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GENERAL INFORMATION

This manual outlines the general procedures for the laboratory for the whole of the course (ie Semesters 1 **and** 2) but only provides a detailed timetable and experimental description for the first Semester as the laboratory courses for the Physics Department are being modernised and reorganised and some of the details for the experimental work to be undertaken during the second Semester have yet to be finalised.

An addendum to this manual will be issued during the first Lab session for each group in the second Semester.

EE1 Laboratory Timetable

Experiment Schedule

		Group	
Week	***Dates***	***A***	***B***
3	**IT** 12th October	**Lab Introduction** Computer Log-on **IT Assignment**	
4	**Experimental Tutorials 1** 19th October		**Lab Introduction** Computer Log-on **IT Assignment**
5	**Experimental Tutorials 2** 26rd October	Dynamics: **Glider & Pulley** Thermal: **Thermal Conduction**	
6	**Experimental Tutorials 3** 2nd November		Dynamics: **Glider & Pulley** Thermal: **Thermal Conduction**
7	**Experimental Tutorials 4** 9th November	Dynamics: **Momentum & Impulse** Thermal: **Boyle's Law**	
8	**Experimental Tutorials 5** 16th November		Dynamics: **Momentum & Impulse** Thermal: **Boyle's Law**
9	**Experimental Tutorials 6** 23rd November	Dynamics: **Hooke's Law, SHM** Thermal: **Heat Loss Mechanisms**	

		Group	
Week	***Dates***	***A***	***B***
10	**Experimental Tutorials 6** 30th November		Dynamics: **Hooke's Law, SHM** Thermal: **Heat Loss Mechanisms**
12	15th December	***Hand in IT, report and notebook!***	***Hand in IT, report and notebook!***

EE1 Laboratory Times

Monday	
Tuesday	
Wednesday	
Thursday	14:00 - 16:30
Friday	

EE1 Laboratory Assessment and Deadlines

You will be assessed on the basis of the following items:

1) Lab records – records written in the lab of each of the experiments you have performed.
2) IT Assignment – the record of your IT assignment, printed out and handed in on paper.
3) A laboratory report – a word processed write-up of one of the experiments Guidelines for the report are given in the appendix.

Task	*Date for completion*	*Marks*
Lab records	**End of each lab, Book handed in Friday, 15th December 2006**	**60**
IT assignment	**Friday, 15th December 2006**	**20**
Lab Report	**Friday, 15th December 2006**	**15**
TOTAL (Scaled to 10% of degree mark)		**95**

N.B. Your laboratory notebook(s) must be handed in at the same time as your report to allow checking of your final assessment mark.

A second appraisal of the same format will take place at the end of the Laboratory work in Semester 2 to give a total Laboratory work contribution 20% of the degree examination mark.

Guidelines

Attendance

- It is your responsibility to ensure that there is a record of your attendance at the labs. If your attendance is not recorded you will not receive marks for your laboratory work.
- If you do extra work, you must ensure that your attendance is recorded either by a demonstrator or a technician.
- **You must obtain approval from a technician for work outside normal lab hours for insurance purposes.**

Submission of work

- All work must be handed in on, or before, 16:00 on the date indicated in the deadline table.
- You must hand your work to the technician and sign to say that the work has been handed in.
- You will receive a receipt to say that the work has been received.
- No credit will be awarded for work, where the sheets are not signed and the student cannot produce their receipt.
- **The penalty for late work is that 10% of the assessed mark for the submitted material will be lost per working day overdue; the possible credit will therefore taper to zero in 10 working days.**

Lab records

- Hand in your notebook at the end of each experimental day so that your marks can be entered into our spreadsheet.
- Include printouts of relevant tables and graphs in your log book and save them to your account / email them to your lab partner. The saved version is useful as you will need these at the end of term to perform your laboratory write-up.
- You must hand in your book at the date shown in the deadline table since this is part of your final grade assessment.

Lab reports

- Lab reports must be submitted in accordance with the rules above.

IT Assessment

- Rules for submission are the same as for the lab reports.
- **If no submission for an IT assessment is received, your name will NOT be included in the list of exemptions from the need to sit the "Certificate of Basic IT competence".**

Minimum Performance

You may be refused credit for Physics EE1 unless:

1. **You submit at least 50% of the work to be assessed.**

2. **There is recorded evidence of your attendance at 50% of the lab sessions.**

Introduction

The work of the laboratory sessions integrates problem solving tutorial questions with related experiments. The questions and the experiments reinforce the work you are covering in your lecture courses.

Aims

- To demonstrate the basics of experimental physics.
- To develop skills required for the clear presentation of scientific results.
- To develop problem solving techniques.
- To experimentally demonstrate concepts discussed in lectures.
- To encourage group-work as a means of effective problem solving.

Objectives

At the end of this laboratory course you should be able to

- record experimental data properly;
- present data in graphical from;
- take effective notes during an experiment;
- know how to estimate the uncertainties in measurements;
- present a word-processed report on an experiment;
- assess the quality of experiments through group discussion.

Demonstrating and Marking

Each experimental tutorial is supervised by one demonstrator, who is usually a research assistant or PhD student. In addition there will be at least one member of the academic staff during any lab session. Marking of your lab records will be done by the demonstrator for your experiment or staff member on duty. The end-of-term reports are marked by demonstrators or staff.

There are ten marks available for each experiment. Each numbered point in the experiment is marked. The numbered points usually account for eight (sometimes nine) of the available ten marks. The other marks are discretionary and are awarded to students who, for example, produce an error analysis, make interesting suggestions about the future use of the experiment or perform the optional extra parts of the experiments.

Experimental Tutorials

- Three experimental tutorials are carried out in each lab session.
- Each experimental tutorial is timed to last fifty minutes. Please use the times for each section to ensure that you keep on track to finishing the experiment.

Before coming to the lab sessions

- Read the notes on the experiment in this manual.
- Read any references cited.
- Make a first attempt at the tutorial questions, you can discuss with your fellow students and demonstrators to refine your answers during the allocated time in the session.
- Each experimental tutorial also has a list of further work questions from the example book and the mastering physics system – use these to practice the material before the sessions and to reinforce the material after the session.
- Preparing well in advance will allow you to complete the experimental tutorial in the hour and to try the optional further work sections.

Lab partners and groups

- You carry out the experimental work with a lab partner.
- You can discuss the experiment with others, and indeed some sessions require you to work as a group to complete the tasks in the experimental tutorial.

Safety

- You must obtain a copy of the departmental safety regulations, and sign a receipt.
- Any breakages or accidents should be reported to a member of staff or the lab technicians.

IT skills and the Departmental PC Clusters

The Physics Department has several Open Access Computing Clusters which you will be able to use at your own convenience, provided the computers are not being used for class teaching.

Attendance

You are required to 'sign-in' and 'sign-out' on the attendance sheets provided. **If you do not attend a lab, you will receive no marks for that lab.**

Missed a lab session?

If you miss a lab because of a medical problem or any other valid reason, you should follow the University code of practice at the back of this manual.

YOU MUST ALSO:

1. HAND A COPY OF THE SELF CERTIFICATE TO A TECHNICIAN OR STAFF MEMBER

2. ARRANGE AN ALTERNATIVE TIME WITH A TECHNICIAN TO COMPLETE THE WORK YOU HAVE MISSED

If it is not possible to re-schedule your missed lab work, you will be awarded a mark for the lab based on what you hand in, provided you have followed the correct procedures. **In this case your lab book must contain a statement explaining why you were unable to reschedule the missed work.**

Problems

- Specific problems relating to the experiments should be discussed with demonstrators or staff on duty.

- General difficulties should be taken to the lab head.

I.T. IN THE PHYSICS CONTEXT

Aims

- To realise the potential of Microsoft Word and Excel as tools for the understanding of Physics.
- To gain experience in using various scientifically-useful functions of Word and Excel.
- To use Word and Excel to create components of a laboratory report.
- To introduce the mastering physics tutorial system
- To provide material to allow exemption from the Certificate of Basic IT competence.

Introduction

In the EE1lab you are required to submit reports on a subset of the experimental work which you carry out in each module. You are also required to make use of spreadsheets to analyse data during some of the experiments. The primary aim of the exercises presented here is to help you learn (or revise) the skills needed for these requirements. Note that the laboratory experiments rely on the fact that you are already skilled at entering equations and producing graphs in Excel, so you need to learn these skills before the 1st week of experiments.

The university also requires that each student attain a '*Certificate of Basic IT competence'* before entry into 2nd year. By adequately completing the tasks in this exercise you will have shown IT competence and will have your name added to a list which will be forwarded to the IT Education Unit in the university and you will automatically gain exemption from their course.

Since the amount of previous experience students have is quite varied, this exercise is *self-paced***.** You are under no pressure to complete everything in the timetabled session, all you are required to do is to submit your assignment *at the end of term (see timetable)*. Please note, though, that demonstrator help will only be available during the timetabled sessions.

Note, you are free to use any of the Departmental Open Access Computer Cluster PCs at any time and are encouraged to check your email and the moodle site regularly.

Getting started

Before beginning any of the exercises, you will need to login into a PC on the University network, and start the appropriate applications. You will be told how to do this at the introductory lab session. *Please ask a demonstrator if you experience problems*[1].

All the information you require to carry out these exercises is provided within this document. However, additional help with using IT packages is offered by the IT

1You will need to be processed by the registry before you can login in to the university network.

Education Unit in the University. The following web address contains links to short help sections:

http://apps.iteu.gla.ac.uk/ITEU/html/topups/index.jsp

You may find it helpful to have this displayed in a web browser as you go through the exercises. This web link is only for help perform the exercises in this book not those on that web page.

As a first step, please use a browser to navigate to the EE1 Moodle site at ***http://moodle.gla.ac.uk/physics/moodle/*** and enrol yourself in the class. The enrolment key (that you will be asked for when you first access the P1 area of Moodle) is **Physics EE1**. Moodle is the medium through which all material and announcements relating to the class will be communicated, **so it is important that you get into the way of accessing it regularly**.

1. Using Microsoft Word

Microsoft's Word package is the most commonly used word processor. In this exercise you will be introduced to some of the useful functions the package possesses for scientific writing. These will be vital for writing your laboratory reports.

A good, thorough laboratory report contains diagrams of experimental set-ups, equations, tables of results and so on. Here you will learn how to create these elements electronically.

Sections 2.1 and 2.2 instruct you in the use of a series of these tools, teaching you what they can do and how to use them. Once you have gained this experience, section 2.3 asks you to employ those skills in four exercises. Your attempts at these exercises must be saved in a word document and presented for marking.

Important note – remember to save your work frequently on to the floppy disk you've been provided with!

1.1 Drawing diagrams.

Here you will use the Microsoft Draw package.

1.1.1 Creating objects

- The first step is to bring up the drawing toolbar. To do this, click on *View* → *Toolbars* → *Drawing*. This toolbar contains several buttons. Run your mouse along the icons to learn what each does.

- Click on the *Line* button. When you move the mouse back over the page, a + will appear. A line is drawn when you depress the left mouse button and drag + across the screen. The line terminates by releasing the mouse button. Holding down the shift key together with the left mouse button will produce a horizontal, vertical or

45^o line.

- Now draw a rectangle, an ellipse and an arc. You can vary the sizes of all these shapes by clicking on one edge or corner and dragging.

- Microsoft Draw does not restrict you to fixed shapes. Find the *freeform* and *scribble* buttons and draw a couple of random shapes.

- Having now created your Microsoft Draw masterpiece, you can give it a title by inserting a text box. Click on the Textbox button and then click the mouse somewhere on your page. By clicking inside this box you can write your title.

1.1.2 Editing objects

- Click on one of the lines you've already drawn. Now go to *Edit → Copy* and then *Edit → Paste* to create a duplicate of that line. Now click on the *Line Style* button and change the thickness of your line. Create another copy and use the *Dash Style* button to create a dashed line.

The *Line Style* and *Dash Style* functions can be used to alter any of the shapes you created.

- Copy a couple of your shapes and experiment with the options.

Draw objects can also be edited by right clicking on the object. This brings up an options window that allows you to specify the size, colour, etc of the object.

- Draw a circle and then use the editing options to change the colour of the circle's interior to blue and its boundary line to red.

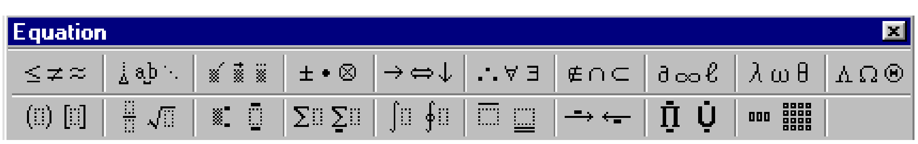
1.2 Using Microsoft Equation editor

In this section you will be shown how to create three separate equations using the Microsoft Equation package.

