Candidate Name	Centre Number	Candidate Number

WELSH JOINT EDUCATION COMMITTEE
General Certificate of Education
Advanced

CYD-BWYLLGOR ADDYSG CYMRU
Tystysgrif Addysg Gyffredinol
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544/01

PHYSICS

ASSESSMENT UNIT PH4: OSCILLATIONS AND ENERGY

A.M. FRIDAY, 20 January 2006

(1 hour 30 minutes)

ADDITIONAL MATERIALS

In addition to this paper you may require a calculator.

INSTRUCTIONS TO CANDIDATES

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.

You are advised to spend not more than 45 minutes on questions 1 to 5.

For Examiner's use only.	
1	
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Total	

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 90.

The number of marks is given in brackets at the end of each question or part question.

You are reminded of the necessity for good English and orderly presentation in your answers.

You are reminded to show all working. Credit is given for correct working even when the final answer given is incorrect.

Your attention is drawn to the table of "Mathematical Data and Relationships" on the back page of this paper.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

Fundamental Constants

Avogadro constant	N_A	=	$6{\cdot}0 \times 10^{23}$ mol^{-1}
Fundamental electronic charge	e	=	$1{\cdot}6 \times 10^{-19}$ C
Mass of an electron	m_e	=	$9{\cdot}1 \times 10^{-31}$ kg
Mass of a proton	m_p	=	$1{\cdot}67 \times 10^{-27}$ kg
Molar gas constant	R	=	$8{\cdot}3$ J mol^{-1} K^{-1}
Acceleration due to gravity at sea level	g	=	$9{\cdot}8$ m s^{-2}
[Gravitational field strength at sea level	g	=	$9{\cdot}8$ N kg^{-1}]
Universal constant of gravitation	G	=	$6{\cdot}7 \times 10^{-11}$ N m^{2} kg^{-2}
Planck constant	h	=	$6{\cdot}6 \times 10^{-34}$ J s
Boltzmann constant	k	=	$1{\cdot}38 \times 10^{-23}$ J K^{-1}
Unified mass unit	1 u	=	$1{\cdot}66 \times 10^{-27}$ kg
Speed of light *in vacuo*	c	=	$3{\cdot}0 \times 10^{8}$ m s^{-1}
Permittivity of free space	ε_o	=	$8{\cdot}9 \times 10^{-12}$ F m^{-1}
Permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}

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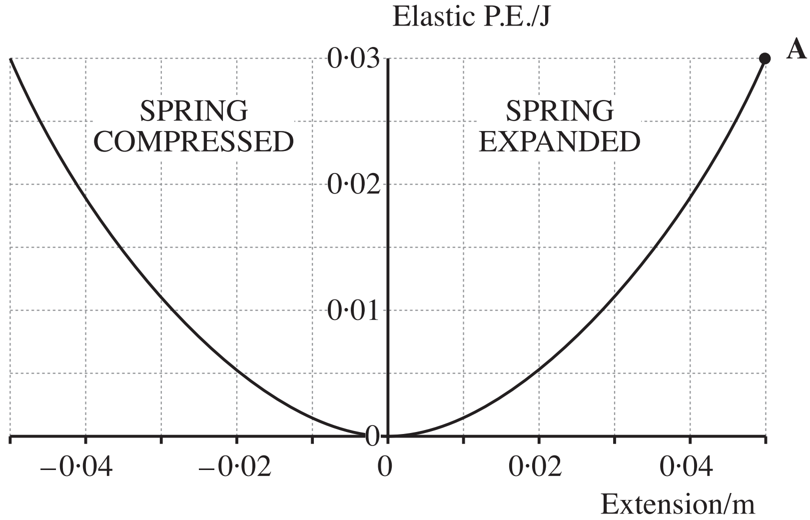
1. An educational supplier sends out technical data with some of its products. The graph below comes with a type of helical spring.



(a) (i) By taking point **A** on the graph, find a value for the spring constant, k (the force per unit extension). [2]

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(ii) By considering an additional point, check that the spring obeys Hooke's Law. Explain your reasoning. [2]

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(b) A student attempts to check the value of k using s.h.m. He attaches one end of the spring to a fixed point and the other end to a trolley of mass 1·50 kg. The trolley can move backwards and forwards freely along straight horizontal rails. Having displaced the trolley from its equilibrium position, and released it, the student finds that 25 cycles of oscillation take a time of 39·0 s. Calculate a value of k **from these results**. Give your answer to 3 significant figures. [3]

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(c) **On the axes above**, draw the graph of *kinetic energy* against displacement for the trolley, when the amplitude of the oscillations is 0·050 m. Assume negligible energy loss through dissipative forces. [3]

Turn over.

