Your task is to carry out an investigation to see how the amplitude, *A*, of vertical oscillation of a mass hanging from two springs in series varies with time, *t*.

Time allowed: You are **advised** to spend 15 minutes to answer parts *(a)* and *(b)* during which time you are allowed to set up and use the equipment for trial readings.

You are provided with the following equipment

500g hanger and masses
2 linked springs
pointer
split cork
2 clamps and stands
G-clamps
Metre rule
Stopwatch
Sticky tape

(a) The relationship between the amplitude of an oscillation, A, and the time t, can be expressed by:

$$A = A_o e^{-\lambda t}$$

where A_o = initial amplitude
and λ = an unknown constant

Rearrange this equation in the form of $y = mx + c$ and explain which graph you will draw to confirm this relationship and also determine the unknown constant λ. [2]

If you are unsure what to do, ask your supervisor for information sheet 1.
You will be deducted 2 marks for this information.

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For supervisor's use only [Tick one box (✓)]	
Yes information sheet **needed**	
No information sheet not **needed**	

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Examiner only

(b) Write a plan of how you will obtain sufficient readings to investigate this relationship. Include a labelled diagram with your plan, and justify all values chosen. [5]
[You are advised **not** to stop the timer as you record readings.]

If you are unsure what to do ask your supervisor for information sheet 2.
You will be deducted 2 marks for this information.

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For supervisor's use only [Tick one box (✓)]	
Yes information sheet **needed**	
No information sheet not **needed**	

Examiner only

(c) Obtain results and record them in a table. State the resolutions of all instruments used. [5]

Examiner only

(d) Draw a suitable graph to determine λ. Error bars are **not** required. [4]

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(e) Does your graph confirm the relationship given in *(a)*?
Explain your answer. [3]

(f) (i) Use your graph to determine a value for λ. Remember to include units with your answer. [3]

(ii) What does the intercept on the y-axis of your graph represent? [1]

(iii) From the graph, determine the time taken for the initial amplitude of oscillation, A_o, to halve. Show your working clearly. [2]

EXPERIMENTAL TASK

MARK SCHEME – TEST 1

Question		Marking details	Marks Available
(a)		ln $A = -\lambda t + \ln A_0$ (1) Plot ln A (vertical axis) against t (horizontal axis) or equivalent stated - accept a sketch showing this. NB. No back-crediting from candidate's graph. (1) [Remember to indicate in the box whether the information sheet has been given and not to award the marks if it has been issued].	2
(b)		Labelled diagram – springs shown approx vertical, securely attached vertical rule, weight shown on spring. (1) Method to avoid parallax [or shown on diagram]. (1) Suitable range of time intervals used which allows the amplitude to decrease by at least 50% and at least 5 equally spaced readings. (1) Justification of the choice of range provided by a statement in the method not just implied from results. (1) e.g. I plan to take these readings because they will show the amplitude decaying by at least half. Suitable initial amplitude, A_0 - minimum 10 cm. (1) [Remember to indicate in the box whether the information sheet has been given and not to award the marks if it has been issued].	5
(c)		Single clear main table: titles with units: including time, amplitude readings and ln A [ignore additional summary tables, e.g. a table with only ln A and t columns]. (1) Resolutions correct ruler 1 mm (accept 0.5 mm), stopwatch 1 s. (1) ln A values correct. (1) Repeat readings and correct means. (1) All readings and means to resolution of instrument and ln A to 2 or 3 s.f. (1)	5
(d)		Axes labelled with units - correct orientation [e.c.f. from *(a)*]. (1) All points plotted correctly to within ½ small square division. (1) Good line of best fit consistent with the data. (1) Suitable scales (not involving awkward factors, e.g. 3 / over ½ each axis used). (1)	4
(e)		NB There is no mark for yes / no only – the marks are for the explanation, straight line / not a straight line. (1) Negative gradient [no e.c.f. on incorrect data]. (1) Points close to line of best fit or not [as appropriate]. (1)	3
(f)	(i)	Large triangle used (should be close to extremities of the line of best fit) [or 2 equivalent suitable points clearly indicated on the graph] and gradient calculated. (1) λ [identified as gradient] and given to 2 or 3 s.f. (1) Units s^{-1} or min^{-1}. (1)	3
	(ii)	ln (original amplitude) or ln A_0 [**not** A_0 on its own]. (1)	1
	(iii)	Calculation of ln (A_0 / 2) given or horizontal line at ln (A_0 / 2) on graph shown. (1) Time calculated consistent with graph [NB No s.f. penalty]. (1)	2
			[25]