To insert an equation using the equation editor, click:

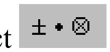
Insert → Object → Microsoft Equation 3.0 → O.K.

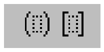
A box in which you insert the equation and the Equation Editor Toolbar will appear. The toolbar is shown below.



Type in the following equations:

(i) $A \cdot (B + C) = A \cdot B + A \cdot C$

- Type A into the Equation Editor box. Select  with the mouse and, keeping the left mouse button depressed, move the mouse pointer to the appropriate symbol. When you release the mouse, the symbol will be inserted.[1,2]

- Select  and as above enter ( ) into the equation.

- Type B+C inside the round brackets.

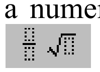
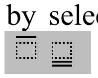
- Complete the equation inside the Equation Editor box.

- Return to your word file by clicking outside the Equation Editor box twice.

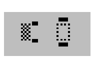
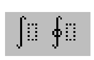
It is possible to edit the text of an equation by pointing at the equation with the mouse and double-clicking.

(ii) $\nabla f = \frac{df}{dx}\underline{i} + \frac{df}{dy}\underline{j} + \frac{df}{dz}\underline{k}$

- The ∇ symbol is obtained by selecting  from the Equation Editor toolbar.

- The expressions with a numerator and denominator (the partial derivatives) are obtained by selecting , and the underscore defining the unit vectors by selecting . Highlight the text to be underscored, then select the appropriate symbol.

(iii) $U_1 - U_2 = \int_{U_1}^{U_2} Eds$

- Here, use  and .

You can copy and paste equations just as you did objects in Microsoft Draw. Just click on the equation you're interested in and select *Edit → Copy*. Then click on the page where you wish the copy to appear, then select *Edit → Paste*.

---

[1] You can also insert the symbol by clicking on the first box, releasing the mouse button, then clicking a second time on the symbol you want.

[2] By the way, if you want to add a footnote of your own, click on the appropriate spot in the text then go to Insert → Footnote. (If you are using Office 2003, it's Insert → Reference → Footnote.)

Example – put the equations into a table.

- Click on a line below equation 3, then click on *Table* → *Insert* → *Table*. This will bring up the "Insert Table" box. Set the number of columns to be 3 and the number of rows to be 2, then click on OK.

- In the cells in row 1 type "Equation 1", "Equation 2" and "Equation 3". Now copy equation 1 and paste it into the first cell in row 2. Repeat this procedure for equations 2 and 3.

Have you been remembering to save your file as you've gone? If not, best do so now!

1.3 Exercises

A)

- Using Microsoft Draw, create the following picture.

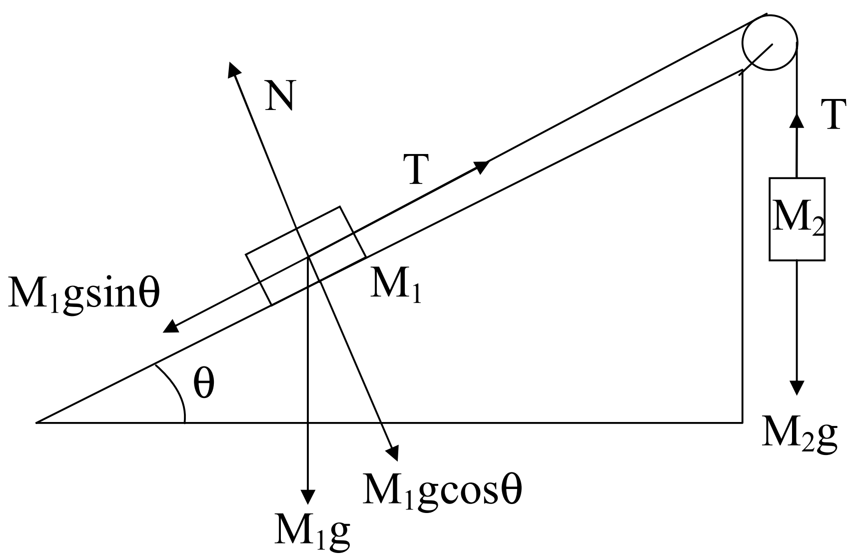
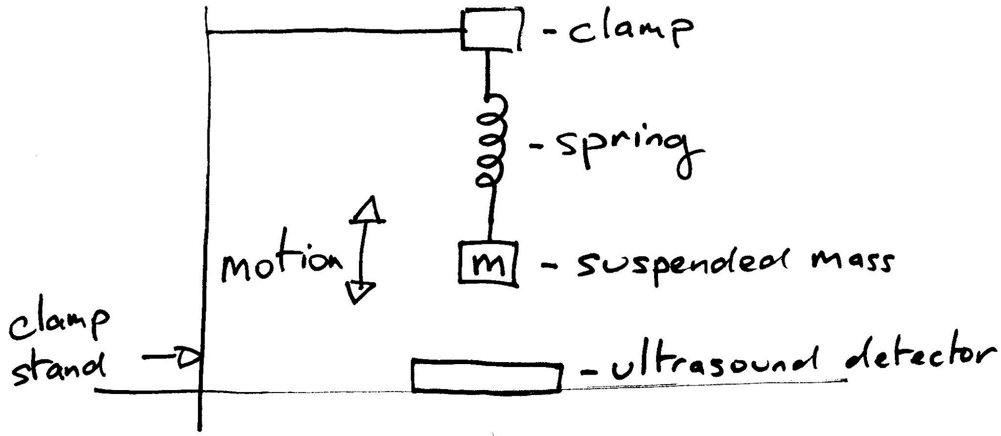


Figure 1: Forces acting on a block on a slope.

B)

- Below is a sketch a student made in their lab book when they were carrying out an experiment to measure the period of a mass bouncing on a spring. They now have to write it up as a report. Create an electronic version of this diagram.



C)

- Another student is writing a report on an experiment where a glider was slid down an air track and its speed noted at two points. They wish to include a table containing the results from their experiment. The table from their lab book is below. Turn this into a Word table.

Run	$u\,(ms^{-1})$	$v\,(ms^{-1})$	$t\,(s)$	$a\,(ms^{-2})$
1	2·3	4·1	1·3	1·4
2	2·5	3·9	1·1	1·3
3	2·4	3·8	1·0	1·4
4	2·3	4·0	1·3	1·3
5	2·1	3·9	1·2	1·5

D)

- Reproduce the following equations:

$$s = ut + \frac{at^2}{2}$$

$$\underline{F}_{12} = \frac{kQ_1Q_2}{r^2}\underline{\hat{r}}$$

$$\sigma_{N-1}^2 = \frac{1}{N-1}\sum_i \left(x_i - \overline{x}\right)^2$$

2. Using Excel to analyse and present data

Microsoft's Excel package allows you to tabulate and manipulate data which you have collected whilst performing an experiment. You can manipulate the data by entering equations and graph the results.

Here, as in section 2, the initial sections (3.1 – 3.3) instruct you in the use of a series of Excel's tools, teaching you what they can do and how to use them. Once you have gained this experience, section 3.4 asks you to employ those skills in three exercises. Your attempts at these exercises must be saved in an excel document and presented for marking.

Again – remember to save your work frequently on to the floppy disk you've been provided with!

2.1 Handling tables of data

- Open up a web browser and go to the following web site:

http://www.physics.gla.ac.uk/~psneddon/P1X_labs.html

(This page is also linked from the Moodle site in the ***Laboratory information*** *section.)*

- Open the file P1X_excel_exercise_A.xls

You should see a spreadsheet with the following information:

		Exam Mark	Laboratory Mark	Total Mark
William	Baker	68	75	
Sophie	Manning	70	72	
Elizabeth	Sutton	62	64	
Peter	McGann	67	72	
Thomas	McCoy	70	81	
Christopher	Pertwee	70	75	
Carol-Anne	Aldred	77	80	
Bonnie	Jamieson	66	68	
Sylvester	Eccleston	59	66	
Patrick	Davison	61	71	
Jon	Troughton	69	71	
Sarah	Bryant	79	80	
Katy	Sladen	55	59	
Paul	Hartnell	48	56	
Nicola	Langford	65	78	
Louise	Hill	79	86	

The spreadsheet details the results of a section of a Physics class giving the lab and exam mark of students (marked out of 100). We want to calculate the total result for each student for the course.

2.1.1 Sorting your data

One of Excel's strengths is its ability to allow you to Sort a set of data in several ways. For instance, we could reorder the above data into exam mark order. However, typically a results list is listed in alphabetical order.

- Select all the data (i.e. cells A2 to D17) and then go to *Data → Sort* and select column B and Ascending order. The table should now be ordered in Surname alphabetical order.

Now, technically the Data Protection Act makes it illegal for the University to share a student's results with the general public, so before we go any further you need to make the data anonymous – i.e. delete the names from this spreadsheet.

- Select columns A and B of the spreadsheet. (Click on the A, then whilst holding down the shift button, click on the B.) Then go to *Edit → Delete*.

However, we want some way to identify the students, so each row of data needs a number.

- Highlight the new column A, then go to *Insert → Columns*. The existing data should be shunted one column to the right, leaving a new, empty column A. Label the contents of the column in cell A1 by typing in ‘identifier’. Then fill in the numbers 1 – 16 down the list.

2.1.2 Calculating the "Total Mark"

The total mark a student gains in Physics is a combination of their mark for their exams and their laboratory mark. It is not a straight addition of the two, though. The exam mark makes up 80% of the total, the labs 20%. We need, therefore, to scale the results on the spreadsheet.

- Insert two new columns between the "Laboratory Mark" and "Total Mark" columns. Label these "Scaled Exam Mark" and "Scaled Lab Mark" respectively. If you cannot see the full heading once it's typed, adjust the column width appropriately. This is done by positioning the mouse over the very top of the divider line at the right hand edge of the column you want to widen. Then simply click and drag right until you can see the full text.

- To scale the exam mark, enter the following into cell D2:

  =0.8*B2

  and press *Enter*. This multiplies the contents of cell B2 (student 1's exam mark) by 0.8, i.e. calculates 80% of that mark. The cell in the spreadsheet should now contain the scaled result.

- You now want to do the same for students 2 – 16. The most efficient way to do this is to click your mouse on the bottom right hand corner of cell D2. Now drag the mouse down until all the cells up to and including D17 are highlighted. When you release the mouse button, these cells will fill in. Click on any one of these and you will see an equation of the same form as above, but with a different cell number. (e.g. B5, B8, etc.)

- Using the same technique, complete the "Scaled Lab Mark" column, remembering that you want to scale the laboratory marks to 20% here.

You can now calculate the total mark for each student, by adding the contents of columns D and E together in column F.

- Enter *=D2+E2* into F2, hit *Enter*, and then repeat the click, drag, release procedure. The column should now contain the final mark of each student

- Sort the data so that the students with the highest total marks are listed at the top.

2.2 Manipulating experimental data

Return to the webpage mentioned in Part 2.1 (or the P1 Moodle site) and open up the file P1X_excel_exercise_B.xls

A student carries out an experiment to calculate the acceleration of a moving object. They do this by measuring the object's speed, v, at various times, t. The spreadsheet you have just opened shows the measured results.

The relevant equation of motion for this object is:

$$v - v_0 = at$$

where v_0 is the object's initial velocity and a is its acceleration. If a graph of $(v - v_0)$ versus t is plotted, the gradient of the graph will be the acceleration.

2.2.1 Performing calculations

- On the spreadsheet write "v0" in cell D1[1], and then "4" in D2. i.e. D2 has the value of the initial velocity.

We are going to put the data for the y-axis of the graph – the values of $(v - v_0)$ – into column C.

- Give the column a suitable heading in C1, then click in cell C2. Enter the following equation:

=(B2-$D$2)

[1] If you want to make the 0 a subscript, click in the cell and select the number. Then click *Format* → *Cells* and tick the "Subscript" box. Click OK, and then hit Enter again to leave the cell.

and then hit *Enter*. (You're taking the data in the velocity column and subtracting the initial velocity.) Now, as you did in part A, click on the right hand bottom corner of C2 and drag down to C9 to fill in the rest of the column.

The use of the "$" signs is vital. Without them, when you drag down, the cell subtracted would move from D2 to D3, D4, etc. Using the "$" locks the reference to the correct place. Try it and see!

2.2.2 Plotting data graphically

You now want to plot the graph of $(v - v_0)$ vs t.