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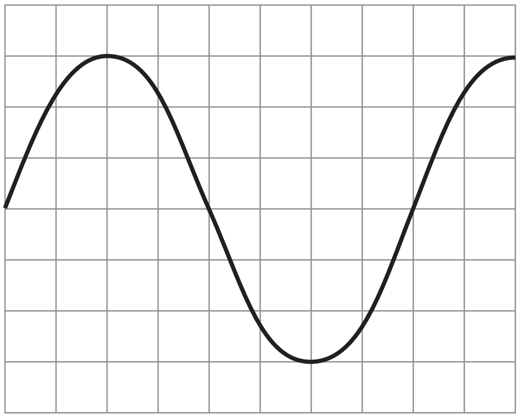
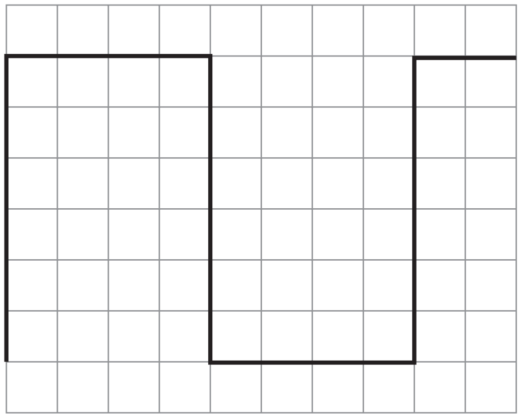
2. A student connects a signal generator to the y-input of an oscilloscope. A sine wave trace appears on the screen as in the left hand diagram. The time-base is set to 1·0 ms/div (1·0 millisecond per screen division) and the y-gain to 5·0 V/div (5·0 volt per screen division).





(a) For the sine wave trace, determine

(i) the **r.m.s.** value of the p.d. produced by the signal generator, [2]

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(ii) the frequency. [2]

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(b) The signal generator is now switched to *square wave* mode, and the trace appears as in the right hand diagram. [No alterations are made to the oscilloscope settings.]

(i) The r.m.s. value of the square wave p.d. is 15 V. Explain how this can be deduced. [2]

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(ii) Write down the frequency of the square wave p.d. [1]

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(c) (i) Explain why, for either the sine wave or the square wave, the r.m.s. value of the p.d. could not be found from the trace if the y-gain were set to 1·0 V/div. [1]

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(ii) Explain why the frequency could not be found if the time-base were set to

(I) 100 ms/div, [1]

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(II) 0·01 ms/div. [1]

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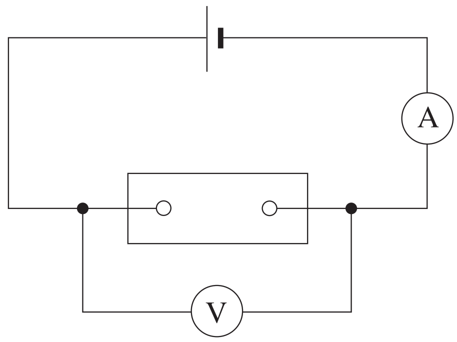
3. A sealed box with two terminals is **known** to contain **either** an inductor (of negligible resistance) in series with a resistor **or** a capacitor in series with a resistor. A student has to find out, by making measurements, the values of the components in the box.

(a) He starts by setting up the circuit shown. The current reaches a steady value of 25 mA for a p.d. of 6·0 V. The student correctly deduces that the combination in the box is an *inductor* in series with a resistor.



(i) Justify this deduction. [1]

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(ii) Calculate the resistance of the resistor. [1]

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(b) The student replaces the battery by a signal generator producing a sinusoidal output at a frequency of 75 Hz, and selects 'a.c.' ranges on the meters. The voltmeter reads 6·0 V r.m.s., and the ammeter reads 20 mA r.m.s.. Calculate

(i) the *impedance* of the combination in the box, [1]

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(ii) the *inductance* of the inductor. [4]

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(iii) The student now places a capacitor in series with the box. He finds that the r.m.s. current increases (even though the signal generator output voltage has not changed.) Explain, using a labelled phasor diagram, why the increase in r.m.s. current occurs. [3]

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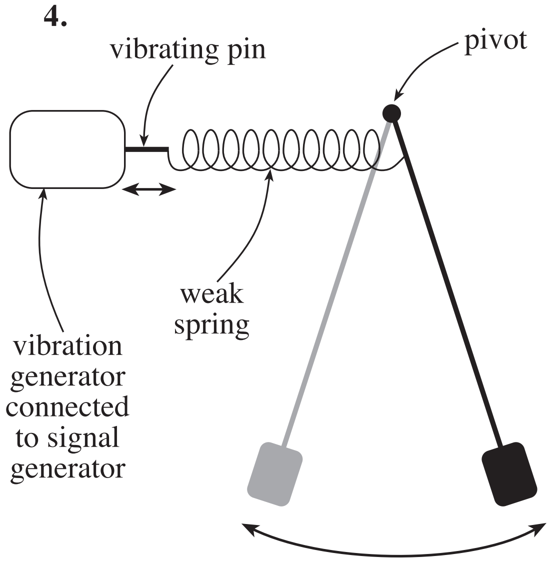

