data

The energy released was measured and recorded for different mass defects.

Mass Defect, m **(x 10^{-28}kg)**	**Energy Released,** E **(x 10^{-11}J)**			**Mean Energy Released,** E **(J)**	**Speed of Light Squared,** c^2 **(m/s)^2**	**Speed of Light,** c **(m/s)**
4.85	4.07	4.06	3.99			
9.96	8.81	8.91	8.89			
14.4	12.6	12.3	12.9			
19.8	16.5	16.5	16.3			
24.5	20.4	20.4	20.2			
29.2	23.5	23.5	24.4			
34.8	29.9	30.7	30.5			

Analysis

Calculate the mean energy released for each mass defect.
What is the precision of the mass defect?
Calculate the percentage uncertainty in the middle mass defect?

What is the uncertainty in the energy released for a mass defect of 4.85 x 10^{-28} kg?
Calculate this as a percentage of the mean energy released.

What is the uncertainty in the energy released for a mass defect of 14.4 x 10^{-28} kg?
Calculate this as a percentage of the smallest energy released for this mass defect
What is the uncertainty in the energy released for a mass defect of 24.5 x 10^{-28} kg?
Calculate this as a percentage of the largest energy released for this mass defect.
What is the uncertainty in the energy released for a mass defect of 34.8 x 10^{-28} kg?
Calculate this as a percentage of the middle energy released for this mass defect.

Use the equation to complete the last columns of the table labelled c^2 and c.
Calculate your mean value for the speed of light c.
What is the difference between your mean value and the accepted value 3.0 x 10^8 m/s?
Calculate this as a percentage of the accepted value.

Plot a graph of mean energy released E (on the y-axis) against mass defect m (on the x-axis).
Draw a line of best fit and describe any pattern or trend shown by your graph.
Calculate the gradient of the line of best fit.
The square root of the gradient gives us a value for c. What value does the gradient yield?
What is the difference between your gradient value for c and the accepted value?
Calculate this as a percentage of the accepted value.

What does accurate mean?
Which of your values is more accurate?
What does reliable mean?
How could the results be made more reliable?

Analysis	Ideal Gases
N. DWYER	

You are going to analyse two experiments which were carried out to find the molar gas constant, R.
The accepted value of R is 8.31

Constant Volume Experimental Data

15 moles of a gas were kept in a container of volume 2.5 ±0.1 m^3. Temperature probe ± 1K

Temperature T (K)	**Pressure p (kPa)**			**Mean p (kPa)**	R
293	14.5	14.2	14.5		
313	15.3	15.5	15.7		
333	16.6	16.4	16.5		
353	17.5	17.5	17.7		
373	18.4	18.8	18.9		

Constant Pressure Experimental Data

15 moles of the same gas were kept at a constant pressure of 1.8 ± 0.1 kPa. Temperature probe ± 1K

Temperature T (K)	**Volume V (m^3)**			**Mean V (m^3)**	R
293	2.04	2.09	2.05		
313	2.26	2.23	2.25		
333	2.31	2.35	2.33		
353	2.44	2.41	2.45		
373	2.67	2.63	2.63		

Analysis 1 – Constant Volume

Calculate the mean pressures and fill in the table.

Use the equation to fill in the last column of the table.
Calculate the mean value of R.
What is the percentage difference of your value from the accepted value?
Plot a graph of pressure (on the y-axis) against temperature (on the x-axis) and draw a line of best fit.
Calculate the gradient of your line and use it to find the value of R.
What is the percentage difference of this value from the accepted value?
Which of your values in more accurate?

Analysis 2 – Constant Pressure

Calculate the mean volumes and fill in the table.

Use the equation to fill in the last column of the table.
Calculate the mean value of R.
What is the percentage difference of your value from the accepted value?
Plot a graph of volume (on the y-axis) against temperature (on the x-axis) and draw a line of best fit.
Calculate the gradient of your line and use it to find the value of R.
What is the percentage difference of this value from the accepted value?
Which of your values in more accurate?

Analysis 3 - Comparison

With reference to the percentage differences explain which of the experiments was more accurate.
With reference to the graphs you have drawn explain which of the experiments was more reliable.
The third run of experiment 1 and the fourth run of experiment 2 should have given you the same value of R. Use the percentage uncertainties for the pressure, temperature and volume in each experiment to calculate the percentage uncertainty in the values of R.
What word can we use to describe the value of R with the lower percentage uncertainty?

Practical	Finding Absolute Zero
N. DWYER	

You are going to carry out an experiment to investigate the how the volume a gas occupies varies with temperature. You will then use this data to predict the absolute zero temperature.

Equipment List

Simple Gas Thermometer	Ice
Ruler (30cm)	Kettle
Beakers	Calibrated Thermometer

Task

- A simple gas thermometer consists of a capillary tube sealed at one end with a thread of sulphuric acid trapping a column of air.
- Measure the room temperature.
- Place the ice, thermometer and capillary tube into the beaker.
- Record the temperature and the length l of the column of trapped air.
- Record values of l for various temperatures as the ice water approaches room temperature.
- Empty the beaker, boil the kettle and fill the beaker. Place the thermometer and capillary tube into the beaker.
- Record values of l for various temperatures as the water approaches room temperature.
- Repeat the experiment two more times.
- Produce a table of the three sets of raw data and the mean values of l for different temperatures
- Plot a graph of length l on the y-axis and the temperature on the x-axis.