- Select the time data (A1 – A9), then whilst holding the Ctrl button select C1 – C9.
- Now click on the *Chart Wizard* icon. Select *XY Scatter* → *Scatter*, then click *Next*.
- A preview of your graph should now appear (step 2 of the *Chart Wizard*). Check the data range is what it should be (i.e. =Sheet1!$A$1:$A$9,Sheet1!$C$1:$C$9), then click *Next*.
- Step 3 of the *Chart Wizard* allows you to label your graph. Input suitable x and y-axes labels, as well as a title for your graph. Click *Next*.
- The final step of the *Wizard* determines where the graph will go. For this example, select Sheet 1 and click on *Finish*.

2.2.3 Finding the gradient of a graph

To find the gradient of a line drawn in Excel we use a programme called *Trendline*.

- Right click on any of the data points. In the menu this brings up, click on *Add Trendline*.
- In the *Type* tab, select *"Linear"*.
- In the Options tab, select "*Automatic*" and "*Display equation on chart*". Click *OK*.

There should now be a best fit line through the data points and an equation of the form $y = mx + c$ (the equation for a straight line of gradient m and intercept c). Here the intercept = 0 and the gradient (= acceleration) = $0.8\ \text{ms}^{-2}$.

2.3: Evaluating (and plotting) a complex equation

In this section you are going to plot the following function:

$$f(x) = \frac{1}{2\sqrt{2\pi}} \exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\} \qquad [*]$$

This is a Gaussian distribution with mean value μ, and standard deviation σ.

- The first step is to open a new spreadsheet and call it Gaussian.xls

2.3.1 Evaluating

Now we need to evaluate the equation $f(x)$ for a range of x values. i.e. we need to convert the above equation into a form that Excel can recognise and interpret. The following steps will do this by breaking the expression into smaller terms, α, β, and γ, where:

$$\alpha = \frac{1}{2\sqrt{2\pi}}, \beta = (x-\mu)^2, \gamma = 2\sigma^2$$

i.e. [*] becomes: $$f(x) = \alpha \exp\left\{-\frac{\beta}{\gamma}\right\}$$

- In your spread sheet create suitable column headings along Row 1. e.g.:

	A	B	C	D	E	F	G
1	*mu*	*sigma*	*x*	*alpha*	*beta*	*gamma*	*f(x)*
2							

For this example we shall define the mean, μ (mu), to be 5 and the standard deviation, σ (sigma), to be 2.

- Enters these numbers into cells A2 and B2 respectively.

- Column C will contain your *x*-values. The first point is 0.0, so enter this in cell C2.

Now we start putting in the equations. We want to put the equation for α in cell D2. Recall $\alpha = \frac{1}{2\sqrt{2\pi}}$. In Excel, this is expressed as *=1/(2*sqrt(2*Pi()))*.

The function *sqrt()* calculates the square root of whatever is within the brackets. Here this is 2π, or *2*Pi()*.

- Put the Excel version of the equation α into cell D2 and click *Enter*. Make sure you have all the correct brackets in place. This is vital in Excel. If there is not the same number of opening brackets as closing brackets, Excel will query your equation. However, if the numbers match it will just calculate whatever you have typed, whether those brackets are in the right place or not.

Now we put the equation for β in cell E2. Recall $\beta = (x-\mu)^2$. In Excel this is expressed as *=(C2-$A$2)^2*. Here the $A$2 is picking up the contents of cell A2, which is the value of μ.

- Enter the Excel version of the equation for β into E2 and hit *Enter*. In Excel the "^" symbol means "to the power", and is applied after the calculation within the brackets.

- Now input the equation for γ in F2. In Excel language, $\gamma = 2\sigma^2$ is expressed as *=2*$B$2^2*.

We are now ready to calculate $f(x)$ by combining the equations that have been entered into cells D2, E2 and F2.

- Type the following into G2:

  *=D2*exp(-E2/F2)*

  In Excel, the equation *exp()* calculates the exponential of whatever is in the brackets.

Now that we have calculated $f(x)$ at x = 0.0, we need to calculate it over a range of x values.

- Create a list of x values from 0.0 to 10.0, increasing in steps of 0.2. To do this, type *=C2+0.2* into cell C3. Then click on the bottom right hand corner of C3 and drag the mouse down to cell C52. When you release the mouse, you should have the required list.

- Fill in the corresponding values of α, β, γ and $f(x)$ by repeating the same click, drag and release procedure on cells D2, E2, F2 and G2. Note – the contents of Columns D and F should be the same in every cell. If not, go back and check that you have correctly typed in the equation in D2 and/or F2.

2.3.2 Plotting

- To plot this function $f(x)$, follow the instructions detailed in Part 2.2.2, selecting column C for your x-values and G for your y-values.

2.3.3 Using Excel functions

In addition to being able to enter your own equations into Excel, the software comes with a range of useful equations, or functions, which you can use. We've already encountered the square root function. Here we will introduce some of the others.

- Open a new spreadsheet and enter the number 1 – 10 into column A.

- In cell B1, type the following:

=sum(A1:A10)

As the name of the function implies, this function adds up the contents of the cells A1 through A10. If this number is then divided by 10, the average of the series of numbers is obtained. It's not a very efficient way to find the average though.

- In cell B2, type the following:

=average(A1:A10)

This calculates the average directly.

These are just two examples of the functions available. A full list can be found by going to *Insert → Function*.

2.4 Exercises

A)

- Go back to the table of data you created in Exercise 2.3C and copy it into a new Excel spreadsheet.

- Insert a new column between the time and acceleration columns and give it the heading *a – calculated*. (Make sure you can see the full heading.) From your knowledge of dynamics, create an Excel equation to generate an acceleration value for each set of data. Format the resulting values so that they have the same number of decimal places as the rest of the data. Does this match with the numbers in the original acceleration column?

- Calculate the average value for each of u, v, t and a.

- Now calculate the error on this average by using the *stdev* function.

- Format the averages and errors to the same number of decimal places as the original data. Then format the error cells to show an extra decimal place – what do you notice?[1]

[1] See the danger of rounding!

B)

A student has carried out a simple experiment to test Ohm's Law. They built a series circuit containing a single resistor and a variable power supply. They varied the voltage across the resistor, and monitored the current for each voltage. Their data is given below.

V(V)	I(mA)
0	0
1	1.4
2	3
3	4.6
4	6.1
5	7.3

- Plot a graph of current against voltage, clearly labelling the axes.
- From the graph, determine the value of the resistor.

A second resistor is now added to the circuit in parallel to the first. The total resistance of this combination is given by the following equation:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

- Using Excel, calculate the total resistance of this new combination, taking the first resistor's value you determined and the letting the second resistor vary from $100\,\Omega$ to $1\,\mathrm{k}\Omega$ in $100\,\Omega$ steps.

C)

- Evaluate the following function between $t = 0.0$ and $t = 50.0$ in steps of 0.5.

$$Q = \varepsilon C\left(1 - e^{-t/RC}\right)$$

($\varepsilon = 5\ \mathrm{V}$, $C = 1\times10^{-6}\ \mathrm{F}$ and $R = 10\ \mathrm{M}\Omega$.)

- Plot this function, clearly labelling the axes.

3. On-line library resources

This section uses the standard text for 1st year Physics not the text for EE1 but the information is just as comprehensive.

The ITEU material for this part can be found at:

http://apps.iteu.gla.ac.uk/ITEU/html/topups/intro1.jsp

- Access the university library's website – the link to this can be found from

  http://www.gla.ac.uk

- Click on the *Merlin-Catalogue* link and carry out a **Title** search on 'University Physics'.

- Now perform an **Author/Title** search on University Physics by Young and Freedman.

- Now use the **Keyword** option to obtain a list of references relevant to a topic within one of your subjects of study. Mark some of the references, then email them to yourself.

- Open up your mail application and copy the text you have received.

- Open up your word document from part 2 and paste the e-mailed library information into it. Preface it with the heading 'Possible References'. Save the file again.

4. Searching the WWW

- Find the University's collection of *Subject Indexes* and select the *BUBL Link Subject Tree*.

- Follow the index links through to the "Physics: general resources section". You are now presented with a short list of external links, accompanied by short descriptions of each website. Select one site and see how well that site matches its description. Copy the web address of the site into your word document.

- Return to the *Subject Gateways* page and select the link to HERO – the Higher Education and Research Opportunities in the United Kingdom website. Now see if you can find a useful link on this web site. If you find something quickly, you can try to find some other sites here or explore some other Subject Indexes. Again, put the address into your word document.

- Go to the list of search engines on the *Merlin* pages (under "Information resources"). Access *Google* and search for web pages on the subject of *Optics*. Now repeat the search, but add the term *Quantum*. Put the top three links from each search into your word document.

5. Finishing off

When you have completed the material from each of the above sections, save the file(s), and print out:

- Your word document: we recommend that this document contains all your work from the Word section. Certainly, it *must* contain your attempts at exercises 2.3 A-D. In addition, don't forget to include the Mastering Physics section.

- Your excel spreadsheets: again we recommend printing out all the work you have carried out and *must* contain your attempts at exercises 3.4 A-C. Make sure that you print both tables and, where appropriate, graphs clearly. Check what you'll be printing using the Print Preview option.

EXPERIMENTS

Dynamics

Glider and Pulley

Aim

- To show the versatility of standard dynamical equations.
- To determine the mass of the glider, from the dynamics of the system.

Part 1:Tutorial question (15 mins)

A glider is placed on an air track and attached to a mass hanging vertically over a pulley at the other end, as shown in figure 1. This causes the glider to accelerate due to the tension in the thread.

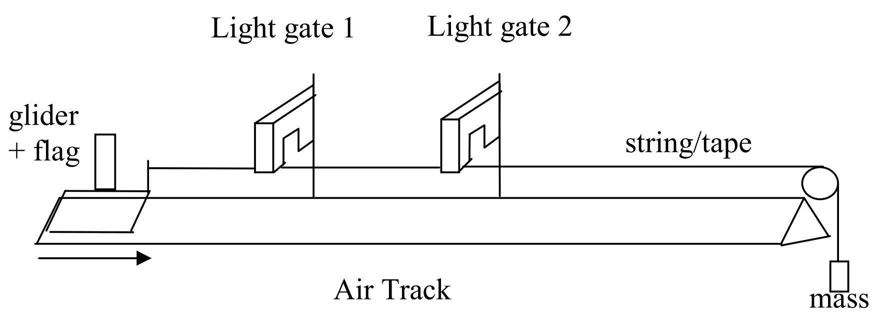


Figure 1: A glider pulled along an air track by the action of a descending mass.

If the glider has an initial velocity, u, then at some later time t, its velocity, v, is given by equation [1]:

$$v = u + at \qquad [1]$$

where a is the constant acceleration of the glider due to the action of the falling mass.

1.1 Sketch the velocity-time graph for the motion of the glider from a point just after it has been released until it has passed through both light gates.

1.2 By considering the area under the graph you have just drawn, show that the distance travelled by the glider, s, can be expressed as follows:

$$s = ut + \frac{1}{2}at^2 \qquad [2]$$

1.3 If the glider is released from rest, how long will it take to travel 1 m when it experiences a constant acceleration of $0.5\ \mathrm{ms^{-2}}$?

Part 2: Deducing the acceleration of the glider (15 mins)

In this part you will calculate the velocity of the glider at each light gate and then deduce the acceleration.

- Ensure the track is level in the horizontal position as shown in figure 1.
- Note the positions of the two light gates on the side of the air track, hence find their separation.
- The thread should be as close as possible to horizontal between the glider and the pulley.
- Connect the other end of the thread to the mass hanger and hold the glider at the end of the track.
- Open the EasySense software package, click on *Timing*, then select *Raw Times*.
- Hold the glider at the other end and add a small mass of 5 g to the mass hanger.
- Once you have clicked *Start*, let go of the glider. The glider will be accelerated along the track, through the two light gates.
- Stop the glider at the other end and click *Stop* to end the experiment.
- Open an Excel spreadsheet and enter the times recorded for each light gate, then enter the necessary formulae to calculate the speed at each light gate.

Hint:

You will need to know the length of the flag to calculate the speeds at each light gate.

2.1 Using the speeds at the 1st and 2nd light gates, and the time between each passing, calculate the acceleration of the glider. Explain how you deduced the time it took for the glider to travel between the two light gates and comment on your reasoning.

2.2 Using the speeds and the acceleration, deduce the separation of the light gates in your spreadsheet. How well does this compare with the true separation? Comment on any differences.

Part 3: The versatility of dynamical relations (10 mins)

In this part of the experiment you will compare your results with those obtained using equation [2] above:

- In a new column of your spreadsheet, use equation [2] to show that the separation you calculate agrees well with that from part 2.
- Add another column to find the acceleration using the above relation and again show that your result compares well with that obtained in part 2.
- Make a printout of your spreadsheet and insert it into your lab book.