MARK SCHEME – TEST 2

Same as TEST 1

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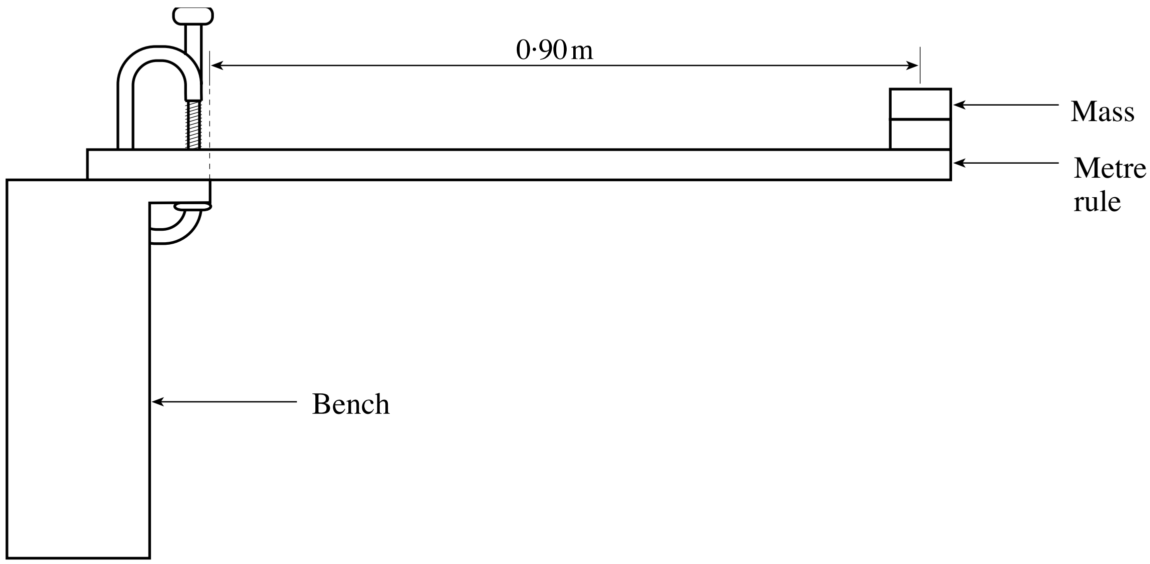
Question 3

You are going to determine the Young modulus of the material of a metre ruler using two different methods.

Method 1

Attach the two 100g masses to the metre rule using the elastic band. Clamp the metre ruler to the bench allowing an overhang of 0·90 metres.



(a) (i) By displacing the metre rule a small amount and releasing determine the period of oscillation. Record your results below. [2]

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(ii) Repeat this procedure for an overhang of 0·60 metres. [1]

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(b) Theory shows that the Young modulus is given by

$$E = \frac{30l^3}{bd^3T^2},$$

where l = length of overhang in m
b = width of rule in m
d = thickness of rule in m
T = period of oscillation in s.

(i) Using the apparatus available, measure a value for b and d for your metre rule. [3]

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(ii) Hence use the above equation to calculate values for the Young modulus at 0·9m and 0·6m. [2]

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(iii) Which of the measurements you have made will have caused the largest error in your calculation, l, b, d, or T? Explain your answer. [2]

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Method 2

(c) (i) With the masses still attached to the rule re-clamp it to the bench with an overhang of 0·90 m. Accurately measure the height of the free end of the rule from the floor. Carefully explain how you did this. [3]

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(ii) Remove the masses from the rule and measure its new height from the floor. Use this measurement to calculate the depression of the rule. [2]

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(iii) Repeat steps *(c)*(i) and *(c)*(ii) to find the depression of the rule for an overhang of 0·60 m. Record **all** your results below. [2]

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Examiner only
Arholwr yn unig

(d) Theory also shows that the Young modulus in pascal (Pa) for this mass is given by:

$$E = \frac{8l^3}{hbd^3},$$

where l = length of overhang in m
b = width of rule in m
d = thickness of rule in m
h = depression in m.

Use your results in *(b)*(i) and *(c)* to calculate two new values for the Young modulus. [2]

(e) Which of the two methods do you consider to be the more accurate? Explain your answer. [2]

Experiment 3

Test 1

The candidate will be expected to determine the Young Modules of the material of a metre rule by two separate methods.

1. Two metre rules, one of them labelled “A”.

2. Two 100 g masses [e.g. slotted masses]

3. One G-clamp.

4. Elastic band of appropriate size and strength to bind the masses firmly to the rule.

5. Set square.

6. Stop watch reading to 0·01 s.

7. Micrometer reading to 0·01 mm.

The candidate should be able to clamp the rule to the horizontal bench surface so that up to 93 cm is projecting.

The supervisor should ensure that at least one of the metre rules has a measurable but not excessive deflection when projecting by 93 cm and loaded at the end with 200 g. This rule should be labelled **“A”**.

Test 2

The apparatus is as for Test 1.