- Your x-axis should have a range of -300°C to 100°C.
- Draw a straight line of best fit for your results and extrapolate it until it crosses the x-axis.

After the Experiment

What were the independent and dependent variables in your experiment?
Look at your graph, what is the relationship between the two variables you have investigated?

What was the precision of the thermometer you used during the investigation?
Calculate the percentage uncertainty in your largest reading of the temperature.
What was the precision of the ruler you used during the investigation?
Calculate the percentage uncertainty in your largest reading of the length of the column of air.
For this reading which of the two instruments is more precise?

Choose any reading from the middle of the range of temperatures you used in the investigation.
Calculate the uncertainty in the value of the mean length.
What is this as a percentage uncertainty of the mean length?

Where does your graph cut the x-axis? This is your value for the absolute zero temperature.
The accepted value is given as -273K, what is the difference between your value and the accepted value?
Calculate the percentage difference of your value from the accepted value.

Comment on the reliability of your results including a reference to your graph.
Explain how taking fewer readings would affect the reliability of your results and why.
Explain how taking more readings would affect the reliability of your results and why.

Identify what you believe is the biggest cause of error in your investigation. How could you reduce this?

Analysis	Finding Absolute Zero
N. DWYER	

Finding Absolute Zero

12.7 m^3 of gas was heated to 40 °C and then cooled. The pressure was measured every 10 °C as it was cooled. Using this we can find the absolute zero temperature and the number of moles of gas.

Experimental Data

The energy released was measured and recorded for different mass defects.

Temperature, T (°C)	**Pressure, p (Pa)**			**Mean Pressure, p (Pa)**	**Temperature, T (K)**
40	187	180	182		
30	188	193	189		
20	200	197	200		
10	207	208	206		
0	211	216	215		
-10	220	222	227		
-20	228	231	231		
-30	242	236	236		
-40	240	251	247		

Analysis

What was the independent variable in the investigation?
Name one of the control variables in the investigation.
What was the dependent variable in the investigation?
What is the precision of the temperature measurement?
What is the precision of the volume measurement?

Calculate the mean pressure for each temperature.
Convert the temperatures into kelvins.
What is the uncertainty in the pressure measurement at 30 °C?
Calculate this as a percentage of the mean pressure at this temperature.
What is the uncertainty in the pressure measurement at 10 °C?
Calculate this as a percentage of the mean pressure at this temperature.
What is the uncertainty in the pressure measurement at -10 °C?
Calculate this as a percentage of the mean pressure at this temperature.
What is the uncertainty in the pressure measurement at -30 °C?
Calculate this as a percentage of the mean pressure at this temperature.

Plot a graph of P against T (x axis) and draw a line of best fit.
Where does the line cut the x axis?
This should be -273 °C, what is the difference between your value and the accepted value?
Calculate this as a percentage of the accepted value.

Pressure and temperature are linked by the equation $pV = nRT$, what does the gradient of your line represent?
Calculate the gradient of your line.
Use the gradient to calculate the number of moles of gas in the container.
The accepted number of moles is 1.2, what is the difference between this value and your value from the gradient?
Calculate this as a percentage of the accepted value.

Practical	Specific Heat Capacity
N. DWYER	

You are going to carry out an experiment to calculate the specific heat capacity of different materials and compare your values to the accepted values.

Equipment List

Power pack
Ammeter
Voltmeter
Immersion Heater
Leads

Calibrated Thermometer
Stop Clock
Test Metals
Beaker and Balance (up to 1kg)
Heat Proof Mat and Lagging

Task

- Connect the immersion heater to the power pack turned to 10V. Set up the voltmeter to measure the potential difference across (V) and an ammeter to measure the current through (I) the heater.
- Measure the mass of the test sample* and state the precision of the instrument.
- Place the immersion heater in the test sample
- Place the calibrated thermometer in the sample and record its initial temperature. State the precision of the thermometer.
- Turn on the power pack and start the stop clock simultaneously.
- Record the readings on the voltmeter and ammeter. State the precision of each instrument.
- Record the temperature of the sample at intervals up to 15 minutes.
- Calculate the Energy supplied for each time interval you measured the temperature at.
- Energy supplied can be calculate using the equation .
- Create a table of Energy supplied (Q) and Temperature Difference (ΔT).
- Plot a graph of Energy (on the y axis) against Temperature Difference (on the x axis). Draw a line of best fit.
- Repeat the experiment for different test samples if you have time.

After the Experiment

What were the independent and dependent variables in your experiment?

Look at your graph, the theoretical equation for the line is given by , how does your line support this?

Use your graph to comment on the reliability of your results.

Calculate the percentage uncertainty in your voltmeter reading.
Calculate the percentage uncertainty in your ammeter reading.
Calculate the percentage uncertainty in the initial temperature reading.
Calculate the percentage uncertainty in your measurement of 15 minutes.
Which is more precise?
What is the percentage error in your value for the Energy supplied after 15 minutes?

Calculate the gradient of your line of best fit.
What does the gradient represent?
Use your gradient to calculate the specific heat capacity of the test sample.
What is the difference between your value and the accepted value?
Calculate this as a percentage difference.

Why is the value you calculated for the energy supplied only an estimate?
How could you have improved the set up?