3.1 Comment on your results for separation and acceleration.

Part 4: Calculating the mass of a glider from the dynamics of the system (10 mins)

The force accelerating the glider of mass M is the tension in the thread, T, due to the mass suspended from the other end, m.

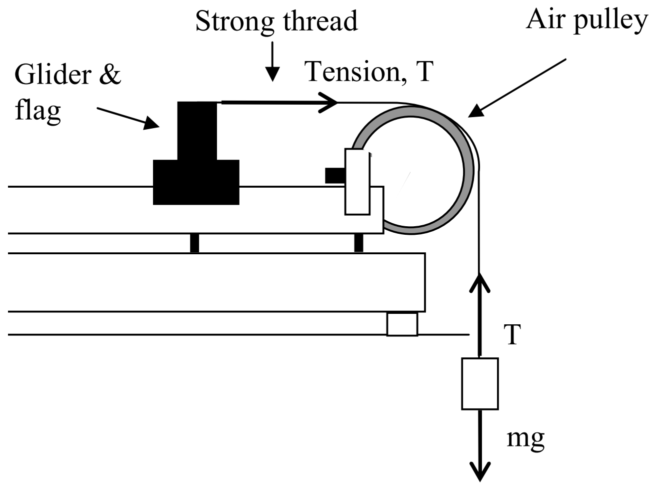


Figure 2: A constant force can be applied to a glider by using recording tape, an air pulley and a small hanging weight.

4.1 Using Newton's 2nd law, and assuming that the tape cannot stretch, derive an expression for the glider in terms of a, g and m.

4.2 Now weigh the glider and discuss how well your estimate agrees with this.

Part 5: Measuring the acceleration due to gravity, g.

The equation you have derived in 4.1 can be rearranged to express the acceleration due to gravity g in terms of the mass of the glider and the suspended mass.

5.1 Using both the actual mass of the glider and that calculated in part 4, calculate a value for g. How well does this agree with the accepted value of $9.81\,\mathrm{ms}^{-2}$. Discuss the possible sources of error which result in any mismatch between calculation and reality.

Hooke's Law and Simple Harmonic Motion

Aims

- To study the oscillations of a mass suspended at the end of a spring.
- To study Hooke's law in the extension of a spiral spring.
- To analyse experimental data by graphical methods.

In this experimental tutorial you will first undertake a tutorial question to predict the motion of and force on a mass oscillating on the end of the spring, and then perform an experiment to measure these quantities.

Part 1: Tutorial Question (15 mins)

A mass is attached to the lower end of a spiral spring and oscillated vertically with simple harmonic motion such that its displacement relative to is **mean** position, x, is given by

$$x = A\sin\left(\frac{2\pi}{T}t\right) \qquad [1]$$

where A is the maximum displacement and T is the period.

1.1 Sketch the motion, clearly marking A and T.

The force, F, due to the **extension** of the spring from its **mean** position is given by Hooke's Law:

$$F = -kx \qquad [2]$$

where k is the spring constant.

1.2 Hence, add a graph of force to your sketch.

The time period of the oscillations is given by

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad [3]$$

1.3 If the period is 0.5 s and the mass is 2 kg, what is the value of the spring constant?

Part 2: Taking data (10 mins)

In this experiment the position of a mass suspended on the end of a fixed spring is monitored used data logging software on a PC. An ultrasound sensor[1] monitors the position. A force sensor monitors the force.

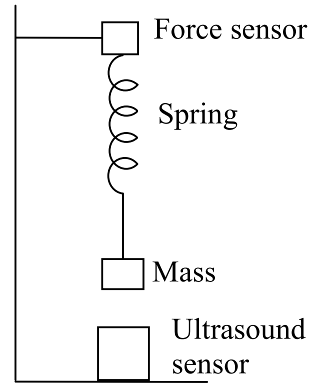


Figure 1: Experimental set-up

To start data taking:

- Click on *EasySense* software icon.
- Select *EasyLog* from New Experiment menu.
- Check that the software has detected the force and motion sensors – look for corresponding boxes in top left of screen.
- Start the mass bouncing. Keep the motion as vertical as possible – avoid swinging.
- Wait until the motion has become regular, and then click on "Start".
- Record data for approximately **20 seconds** and then click on "Stop".

Part 3: Calculating period of oscillation and spring constant (5 mins)

- From the *Display* option on top toolbar select *Show Table* – this reveals the columns of data of time, force and distance.
- Clicking on a row of the data brings up a marker on the graph. Using the up and down arrow keys, move the marker until it is on a maximum of one of the sine waves. Note down the corresponding time for this maximum. Now move along 10 maxima, and note the corresponding time.

3.1 Calculate the average period.
3.2 Hence calculate the spring constant.

Part 4: Calculating the spring constant from Hooke's Law (20 mins)

In this part you will analyse your data using Excel.

- In *EasyLog*, click on *File – Transfer to Excel*. This opens Excel with your data clearly labelled in three columns.

4.1 Use Excel to plot (i) the force due to extension of the spring and (ii) distance about mean position against time on a single graph.

[1] This sends out a signal that is reflected from the base of the suspended mass. The reflected signal is then detected. The time between emission and detection allows the distance between mass and detector to be calculated.

Hints:

(a) To calculate the average of a column of data in Excel, use the *AVERAGE* function.
(b) When referencing a single, specific cell in an Excel equation, use $ signs, e.g. $E$2.
(c) Plot the distance in centimetres so that the scale is similar to that of the force on your graph.

4.2 Compare this plot with the graph you sketched in Part 1.
4.3 From your data for force and distance, use Hooke's Law to calculate values for the spring constant.

Hint:

(d) Consider your columns of data – discard any rogue points.

4.4 From your values, calculate a single, average value for k and compare this with your value from Part 3.

Remember to save your work to disk and to add your spreadsheet to your lab book.

Part 5: Calculating velocity (Optional)

- Shut down the Easy Sense software, and then reopen it, this time selecting New Experiment – Graph.
- When prompted de-select the force sensor as we are only interested in distance this time.
- Set the data acquisition to run for 2 s, taking points every 20 ms. This will give you 100 data points.

5.1 Plot this scaled velocity and distance on the same graph. What is the phase difference between these two plots?
5.2 How can you explain this in terms of the motion and equation [1]?

Hints:

(a) As in Part 2 set the mass bouncing vertically again and let the motion settle. Then start the data taking. This time you do not need to stop it yourself.
(b) Transfer the data into Excel as before.
(c) Correct the distance data as before.
(d) Calculate velocity using $\frac{x_1 - x_2}{t_1 - t_2}$ where x_1, x_2 are the corrected distances for consecutive data points and t_1, t_2 their times.
(e) Scale the velocity so that its maximum value is similar to that of the distance.

Momentum and Impulse

Aims

- To study the conservation of momentum.
- To investigate the impulse-momentum theorem.

Part 1: Tutorial Question (15 mins)

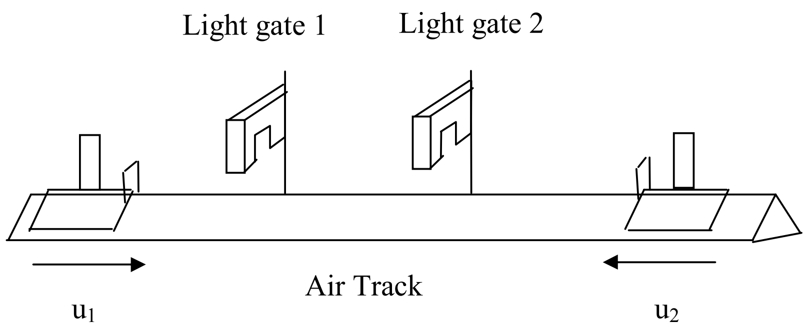


Figure 1

Two gliders on a frictionless air-track are set in motion. The first glider is travelling with a speed u_1 to the right, while the second glider is travelling with speed u_2 to the left. The two gliders collide and move apart with speeds v_1 and v_2 respectively in directions opposite to their incoming directions.

1.1 If the masses of the gliders are the same, m, and the initial speeds u_1 and u_2 are the same, then what are their speeds after;

a) An elastic collision,
b) An inelastic collision where a fraction x of the energy is dissipated.

1.2 A glider of mass m on the air-track, travelling with speed u, hits a barrier fixed to the air-track, and bounces back with speed $v<u$. The barrier does not move. What is the total impulse of the collision?

1.3 Make a sketch of force applied to the glider (on the y-axis) against time (on the x-axis). What quantity on your graph corresponds to the total impulse you calculated?

Part 2: The collision of two gliders (20 mins)

In this experiment you will collide together two gliders on an air-track, measuring their velocities before and after the collisions.

- Click on the *EasySense* software package, select graph from the *New Experiment* menu. The computer should detect both the light gates – seek help if this doesn't happen.

- Next, tick the box asking speed at A or B, then enter the length of the piece of card or metal that will cut the light gate.
- Click *finish*.
- Now, start the experiment by clicking on the start button and by gently pushing the two gliders towards each other simultaneously - the metal bumpers at the front.
- The software will measure the speed of the two gliders before and after the collision i.e. you should see four readings. The gliders should stop at either end of the track on their own accord but you may need to intervene.
- Enter these velocities into an Excel spreadsheet, distinctly showing values for each glider.
- Weigh the mass of each glider and add data to spreadsheet.
- Calculate the total momentum before and after the collision.
- Calculate the total energy before and after collision.

2.1 Is momentum conserved?
2.2 Is energy conserved?

Hints:

Remember to put minus signs in front of speeds travelling in the relevant directions.

Part 3: The collision of a glider with a barrier (25 mins)

In this part you will collide the **flat** side of the glider against a force gauge fixed at one end of the track. You will measure the velocity of the glider before and after the collision in order to work out its change in momentum. Using the *EasySense* software package and the data colleted by the force gauge, you will be able to plot force against time. This will allow you to calculate the impulse and verify the impulse-momentum theorem given as:

$$J = \int_1^2 F(t)dt = \Delta p$$

- First, remove one of the light gates from the system and affix the force gauge with the soft rubber attachment to the end of the air-track.
- Click on the *Home* button in the top left of the screen, then choose *Graph* and select *Next*. Choose *10ms* total recording time and intervals of *5ms*, then *Finish*.
- You can now start taking measurements.
- From the display menu, select show table, then scroll down the cells until you view the change in light gate reading from ~3 to ~100. Note the number of 5ms intervals until it reverts back to ~3. Knowing the length of the intervening metal/card you can calculate the speed of the glider before collision.
- Scroll down again until you reach the next time the light gate is cut, and note the number of 5ms intervals as before. You can now calculate the speed after collision in the opposite direction.
- Enter these values into a spreadsheet along with the mass of the glider.
- You can now enter formula as before to calculate the change in momentum.
- Scroll back up the table to where the force gauge reading changes. Click on the cell before the change occurs and using the shift key highlight the cells that show

negative values until they reach zero again. There may be a subsequent damped oscillation which occurs that you don't want to include in your results.

- From the menu select *use selection* then click on the *area* button from the toolbar.
- Compare this to the change in momentum of the glider.

3.1 What can you conclude about the comparison between change in momentum and the area of force against time?

3.2 Suggest any reasons why your results show deviation.

Hints:

Think about the time steps in which the software package takes data – does it miss anything?

Thermal

Thermal Conductivity

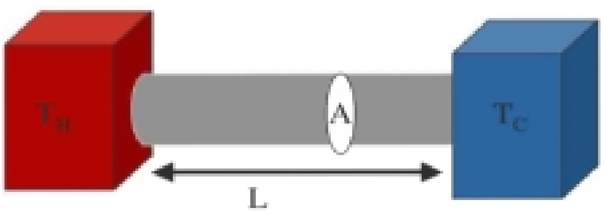
Aims

- To investigate the thermal conductivity of different metals.
- To use and manipulate the heat flow equation.

In this experimental tutorial you will first undertake a tutorial question to understand the operation of the *Heat Flow* equation. You will then carry out a series of measurements to investigate the characteristics of heat flow and properties of different metals.

Part 1: Tutorial Question (15 mins)

When there is a temperature difference between two parts of an object, heat flows from the hot part to the cold part of the object in a process called heat conduction.



The heat flow H is the rate of energy transfer $\Delta Q/\Delta t$ through the material. This is proportional to the cross-sectional area A and to the temperature gradient $\Delta T/L$. Here A is the 2-dimensional "width" of the path connecting the hot part of the object to the cold part, and L is the length of material the heat passes through.

$$H = \frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{L} \qquad [1]$$

The other quantities appearing in this equation are the energy transferred ΔQ, the time taken Δt, the thermal conductivity k of the material (a measure of how well it conducts heat) and $\Delta T = T_H - T_C$, the temperature difference across the material.