PH3 Mark Scheme – May 2004

Notes: This marking scheme, whilst reasonably complete does not give **all** the responses, which were credited by the examiners. It is hoped that the scheme is self-explanatory, though it will need to be read alongside the question paper. The following clarifications may be of use:

Statements in brackets [ ] are exemplification, alternatives, indications of acceptable range of numerical answers (with ±), **or** statements which, whilst desirable in an answer were not required on this occasion for full marks.

The numbers in parentheses ( ) are the marks, usually 1, for each response.

By the nature of a practical examination, the data are the candidates own and every attempt is made not to penalise candidates unduly for poor results, especially in the sections involving their analysis. The various sections of the questions are independent. e.c.f. stands for *error carried forward,* and indicates that the results of previous (incorrect) calculation or poor measurement will be treated as correct for the current section, i.e. the mistake will only be penalised once. This does not extend to errors of principle, for example inappropriately drawing a best-fit line through the origin and subsequently stating that the intercept is zero.

Question	Answers / Explanatory notes	Marks available
1. *(a)* (i)	Units of *v* shown as m s^{-1}(1) Manipulation of $m\,s^{-2}m$ in $\sqrt{2gh}$ (1)	2
(ii)	Air resistance [accept the value of *g* is not accurate]	1
(iii)	Use of callipers (1) Reading taken to the nearest mm(1) (State that) repeat readings taken (1)	3
(b)	Table: Diameter readings all taken to the nearest mm / 0·5 mm (1) $\bar{d}$ and d^2 correctly given to consistent s.f.'s (1) velocity calculated correctly to 2/3 s.f. (1)	3
(c)	Graph: Axes labelled including units (1) Suitable scale [at least ½ paper; no factors of 3] (1) All points (including 0·10 m) plotted correctly (1) Line of best fit [N.B. can be a curve] (1)	4
(d)	Yes (e.c.f. from candidates own results) (1) Straight line graph (1) through the origin (1)	3
(e)	Correct result chosen – from the table (1) Correct calculation: $\frac{u_{max} - u_{min}}{2}$ - ignore units (1)	2
(f)	Any 2 × 1 of: Release mechanism ✓; greater sample size ✓; greater range ✓; other suitable comment ✓.	2
		[20]

Question			Answers / Explanatory notes	Marks available
2.	*(a)*		All symbols present / correct [accept cell for power supply] (1) Ammeter in series and voltmeter in parallel. (1)	2
	(b)		Reading correct to 2 d.p. with units.	1
	(c)		Table: Minimum of 5 readings (1) Headings correct, with units (1) Suitable range consistent with max/min readings (1) All readings to 1-2 d.p. all to 0·01 (1)	4
	(d)		Graph: Headings and units on axes – correct alignment (1) Suitable scales chosen (1) Allpoints correctly plotted (1) Smooth curve drawn from (0,0) (1)	4
	(e)	(i)	Tangent drawn [Δ if a straight line] (1) Gradient calculated correctly (1) Resistance correct (1/gradient) (1) } (ignore s.f.'s)	3
		(ii)	R calculated using $R = \frac{V}{I}$ (not tangent) (1) } (ignore s.f.'s) Units correct in either (i) or (ii)(1)	2
			Resistance increases – e.c.f. from (i) and (ii) (1) Filament heats up (1)	2
	(f)	(i)	Straight line (through the origin)	1
			Lower gradient – e.c.f. if axes incorrect orientation	1
				[20]

Question			Answers / Explanatory notes	Marks available
3.	*(a)*	(i)	Accurate results ± 0·1 s [no unit penalty] (1) Repeat readings taken **or** more than 1 oscillation measured. (1)	2
		(ii)	Correct result – smaller than in *(a)* – to nearest 0·01 s [accept 0·005] – units – 2/3 d.p.	1
	(b)	(i)	Repeat readings for either (1) Correct values: *b* ± 1 mm; *d* ± 0·2 mm (1) [N.B. Only 2 marks here – error on printed paper]	2
		(ii)	Calculations correct (1) Correct unit – Pa or N m^{-2} (1)	2
		(iii)	*d* (1) [accept *T*] Smallest value / cubed (1) [difficulty of counting rapid oscillations]	2
	(c)	(i)	metre rule used (1) rule vertical / use of set square / parallax (1) measurement to nearest mm / 0·5 mm; units; repeats (1)	3
		(ii)	Measurements to nearest mm (1) Correct calculation (1)	2
		(iii)	All readings shown with units (1) Readings to nearest mm (1)	2
	(d)		Correct calculations (1) Correct number of s.f. [2 d.p. max] (1) [If only 1 value found – 1_{max}]	2
	(e)		Correct method (2^{nd}) (1) Correct reason (T^2 in method 1, but only *h* in method 2) (1) [Accept: any valid reason]	2
				[20]