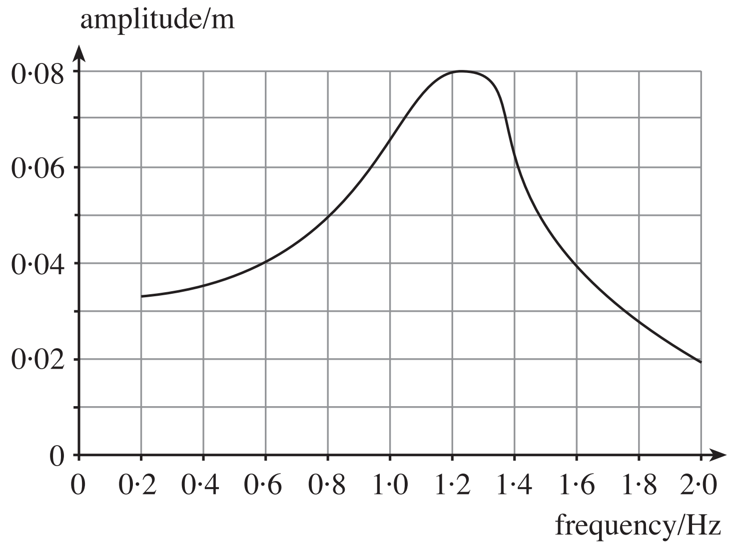

The diagram shows apparatus for investigating *forced oscillations*. [You are not expected to have met this apparatus before.]

The signal generator is set to give a sine wave output of very low frequency, and the vibrating pin moves backwards and forwards as shown. The amplitude of the pendulum's oscillations is measured when it has reached a steady value. The procedure is repeated for different frequencies, enabling a graph to be plotted as shown.

(a) (i) State the natural frequency of the pendulum. [1]

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(ii) Describe a practical method that would confirm that this is its natural frequency. [3]

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(b) Forced oscillations may be defined as oscillations which occur when a *sinusoidally-varying force* is applied to an *oscillatory system*. Explain how this definition applies to the set-up above. Pay particular attention to the words in italics. [3]

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(c) Using the same graph axes (above), sketch the graph you would expect if the *damping* on the pendulum were increased (for example by attaching a light sheet of paper to it). [3]

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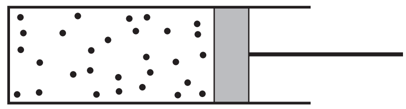
5. *(a)* A sample of gas, initially at atmospheric pressure, is contained in a metal cylinder with a leak-proof piston.



(i) Briefly describe how, in practice, you could increase the internal energy of the gas

(I) by doing work, [1]

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(II) by heating. [1]

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(ii) For each method, state which of the quantities must be positive and which, if any, must be negative in the equation

$$Q = \Delta U + W.$$

(I) by doing work [1]

....

(II) by heating [1]

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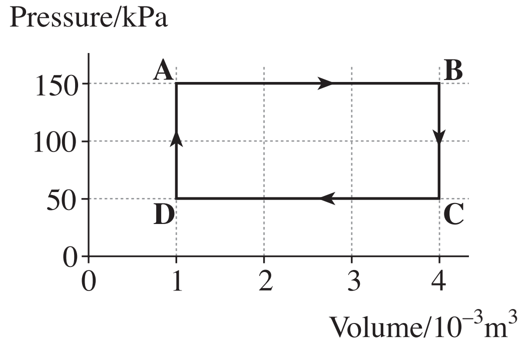
(b) A gas undergoes the cycle of changes **ABCDA** shown on the diagram.



(i) Over which sides of the rectangle is no work done on the gas or by the gas? [1]

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(ii) Calculate the net *work* over the complete cycle, stating whether this is done *on* the gas or *by* the gas. [3]

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(iii) Hence **explain** whether heat is taken in, given out, or neither, during the cycle. [2]

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6. *(a)* (i) State Newton's Third Law of Motion. [If you use the terms *action* and *reaction,* explain what they mean.] [2]

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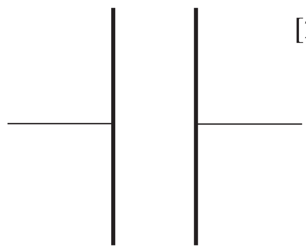
(ii) Explain how the law applies to the plates of a charged capacitor, adding to the diagram if you wish. [2]



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(b) An experimental capacitor consists of square metal plates, each measuring 0·30 m × 0·30 m, separated by an air gap of 2·0 mm. [The **relative** permittivity of air is 1·00.] A power supply of terminal p.d. 80 V is connected across the plates. Calculate

(i) the capacitance of the capacitor, [3]

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(ii) the charge on either plate, [1]

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(iii) the energy stored. [2]

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(c) The power supply is now disconnected from the capacitor of part *(b)*, so that **the plates are still charged, but electrically isolated**. The plates are now pulled apart by a further 1·0 mm (using insulated handles).