1.1 ΔT can be measured either in degrees Kelvin or degrees Centigrade. Explain why, in this case, these are equivalent.

1.2 Use equation 1 to show that the dimensions (units) of k are $Wm^{-1}K^{-1}$.

- A metal bar has a width of 9mm and a thickness of 3mm. Calculate its cross-sectional area in m^2.

1.3 A copper bar, of length 10cm width 9mm and thickness 3mm has a thermal conductivity 400 $Wm^{-1}K^{-1}$. This is connected between two objects whose temperatures differ by 60^oC. Calculate the rate of heat flowing through the bar.

1.4 The copper bar is replaced by a steel bar with $k = 50$ $Wm^{-1}K^{-1}$. What cross-sectional area should this bar have to give the same rate of heat flow?

Part 2: Comparison of thermal conductivities of different metals (15 mins)

Setup the apparatus as shown in figure 2.1 below.

The set of metal bars have temperature sensitive strips attached to their front. As the temperature increases these change from black to cloudy, then to green and finally blue. The most sensitive indication is when the temperature strip changes from black to cloudy. It is harder to judge the change of colour to green and blue. We are going to immerse one end of the bars in hot water and measure how long it takes for heat to reach the far end of the bar.

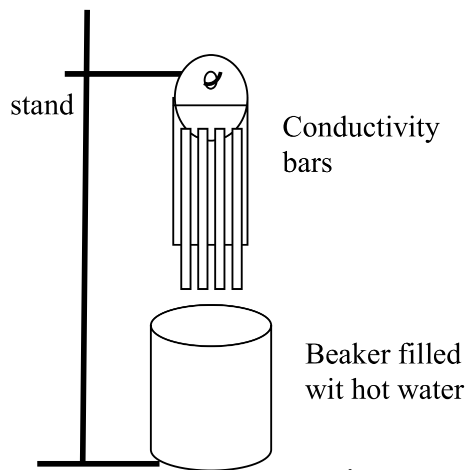


Figure 2.1

As heat is transferred along the bar the temperature of successive parts of the bar will rise and the colour of the temperature strip will change. This change in temperature occurs when each part of the bar has absorbed the same amount of energy.

A, L and *k* are all fixed and we will also assume the heat ΔQ required to cause the temperature strip to change colour is a fixed quantity.

- Measure the width and thickness of the four metal bars and check they have the same cross-sectional area.
- Use the kettle to boil some water and then pour the hot water into the pyrex beaker until it is roughly half full.
- Use a thermometer to measure the water temperature to the nearest degree centigrade.
- You want the temperature of the water to be ~ 70-80 ^oC, so you may need to add some cold water to bring the temperature down. Take a note of the room temperature as you will need this to determine the temperature difference later.
- Loosen the correct screw on the clamp stand to lower the metal bars in the beaker of hot water to a depth of around 2cm, ensuring the plastic is not immersed, and tighten the screw. At the same time start the timer and measure the times Δt_{copper}(s), $\Delta t_{aluminuium}$(s), Δt_{brass}(s) and Δt_{steel}(s) until the top end of the temperature strips on each of the four bars turn cloudy.

2.1 Rearrange equation [1] to show the dependence of thermal conductivity k on Δt and predict whether the ends of the copper or steel bars will heat fastest.

2.2 Evaluate $1/\Delta t$ for each bar placed in water with ΔT ~ 50-60^oC. This quantity should be proportional to the thermal conductivity of the bar.

2.3 Given that the thermal conductivity of copper is 390 $Wm^{-1}K^{-1}$, calculate the thermal conductivities of the other three bars.

Part 3: Conductivity of copper (20 mins)

- Place the metal bars in a bath of cold water and use the digital thermometer to measure the temperature of the water. Again an accuracy of one degree will be sufficient.
- Boil some more water in the kettle then half fill the beaker as before. By the time the hot water heats the beaker you will find its temperature is somewhere in the range 80-90°C. Anywhere in this range is fine. This should give a temperature difference with the cold water temperature of somewhere around 70°C.
- Once the temperature sensitive strips have turned black affix them to the clamp stand.
- Lower the conductivity bars into the beaker so they are immersed ~ 2cm. At the same time start the timer and measure the time it takes until the top end of the temperature strip on the copper bar turns cloudy.
- Repeat the measurement on the copper bar using temperature differences of around 60°C and 50°C. Firstly, cool the bars by placing them in the cold water bath until the temperature strips turn black again. By the time you have done this the hot water in the beaker will have cooled further. If necessary alter the water temperature by adding small additional amounts of hot or cold water.

3.1 Draw up a table of measurements. For each measurement tabulate the temperature difference ΔT, the time taken Δt and the product $\Delta T \Delta t$.

3.2 By rearranging equation 1 discuss what trends do you expect the product $\Delta T \Delta t$ to show? Do your results agree with this prediction?

Part 4: Extension material (optional)

4.1 Here you can gain additional points for successful completion of **either** (a), (b) or (c).

a) Repeat the investigation of how the time taken Δt for heat to travel along a bar depends on temperature difference ΔT for the brass bar.

b) Taking the values of thermal conductivity for copper and brass, together with the time you measured for the whole of the temperature strip on the copper bar to turn cloudy, with a temperature difference ΔT of 60°C, calculate the time for the whole temperature strip on the brass bar to turn cloudy.

c) The specific heat capacities of the four metals are given in the table below. Discuss how the differences between the values for the different metals could affect your calculations of thermal conductivities.

Metal	Specific Heat Capacity ($Jkg^{-1}K^{-1}$)	Density (kgm^{-3})	Density x Specific Heat Capacity ($JK^{-1}m^{-3} \times 10^3$)
Copper	385	8900	3426

Aluminium	900	2700	2430
Brass	380	8500	3230
Steel	450	7900	3555

Heat Loss Mechanisms

Aims

- To understand the different mechanisms of heat transfer.
- To carry out an experiment demonstrating some of these mechanisms and the properties of different coloured surfaces.

Part 1: Tutorial question (15mins)

1.1 What are the three mechanisms of heat transfer?

1.2 Here are two equations used that describe different types of heat transfer:

$$H = \frac{kA\Delta T}{l} \qquad [1]$$

$$H = A\varepsilon\sigma T^4 \qquad [2]$$

State which mechanisms equations 1 and 2 belong to, and, describe what each of the symbols represent giving their standard units.

- Three identical metal bottles are placed on an insulated surface and differ only by surface colour; one is black, one is white, and one is silver. They are each filled with the same volume of **boiling** water and allowed to cool.

1.3 Which mechanisms of heat transfer will be significant?
1.4 Which bottle will cool quickest and why? Which bottle will cool slowest and why?

Part 2: Monitoring water cool in different containers (25mins)

Warning: *this experiment uses* ***boiling*** *water. Please take care when handling boiling water to avoid scalding yourself or your lab partner. Also, please use the insulated gloves provided when filling metal bottles or moving them around.*

The apparatus should be set up as follows:

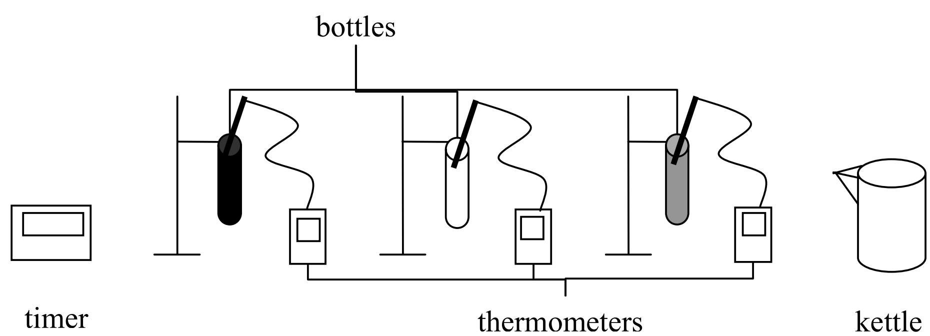


Figure 1

- Firstly, pour at least 1 litre of water in the kettle and switch the kettle on to boil.
- Use the plastic measuring jug provided to pour some of the boiling water into each of the three metal bottles to heat them up - funnels are provided to ease the pouring and minimise spillages.
- Pour all the water from the bottles back into the kettle and switch it on to boil again.

You will now fill each bottle with 300ml of boiling water **but** it is important the starting temperatures of are the same – differing by no more than 2 °C. The following procedure should ensure this for you, if not ask a demonstrator.

- You should now use the measuring jug and funnel to pour 300ml of boiling water into the silver bottle, then pour 150ml of boiling water into the white bottle, next pour 300ml of water into the black bottle and the final 150ml into the white bottle again.
- Place a digital thermometer into each of the bottles and seal with caps to reduce heat loss by convection.
- Start the timer and note the temperatures of the black, white and silver bottles – check that their temperatures are all within 2 °C of each other.
- Take temperature measurements of each bottle every minute for a total of 20 minutes. These readings should be to the accuracy of the thermometer i.e. one decimal place.

Part 2: Analysis (10 mins)

2.1 Plot a graph of the cooling for all three bottles on the one graph. Draw a line (curve) of best fit through each set of points. (Please use different symbols and/or colours to distinguish between the three different bottles).

2.2 Which bottle cooled the slowest? Give an explanation for your answer. Which bottle cooled the fastest? Is this related to the properties of the colour of the bottle or because the starting temperature differed slightly from the rest?

2.3 What is the dominant heat loss process for the bottles?

Part 3: (Optional)

Take a look at the Crookes Radiometer and observe what happens when light is incident upon one side.

3.1 Can you explain the movement of the “paddles” contained within the vacuum?

Hint:

One side of the paddle is black and the other is white.

Boyle's Law

Aims

- To investigate the features of Boyle's Law and the Ideal Gas Law.
- To confirm theoretical prediction with experimental procedure.

Part 1: Tutorial Question (10 mins)

An ideal gas at a fixed temperature T behaves according to Boyle's law, which is expressed as:

$$pV = C \qquad [1]$$

where p is pressure, V is volume and C is a constant. A cylinder of gas connected to a pressure gauge is kept at room temperature, as shown in figure 1.

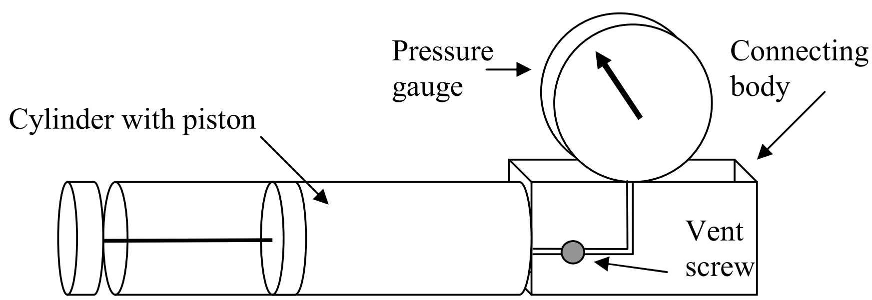


Figure 1

1.1 At a volume of 1 unit, the pressure gauge reads 10 Ncm^{-2}. Assuming the temperature of the air remains constant, what will the pressure gauge display when;

(a) the volume of air within the cylinder is increased to 2 units?
(b) the volume of air within the cylinder is increased to 4 units?

Part 2: Verifying Boyle's Law (15 mins)

In this part of the experiment you will take measurements of the gas at room temperature, and then by taking subsequent measurements at a different volume you can verify Boyle's law.

The following steps must be done with the pressure gauge of the apparatus sitting upright as shown in Figure 1:

- Open the vent by turning the screw anti-clockwise.
- Move the piston until you have selected a volume of your choice – it may be wise to choose an easily distinguishable volume e.g. 1, 2, 3 …
- Tighten the vent screw and note the pressure gauge reading. It is important to be as accurate as possible, it may be necessary to gently tap the pressure gauge so as not to read an erroneous measurement.

- Change the volume of the air by pulling/pushing the piston at the end of the cylinder.
- Note both your new volume and the new pressure gauge reading.

2.1 Assuming the temperature of the air inside the cylinder is at the same temperature as initially, verify Equation 1.

Part 3: Tutorial Question (10 mins)

The ideal gas law is given as:

$$pV = nRT \qquad [2]$$

3.1 State what each of the symbols represents.

3.2 What is the dimension (units) of the left hand side of equation 2? Given that a Newton metre, *Nm*, is dimensionally equivalent to a joule, *J*, write down the dimensions of *R*.

