Candidate Name	Centre Number	Candidate Number

WELSH JOINT EDUCATION COMMITTEE
General Certificate of Education
Advanced

CYD-BWYLLGOR ADDYSG CYMRU
Tystysgrif Addysg Gyffredinol
Uwch

544/01

PHYSICS

ASSESSMENT UNIT PH4: OSCILLATIONS AND ENERGY

A.M. THURSDAY, 15 June 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.

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 information "Mathematical Data and Relationships" on the back page of this paper.

For Examiner's use only.	
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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
Unified mass unit	1 u	=	$1 \cdot 66 \times 10^{-27}$ kg
Boltzmann constant	k	=	$1 \cdot 38 \times 10^{-23}$ J K^{-1}
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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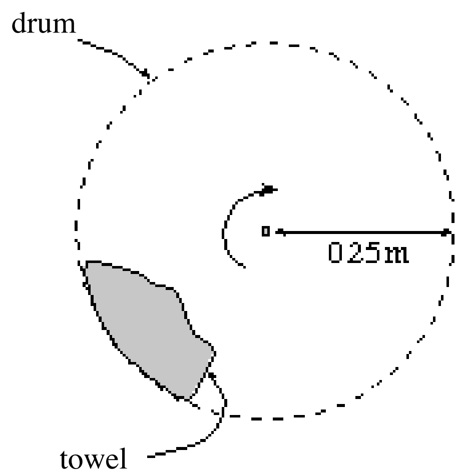
1. *(a)* The drum of a washing machine has a radius of 0·25 m. On 'fast spin' it rotates at 1400 revolutions per **minute**.



(i) Calculate the angular velocity of the drum in S.I. units. [3]

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(ii) Calculate the centripetal force on a wet towel of mass 1·5 kg which is carried round on the inner wall of the drum, as shown. State any approximation you make. [3]

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(b) The washing machine's drum system is held to the outer case of the machine by sturdy springs, and has its own natural frequency of vibration. When the fast spin is over the drum slows down and eventually stops. Over a small range of angular velocities, the drum can shake violently if its contents are unevenly distributed. This can be explained in terms of *forced oscillations*.

(i) Define *forced oscillations*. [2]

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(ii) Explain carefully why the shaking takes place as described above. [2]

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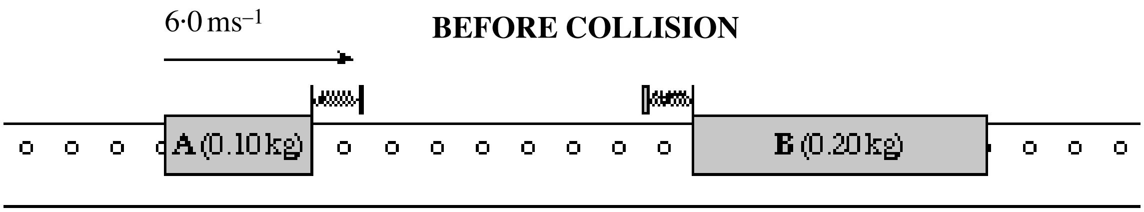
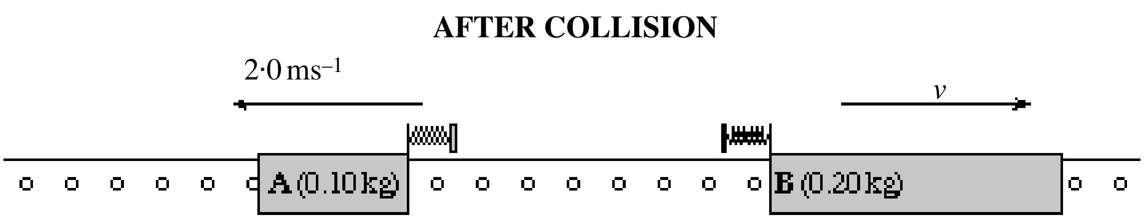
2. Two gliders, **A** (of mass of 0·10 kg) and **B** (of mass of 0·20 kg), on an air track are fitted with spring 'buffers'. The diagram shows the velocities of the gliders before and after a collision in which **B** is initially stationary.





(a) (i) Use the *Principle of Conservation of Momentum* to find v. [3]

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(ii) Show clearly whether or not the collision is *elastic*. [3]

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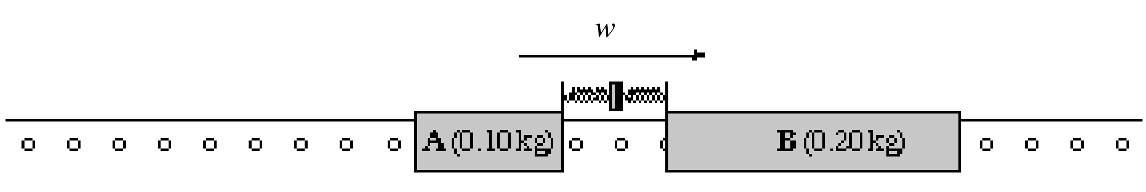
(b) When **A** and **B** were closest together during the collision (see diagram below) they both had the same velocity, w.



(i) Find w. [2]

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(ii) Hence show that at this stage in the collision the total kinetic energy of **A** and **B** was less than **A**'s initial kinetic energy. [1]

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(iii) Where is the 'missing' energy? [1]

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3. In a garden 'water feature' water is pumped up from a reservoir, through a hidden pipe, to the top of a pile of rocks above the reservoir. The flow-rate through the pipe is 900 litres per **hour**, and the water is raised through a height of 1·2 m.