(i) Calculate the new capacitance. [1]

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(ii) Show that the stored energy is **increased** by 0·6 μJ, explaining your reasoning. [4]

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(iii) State the *Principle of Conservation of Energy*. [2]

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(iv) Hence state the amount of work that had to be done on the plates in order to increase their separation. [1]

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(v) Hence calculate the mean *force* between the plates while their separation was being increased. [2]

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7. *(a)* (i) In a cylinder of helium gas, three of the molecules have speeds of 950 ms^{-1}, 1300 ms^{-1}, and 1650 ms^{-1} at one instant. Calculate the r.m.s. speed of this group of molecules at that instant. [3]

(ii) Explain why the speed of a gas molecule frequently changes. [1]

(iii) The cylinder has a volume of $5{\cdot}0 \times 10^{-3}\,m^3$ and contains $8{\cdot}0 \times 10^{-3}$ kg of helium at a pressure of 900 kPa. Calculate

(I) the number of helium **molecules** (relative molecular mass 4·0) in the cylinder [2]

(II) the r.m.s. speed of all the molecules in the cylinder, [3]

(III) the r.m.s. speed of all the molecules if the kelvin temperature of the gas were doubled. [2]

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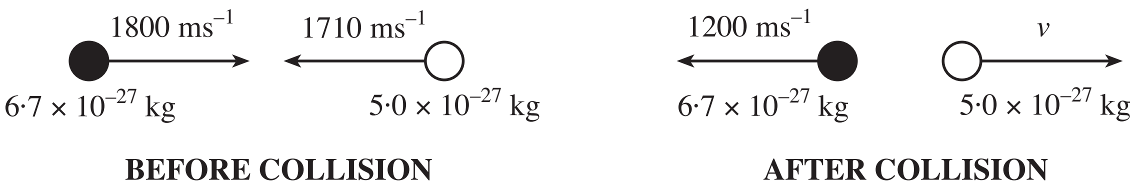
(b) In a sample of helium gas a few of the molecules are of a lighter isotope of helium. The diagrams give data for a particular head-on collision between the two types of molecules.



(i) State the *Principle of Conservation of Momentum*. [2]

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(ii) Use the Principle to determine the velocity of the lighter molecule after the collision. [3]

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(iii) Textbooks assert that collisions between gas molecules are *elastic*.

(I) State what is meant by an elastic collision. [1]

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(II) Show clearly whether or not the above collision is elastic. [3]

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Turn over.

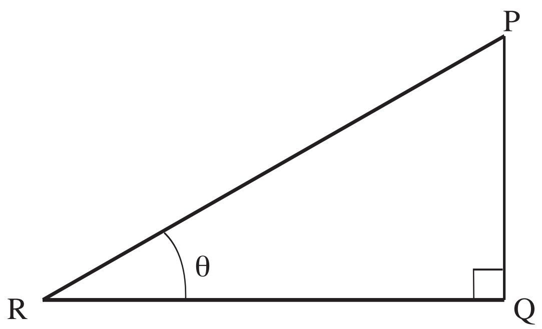
Mathematical Data and Relationships

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P

Geometry and trigonometry



$$\sin\theta = \frac{PQ}{PR}, \quad \cos\theta = \frac{QR}{PR}, \quad \tan\theta = \frac{PQ}{QR}, \quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$PR^2 = PQ^2 + QR^2$$

Areas and Volumes

Area of a circle = $\pi r^2 = \frac{\pi d^2}{4}$

Area of a triangle = ½ base × height

Solid	Surface area	Volume
rectangular block	$2\,(lh + hb + lb)$	lbh
cylinder	$2\pi r\,(r + h)$	$\pi r^2 h$
sphere	$4\pi r^2$	$\frac{4}{3}\pi r^3$

Logarithms

[Unless otherwise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log\left(\frac{a}{b}\right) = \log a - \log b$

$\log(x^n) = n\log x$

$\log(kx^n) = \log k + n\log x$

$\log_e(e^{kx}) = \ln(e^{kx}) = kx$

$\log_e 2 = \ln 2 = 0{\cdot}693$