3.3 The volume of 1 unit on the cylinder is $47.12 \times 10^{-6}\,\mathrm{m}^3$, which at a temperature of 300 K, contains 1.9×10^{-11} moles of air. If the volume is kept constant but the pressure gauge is observed to change from 10 $\mathrm{Ncm^{-2}}$ to 11 $\mathrm{Ncm^{-2}}$, calculate the new temperature of the air.

Hints:

(a)1 m^2 = 10,000 cm^2, 1 Nm = 1 Pa, R = 8.315 $\mathrm{Jmol^{-1}K^{-1}}$
(b) is there an easy method to do this?!

Part 4: Verifying the Ideal Gas Law (15 mins)

In this part of the experimental tutorial you will change the temperature of the air inside the cylinder and keep the volume constant. A change in pressure will occur and you will then be able to verify the ideal gas law.

The following steps must be done with the apparatus sitting up right as shown in Figure 1:

- Select a reference volume which gives a pressure gauge reading of 10 $\mathrm{Ncm^{-2}}$ and ensure the vent screw is tightly closed.
- Note this volume in your lab book along with the room temperature.
- Now raise the temperature of the cylinder by placing it in the basin and covering with a hot water bottle. Please take care when filling these bottles by using the funnels provided to reduce the risk of scalding.
- It will take around 5mins for the temperature of the gas inside the cylinder to raise enough to make a noticeable difference on the pressure gauge, e.g. 11 $\mathrm{Ncm^{-2}}$.
- Ensure the volume doesn't change. It may be necessary to readjust the piston back to the reference volume.
- Assuming the gas is now at the same temperature of the cylinder, use the infra-red thermometer to measure this temperature. This is best done by taking several readings at different angles and averaging the temperatures showing similarity.

4.1 Using the ideal gas law, deduce the relationship between the initial pressure/volume/temperature and the final pressure/volume/temperature.

4.2 Hence, or otherwise, calculate the final temperature of the air within the cylinder and compare it with the temperature you measured. Discuss any causes for deviation.

Appendices

Records and Reports

Units[1]

You should **always** use SI units to express results[2]. In addition, try to ensure

- ✓ your answers are given to an appropriate number of significant figures (usually 2 or 3).
- ✓ that you use scientific notation.

Uncertainties[3]

All measurements of physical quantities are liable to uncertainty. When analysing uncertainties in this lab, you are expected to be able to:

- ✓ distinguish between random uncertainties and systematic effects (including calibration uncertainties).
- ✓ estimate the uncertainty due to scale reading of instruments.
- ✓ know that repeated measurements of quantities are desirable.
- ✓ calculate the mean value of a number of measurements, and use this as the best estimate of the "true" value.
- ✓ know that systematic effects can cause the measurements to be offset from the "true" value.
- ✓ calculate the random uncertainty in the mean value of a set of measurement using $uncertainty = \frac{(max.\,value)-(min.\,value)}{number\ of\ measurements}$
- ✓ express uncertainties in absolute, percentage or relative form.
- ✓ identify the main source of uncertainty in an experiment, and use this when appropriate as a percentage uncertainty for the final result of the measurement.
- ✓ express final answers in the form $value \pm uncertainty$
- ✓ compare the numerical result of one experiment with that of another.

Tables

Readings and observations should almost always be recorded in a table. Whether done roughly in a lab record, or neatly in a lab report, a table should include:

- ✓ A title or caption.
- ✓ Correct column headings.
- ✓ Appropriate units.
- ✓ Correctly entered readings/observations.
- ✓ (for lab reports only) data should be entered sorted with ascending or descending independent variable.

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1 Reference: University Physics 11th Edition: 1-3, 1-4
2 See "The International System of Units", Appendix A, University Physics 11th Edition
3 Reference: University Physics 11th Edition; 1-5

Graphs

- ✓ Data are usually best seen in graphical form. Both in records and reports, make sure that your graphs include:
- ✓ a title or caption.
- ✓ suitable scales, and axes labelled with quantities and units. (Try to aim for graphs which fit on one page of your lab notebook - **the graph paper side!**)
- ✓ data points **clearly** visible.
- ✓ plot the independent variable on the x-axis.
- ✓ a line of best fit, where appropriate.

Example

You are often required to derive results from the gradient or intercept of a straight-line graph. As an example, consider the case of the measurement of a spring constant by measuring the period of oscillation. It can be shown that the period *T* depends on the mass *M* on the spring as $T = 2\pi\sqrt{\frac{M}{k}}$, where *k* is the spring constant. By varying *M* (the independent variable) and measuring *T*, we can calculate *k* by plotting a graph of T^2 against *M*. This means that we will have a graph of the form $y=mx+c$, where $m = \frac{4\pi^2}{k}$ and $c=0$.

To calculate the gradient, take two points $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$ (not too close), then

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

[Note that since you do not measure the point M=0, it should **NOT** be part of the fitting process.]

Records

Lab records are what you will be marked on for each experiment. The following section is a guide to producing a good set of records. You should show in a clear way the main features of the experiment. The emphasis is on clear presentation of the data, calculations, results and conclusions, **NOT** a lab report!

You are marked on the numbered items in the experimental tutorial – so make sure these are clearly labeled in your lab book.

Get a lab notebook* (available for purchase in the lab!) *- they are either hard- or soft-back, with alternate lined and graph-paper pages.

- ✓ **You will be given a label to stick on the front cover of your notebook**.
- ✓ **Each lab record** should have:
- ✓ **Date of experiment.**
- ✓ **Title of experiment.**

- ✓ **Answers to tutorial questions.**
- ✓ **Reference to page in lab manual:** There is no need to repeat all the information in the lab manual. Only draw figures of apparatus or note the method you use if you are explicitly asked to do so.
- ✓ **Data:** In tabular form - see section on tables.
- ✓ **Graphs (where appropriate):** See notes on graphs
- ✓ **Calculations:** For each section, show enough details of your calculation so that the demonstrator can see how your result is obtained. Values should be expressed along with an estimate of the uncertainty.
- ✓ **Conclusions:** The result(s) for each section should be presented in the section with a brief comment including if appropriate a comparison with any accepted value.
- ✓ **Answers to group questions.**

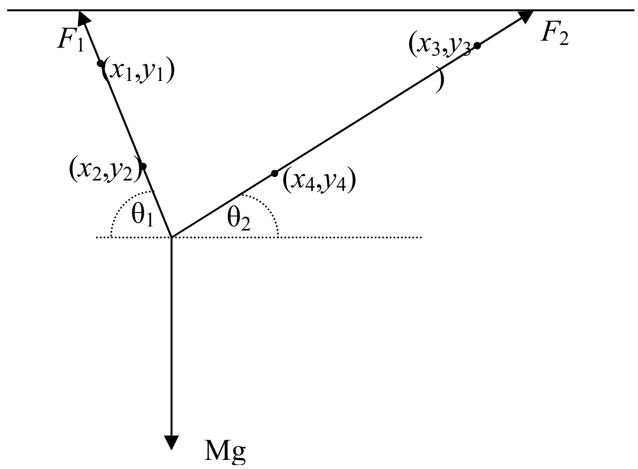
Example of a Laboratory Record

The following is an example of how we would expect you to produce a record of an experiment on Forces and Accelerated Motion. You should use the example for guidance. Note that you are **NOT** expected to write perfect notes - as long as what you write is legible to your demonstrator and yourself! Typed notes are **NOT** appropriate.

Additional notes are shown in italics

25.10.99 Forces and Acceleration.

Part A; Static forces.
The apparatus was setup as described in the lab manual.



Diagrams like the one above should be drawn on the graph-paper side of your notebook

	$F_1 = 14.61\ N$
Forces	
	$F_2 = 8.79\ N$

x and y co-ordinates. (measurements in mm from arbitrary x and y axes).

(x_1,y_1)	=	(220,729)
(x_2,y_2)	=	(271,614)
(x_3,y_3)	=	(444,698)
(x_4,y_4)	=	(361,601)

i.e.

$$\tan\theta_1 = \left|\frac{y_1 - y_2}{x_1 - x_2}\right| = \left|\frac{729-614}{220-271}\right| = 2.255 \Rightarrow \theta_1 = 66.1^\circ$$

$$\tan\theta_2 = \left|\frac{y_3 - y_4}{x_3 - x_4}\right| = \left|\frac{689-601}{444-361}\right| = 1.169 \Rightarrow \theta_2 = 49.4^\circ$$

Component equations.

$$F_1 \cos\theta_1 = 5.92$$
$$F_2 \cos\theta_2 = 5.72$$

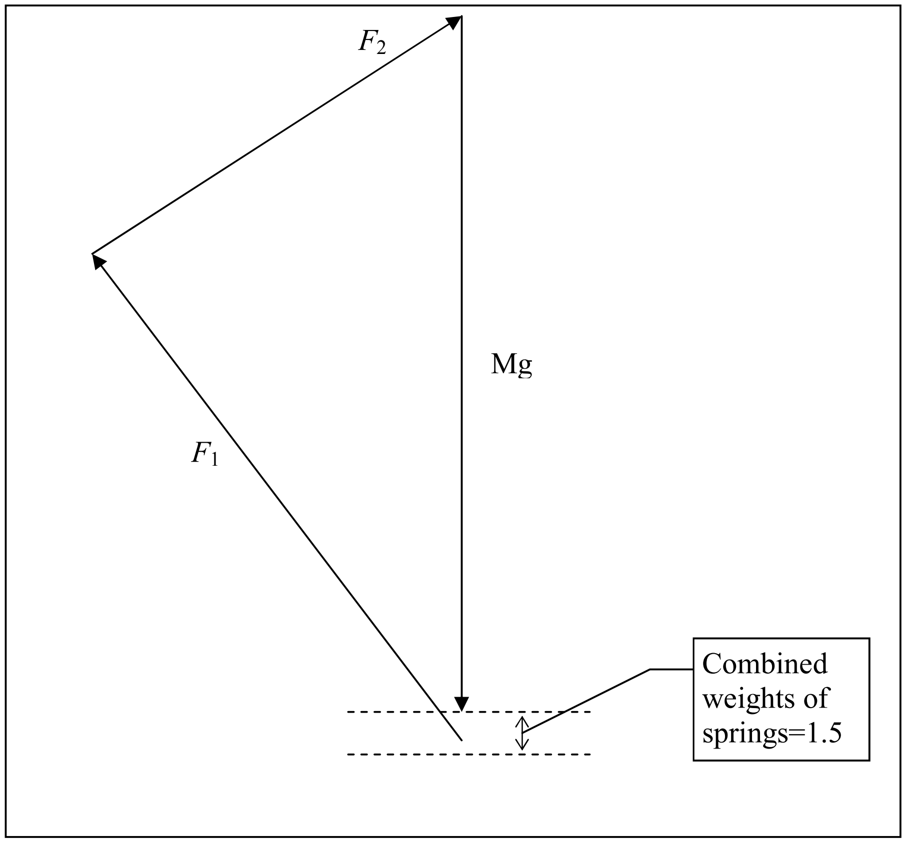
$$F_1 \sin\theta_1 + F_2 \sin\theta_2 = 20.03$$
$$Mg = 19.62$$

Agreement not exact, but it is reasonable given the errors in measuring the co-ordinates.

Vector addition of forces.

Masses of the springs: 82.3 and 70.8 gm.
i.e. vertical downwards force from spring masses = 1.5 N.

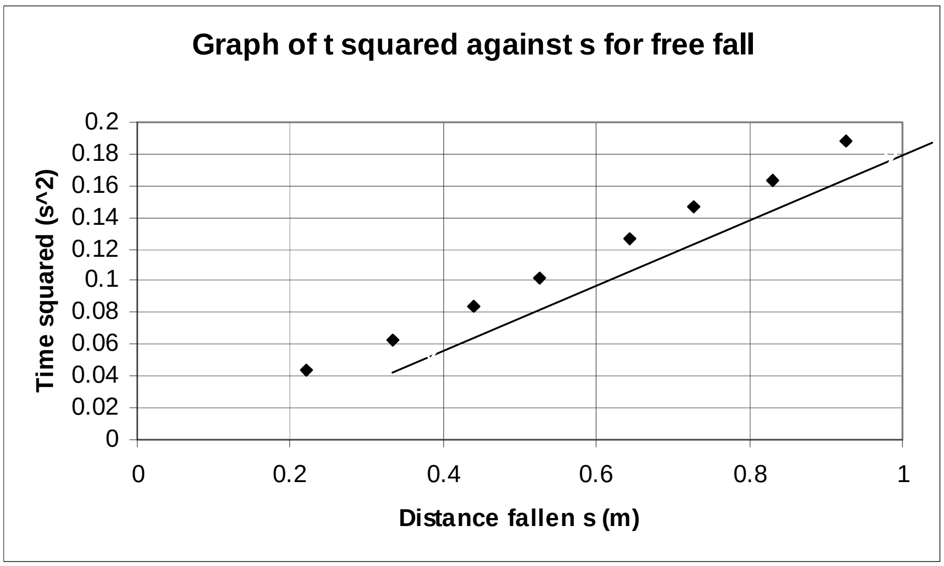
Three main forces almost add up vectorially to zero. Masses of springs could account for small discrepancies in the vector sum.



Part B: Free-fall under gravity.

Time (t) taken to fall a distance (s).

Measurement	1	2	3	4	5	6	7	8
s(m)	0.926	0.83	0.727	0.643	0.527	0.44	0.333	0.22
t(s)-1st	0.43	0.41	0.39	0.36	0.32	0.29	0.25	0.21
t(s)-2nd	0.43	0.41	0.38	0.35	0.32	0.29	0.25	0.21
t(s)-3rd	0.44	0.39	0.38	0.36	0.32	0.29	0.25	0.21
t(s)-av.	0.433	0.403	0.383	0.357	0.32	0.29	0.25	0.21
t-sqred (s^2)	0.188	0.163	0.147	0.127	0.102	0.084	0.063	0.044



Using the crosses to define two points on the straight-line fit:

$$\text{Gradient} = \frac{0.176 - 0.053}{0.88 - 0.28} = 0.205\frac{s^2}{m} = \frac{2}{g}$$

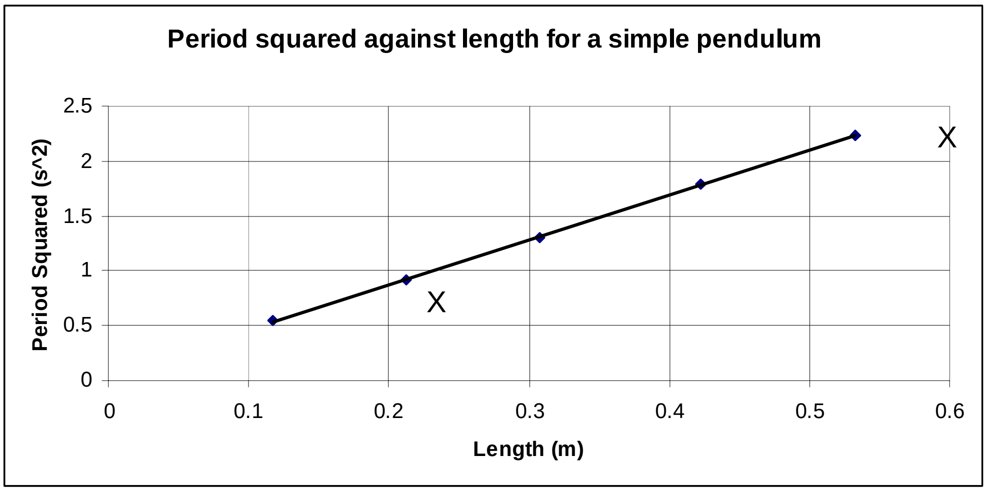
Hence $g = 9.76ms^{-2}$

Accepted value of g is 9.81 $ms^{-2.}$

Part C: Simple Pendulum.

Simple Pendulum - Period (T) as a function of length l.

Measurement	1	2	3	4	5
length(m)	0.533	0.422	0.307	0.212	0.117
Time(s)-50 swings	24.78	66.92	56.89	47.94	36.57
Period (s)	1.469	1.338	1.138	0.959	0.731
Period squared- s^2	2.24	1.79	1.3	0.92	0.54



$$\text{Gradient} = \frac{2.0-0.73}{0.48-0.16}\frac{s^2}{m} = 4.06\frac{s^2}{m} = \frac{4\pi^2}{g}$$

$$\text{Hence g} = 9.72ms^{-2}$$

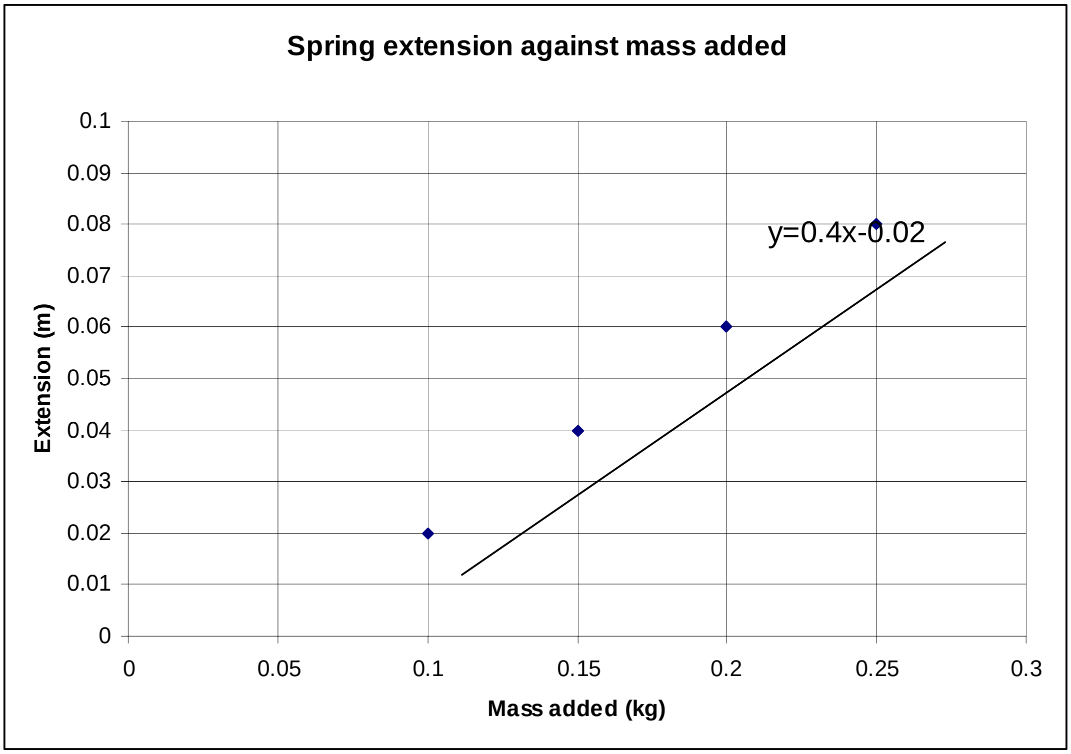
Accepted value for *g* is 9.81 ms^{-2}.
The two experimental results are in agreement with each other to better than 1%

Part D: The Spiral spring.

Spiral spring constant : static and dynamic.

Mass (kg)	Extn. (m)	50 Vibrtns. (s)	Period-T (s)	T^2 (s^2)
0.25	0.08	31.26	0.625	0.39
0.2	0.06	28.68	0.537	0.33
0.15	0.04	25.06	0.501	0.25
0.1	0.02	21.15	0.423	0.18

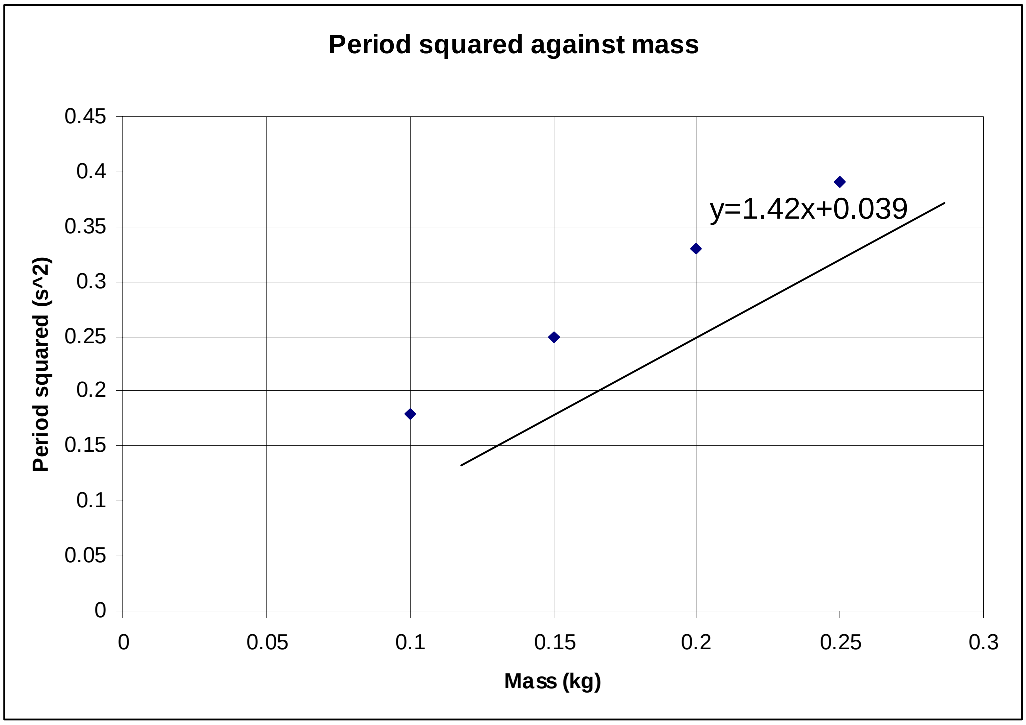
Static Measurement.



Gradient = 0.4 mkg^{-1}, ie. spring constant $k = \frac{g}{gradient} = 24.5 Nm^{-1}$.

Graph shows data point to be in a straight line, indicating reasonable measurements.

Dynamic Measurement.



$$\text{Gradient} = \frac{0.35-0.19}{0.225-0.113} = 1.43 s^2 kg^{-1} = \frac{4\pi^2}{k}\text{, hence } k = 27.6\ \text{Nm}^{-1}$$

Graph shows good straight-line fit. Measurement agrees with previous one to within 12%.

Conclusions:

- It was shown that if a system of forces is at rest, the vector sum of the forces is, to a reasonable approximation, zero. Uncertainty in the measurements means that the sum is not exact.
- The two measurements of *g* have been found to be within reasonable agreement with each other and the accepted value. This shows that the measurements were reasonably accurate.
- The two measurements of spring constant were found to be within 12% of each other. It is not possible to judge which method is better since the actual value is not known.

Reports

The report should be written in your own words in an impersonal passive style. It should be complete and free-standing allowing the informed reader to repeat the experiment on the basis of your report alone. It should not include the tutorial questions as such, but the material covered in them may be relevant to explaining the theory and analysis of your experiment.

If the experiment has several parts, it is better to describe each part individually, as above, and draw the whole report together at the end with a short, overall conclusion.

Examples of previous years' reports will be available in the lab to give you an idea of what is expected. Since the IT component of the assessment is based on your reports, you must bear in mind that reports

- ✓ should be word processed (using Microsoft Word, or equivalent).
- ✓ diagrams, tables and graphs should be printed.
- ✓ should be printed on A4 size paper and stapled or bound, with your name and lab session clearly marked.
- ✓ ***should not be more than 5 pages in length.***

A typical report may be divided up into the following sections but think first about the appropriate structure for your experiment.

Title (including date)

Introduction

The aim of the experiment.

Theory

Explain and quote the formulae used and state what the symbols mean but don't derive the formulae.

Apparatus

Describe the experiment briefly. Include

- ✓ a clear carefully annotated diagram. Give diagrams figure numbers and refer to them in your text.
- ✓ a description of the apparatus, and instruments used.

Method

- ✓ For each measurement as appropriate, describe what was varied what was measured and how it was measured.

Results

- ✓ data in tables with a label
- ✓ graphs with a label where appropriate

Analysis

- ✓ The calculations involved in obtaining the final results. All arithmetic details should not be shown but they should be sufficient to enable the analysis to be checked.
- ✓ Results should include an estimate of the uncertainties.

Conclusions

- ✓ summarize final results.
- ✓ link the objectives of the experiment with the results obtained.
- ✓ comment on effectiveness of procedures
- ✓ discuss limitations of equipment, and possible improvements
- ✓ discuss sources of uncertainty.

EE1 Physics Laboratory Report Feedback

This section is intended to give you some general tips on report writing, based on some of the more common errors seen in reports in the past.

Use an impersonal style in the passive voice
This might make what you write sound a bit dull, but it is the accepted convention. **Do not** write things like "I switched the power supply on...", instead write "The power supply was switched on.."

Choose the correct tense
Normally when you are reporting on what you *have done,* you would use the ***past tense.*** Occasionally, you can use the ***present*** tense, if you are describing how something works, e.g. "The cathode ray tube works by ... It was switched on at the start of the experiment..."

Write in English prose, not just in note fashion
Do not write down the method as if it were a recipe (that's what the lab manual is for!), but describe as concisely as possible what you did in complete sentences. In particular, ***do not copy the lab manual*** – this would be plagiarism.

Be consistent with significant figures and accuracy
Saying something like "the measured value of g=9.521ms^{-2} was very accurate because it is within 2% of the accepted value" . **NO** – the implied accuracy is +/- 0.0005, meaning that the upper value consistent with the measured data is 9.5215. This is statistically inconsistent with the value of 9.81ms^{-2}. ***There is rarely a need to quote results to more than three decimal places in the P1X/Y laboratory.***

Write down only the appropriate results
In a report, tables should adequately summarize the data taken. e.g. in the thermal physics experiment, a graph of temperature vs. time would suffice, instead of printing out the 60 data points.

Make graphs big!
At least half the size of an A4 page; any less is pointless.

Use the same font size throughout
Apart from section headings and the like, the body of text should be in the same font size to make it look professional. This means symbols in equations as well, but you can of course have *italicized text,* **bold text** or ***bold italicized text***.

Use the Equation editor for formulae
Most word processors have one, and it avoids the need for jumping through hoops to get all your symbols to line up.

Beware of the Microsoft version pitfalls
If you are going to work on your report at home and in the department cluster, be sure that you are able to read things like equations and diagrams in both versions of your word processor. Not being able to print out reports because of version incompatibilities with home/department packages seemed to be one of the most common excuses for handing in reports late!

Do not include answers to tutorial questions
-- they are not relevant to the report. However, you may need to include material similar to the tutorial question to explain the theory and analysis of the experiment.

Do not quote only formulae in the background section
This is encouraged at school level, but in EE1 we want you to explain the meaning of formulae and where they have come from.

Do not join dots
If your graph is meant to show a linear relationship, **DO NOT** join data points with straight lines - you should include a best fitting straight line through the points.

EE1 Physics Report Feedback
In order to help you understand any problems with your report writing, you will receive a form similar to the following when your report is returned to you.

Student Name: ....

Matriculation No.: ....

	Marks[1]	***Comments***
Description of Background and Theory	(6)	
Experimental Method and Apparatus	(8)	
Presentation of results	(10)	
Discussion and Conclusions	(6)	
Total	**(30)**	

Marked by:...

Date:...

1 Maximum for section given in brackets

Plagiarism

The following is the University of Glasgow's Plagiarism Statement:

The full details can be found at ***http://senate.gla.ac.uk/academic/plagiarism/***

In the case of EE1, the above warning is not intended to stop you discussing your tutorial problems or laboratory results with your classmates - in fact we encourage this. You should not, however, use someone else's laboratory measurements without acknowledging this, and naming the person, in your record book. **The one formal laboratory report in each module must be your own unaided work.**

XXXI PLAGIARISM STATEMENT *(amended by Senate 6 May 2004)*

Introduction

31.1 The University's degrees and other academic awards are given in recognition of a student's personal achievement. All work submitted by students for assessment is accepted on the understanding that it is the student's own effort.

31.2 Plagiarism is defined as the submission or presentation of work, in any form, which is not one's own, without acknowledgement of the sources. Special cases of plagiarism can also arise from one student copying another student's work or from inappropriate collaboration.

31.3 The incorporation of material without formal and proper acknowledgement (even with no deliberate intent to cheat) can constitute plagiarism. Work may be considered to be plagiarised if it consists of:

- a direct quotation;
- a close paraphrase;
- an unacknowledged summary of a source;
- direct copying or transcription.

With regard to essays, reports and dissertations, the rule is: if information or ideas are obtained from any source, that source must be acknowledged according to the appropriate convention in that discipline; and any direct quotation must be placed in quotation marks and the source cited immediately. Any failure to acknowledge adequately or to cite properly other sources in submitted work is plagiarism. Under examination conditions, material learnt by rote or close paraphrase will be expected to follow the usual rules of reference citation otherwise it will be considered as plagiarism. Departments should provide guidance on other appropriate use of references in examination conditions.

31.4 Plagiarism is considered to be an act of fraudulence and an offence against University discipline. Alleged plagiarism, at whatever stage of a student's studies, whether before or after graduation, will be investigated and dealt with appropriately by the University.

Referral

31.5 Where a student is suspected of plagiarism[1] the member of staff shall refer the case to the Head of Department[2] or equivalent (hereinafter referred to as Head of

[1] If a student suspects a fellow student of plagiarism then he or she should speak to a member of staff in the department
concerned. The identity of the student making the report shall remain confidential.

[2] Where the Head of Department has a potential conflict of interest (eg teaches or examines on the course concerned) then he or she should pass the case to another senior member of academic staff in the Department. In the case of small departments, where it may not be possible to pass the case to another senior member of academic staff, the case should be passed to the Head of a cognate department.

Department) along with all appropriate documentary evidence (the piece of work in question duly marked-up, a copy of the original source of the plagiarism, information on the contribution of the piece of work to the overall assessment, etc). Any further departmental consideration of that piece of work shall be held in abeyance until the procedures set out below have been completed. The student shall be informed in writing that his or her marks have been withheld pending an investigation of suspected plagiarism.

31.6 The Head of Department shall assess the extent of the suspected plagiarism and, if necessary, consult with the Senior Senate Assessor for Discipline. The Head of Department will deal with suspected cases that are first offences and not considered to be severe. The Head of Department will refer all suspected second offences and cases of severe plagiarism directly to the Clerk of Senate or to the Head of the Senate Office for investigation under the provisions of the Code of Discipline.

31.7 Whilst there is no definitive list, examples of cases which would be regarded as severe plagiarism include:

(i) any case of serious and or blatant plagiarism when considered in relation to the student's level of study and length of exposure to the procedures, practices and regulations of the University;

(ii) a first offence where a reduction in marks would put at risk the student's degree or direct progression;

(iii) any case, regardless of extent, where it is inappropriate to deal with it within a department.

Procedure before the Head of Department

31.8 At all times the principles of natural justice shall be observed.

31.9 With respect to cases that are first offences and not considered to be severe, the Head of Department shall interview the student concerned. He or she can also interview any students who have allegedly allowed their work to be copied. As soon as practicable, the student will be informed in writing of the alleged offence and of the requirement to attend for interview. The student will also be provided with a copy the marked-up piece of work in advance of the interview.

31.10 The student shall have the right to be accompanied, assisted or represented at the interview by one of the following: a parent or guardian; a fellow student or other friend; an Officer of the Students' Representative Council; a member of University staff, or a legal representative. At the beginning of the interview, the Head of Department will ascertain who is to be the spokesperson for the student (the student or a representative). The foregoing not withstanding, the Head of Department shall have the right to question the student directly, where necessary.

31.11 The Head of Department shall have a member of support staff present to keep a record of the meeting.

31.12 At the interview, the student will be shown a copy of his or her work, duly marked-up and be given a clear explanation of what he or she has allegedly done. The student will be given the opportunity to justify the work and be invited to admit or
deny responsibility.

31.13 If the Head of Department is satisfied beyond all reasonable doubt that an offence has occurred he or she may impose an academic penalty, which will take account of the extent of the plagiarism. The Head of Department may reduce the marks or results up to the point where the academic rating for the piece of work in question is reduced to zero. Consideration will also be given to resubmission opportunities; the maximum mark that can be awarded to any resubmission is the pass mark appropriate to the degree programme being followed. The student shall be given instruction about plagiarism and the necessity of properly acknowledging and referencing sources.

31.14 If the Head of Department is not satisfied that an offence has occurred but considers that the student has engaged in poor academic practice then the student should receive a warning, instruction about plagiarism and the necessity of properly acknowledging and referencing sources.

31.15 The student will be notified in writing of the outcome. A copy will be kept on record in the Senate Office.

31.16 If it is judged that there is no case for the student to answer, the student will be informed in writing and the piece of work in question will be marked in accordance with normal arrangements, without penalty. The Senate Office does not need to be notified of such instances.

31.17 The Head of Department shall inform the Board of Examiners of any reduction in marks. The Board of Examiners shall not have the authority to revisit or alter academic penalties imposed by this process.

Right of Appeal

31.18 The student shall have the right of appeal to the Senate Assessors for Discipline in respect of any penalty imposed by the Head of Department. A student who wishes to appeal must do so in writing to the Head of the Senate Office within 14 days of the date of the issue of the written decision of the Head of Department.

31.19 The Senate Assessors for Discipline will consider an appeal against the penalty imposed by a Head of Department only on the grounds that:

(i) new evidence has emerged which could not reasonably have been produced to the Head of Department;

(ii) there has been defective procedure at the Head of Department level;

(iii) the penalty imposed by the Head of Department was clearly unreasonable.

The letter of appeal must clearly specify the details of any new evidence, the manner in which the procedures were defective or in what respects he or she believes the Head of Department has erred or been mistaken in imposing a penalty. The letter should also specify the remedy that the student seeks.

Plagiarism in the work of a graduate

31.20 The University will investigate any suspected case of plagiarism in the work of a graduate, which has already been assessed for an award of the University, to determine if the nature and extent of the plagiarism had been material to the award of the degree, diploma or certificate, or class within the degree.

31.21 All such cases will be considered as severe plagiarism. The Head of Department will conduct an investigation and refer the case to the Clerk of Senate or the Head of the Senate Office in accordance with §31.6 above.

Absence

If you are absent from the lab because of a medical problem or any other valid reason, you should:

- ✓ **Inform the lab head** of your absence (by e-mail, or in person). You could also inform any other member of staff on duty in the lab.
- ✓ **Follow the university guidelines**, as set out below. A self-certificate form can be obtained from one of the lab technicians, or staff demonstrating in the lab. The person to send the information to is given on the form.
- ✓ **Give a copy** of the self-certificate or medical note to the lab technician. This is **very important** - it means that we can keep marks up to date.

1. GENERAL ABSENCE DUE TO ILL-HEALTH OR OTHER REASON

	Duration	**Reason**	**Form of Notice**	**Notice to be given to**	**Follow-up action**
1.1	up to 5 term-time days excluding Saturdays and Sundays	ill-health	GU student self-certification form	Senior Faculty Adviser (see form)	Senior Faculty Adviser to inform student's Adviser and depts at discretion
1.2	up to 5 term-time days excluding Saturdays and Sundays	other than ill-health	letter from student	Senior Faculty Adviser	Senior Faculty Adviser to inform student's Adviser and depts at discretion
1.3	6 or more term-time days excluding Saturdays and Sundays	ill-health	Doctor's medical certificate	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*
1.4	6 or more term-time days excluding Saturdays and Sundays	other than ill-health	letter from student, family member or Adviser	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*

2. ABSENCE DUE TO ILL-HEALTH OR OTHER REASON WHICH PREVENTS THE SUBMISSION OF A COURSEWORK ASSIGNMENT BY THE DUE TIME (CONT'D OVERLEAF)

	Duration	**Reason**	***Form of Notice***	**Notice to be given to**	**Follow-up action**
2.1	up to 5 term-time days excluding Saturdays and Sundays	ill-health	GU student self-certification form □	Senior Faculty Adviser (see form)	Senior Faculty Adviser to inform student's Adviser and depts at discretion
2.2	up to 5 term-time days excluding Saturdays and Sundays	other than ill-health	letter from student	Senior Faculty Adviser	Senior Faculty Adviser to inform student's Adviser and depts at discretion

- The Head of the Registry and the Senior Faculty Adviser will consult and decide when it is necessary to notify an absence to the SAAS/LEA.

- A Head of Department reserves the right to require a student to provide a doctor's medical certificate or report, for which the doctor may charge a fee. If payment of such a fee will cause the student financial hardship, he/she should seek advice from Registry on taking out an emergency Student Loan or applying to the Student Hardship Fund.

	Duration	**Reason**	**Form of Notice**	**Notice to be given to**	**Follow-up action**
2.3	6 or more term-time days excluding Saturdays and Sundays	ill-health	Doctor's medical certificate	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*
2.4	6 or more term-time days excluding Saturdays and Sundays	other than ill-health	letter from student, family member or Adviser	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*

3. ABSENCE FROM ANY EXAMINATION DUE TO ILL-HEALTH OR OTHER REASON

	Duration	**Reason**	**Form of Notice**	**Notice to be given to**	**Follow-up action**
3.1	any	ill-health	Doctor's medical **report** explaining the reason for absence or medical certificate only in the case of class exams	Registry within one week	Registry to inform all relevant depts and Senior Faculty Adviser
3.2	any	other than ill-health	letter from student, family member or Adviser or Student Counsellor	Registry within one week	Registry to inform all relevant depts and Senior Faculty Adviser

* The Head of the Registry and the Senior Faculty Adviser will consult and decide when it is necessary to notify an absence to the SAAS/LEA.