(a) Calculate, in S.I. units, the water's **rate** of gain of gravitational potential energy. [The mass of 1·00 litre of water is 1·00 kg.] [4]

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(b) The pump is electrically powered by a supply of 230 V (r.m.s). Its *efficiency* for raising water is 10%. Calculate the r.m.s. electric current. [Assume current and p.d. to be in phase.] [3]

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(c) The water becomes slightly warmer as it passes through the tube. Explain carefully, in terms of force, work and energy, identifying the relevant force, why this is to be expected. [3]

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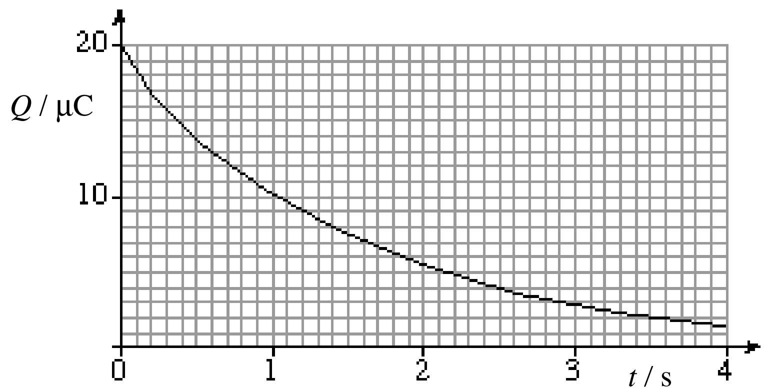
4. When a capacitor discharges through a resistor, the charge, Q on either plate is given by the equation

$$Q = Q_0 e^{-\frac{t}{CR}}$$

A graph of Q against t for a particular case is given below.



(a) (i) Show that the *time constant* for the system is approximately 1·5 s, explaining your method. [2]

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(ii) The capacitance of the capacitor is 8·0 μF. Calculate the resistance of the resistor. [2]

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(b) (i) By considering the p.d. across the resistor-capacitor combination, show that the magnitude of the current through the resistor is given by [1]

$$I = \frac{Q}{RC} .$$

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(ii) Determine I at time $t = 1{\cdot}0\,\text{s}$ by drawing a tangent to the graph. [3]

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(iii) Hence find another value for the time constant, using the equation in part *(b)*(i). [2]

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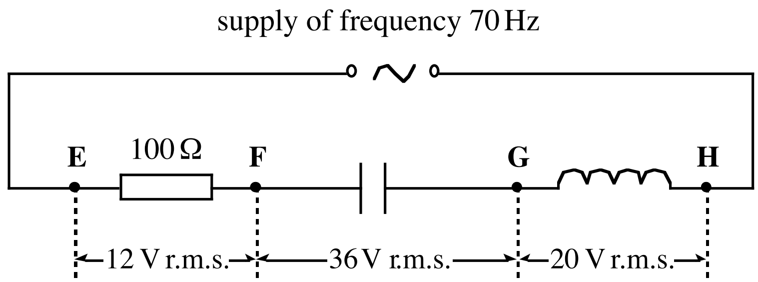
5. A 100 Ω resistor, a capacitor and an inductor of negligible resistance are connected in series across the terminals of a signal generator giving a 70 Hz sinusoidal output. A digital meter is used to measure the r.m.s. p.d.s. between **E** and **F**, **F** and **G**, **G** and **H** in turn. The readings are shown on the diagram.



(a) Calculate

(i) the r.m.s. current, [1]

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(ii) the capacitance of the capacitor. [3]

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(b) (i) Represent the r.m.s p.d.s given in the circuit diagram by a labelled vector (phasor) diagram in which the vectors are assumed to be rotating anticlockwise. [2]

(ii) Calculate the r.m.s. p.d. between **F** and **H**. [1]

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(iii) Calculate the r.m.s. p.d. between **E** and **H**. [2]

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(iv) Calculate the *impedance* of the capacitor, inductor and resistor in series. [1]

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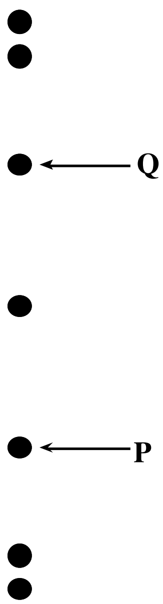

A metal sphere of mass 0·15 kg hangs from a helical spring. The top of the spring is attached to a rigid support. The sphere is pulled down below its equilibrium position and released.

The diagram (based on a multi-flash photograph) shows the sphere at its lowest position, and at intervals of 0·050 seconds up to and including its highest position. **The diagram is full scale** (except that the size of the sphere itself has been reduced).

(a) Measure the *amplitude* of the motion. [1]

(b) Show clearly that the periodic time is 0·60 s. [1]

(c) Define *Simple Harmonic Motion*. [2]

(d) (i) Measure the *displacement* of the sphere **from its equilibrium position** when it is at **Q**. [1]

(ii) Showing your reasoning clearly, check whether or not this displacement agrees with the s.h.m. equation

$$x = A \sin \omega t$$ [3]

in which $t = 0$ as the sphere first passes through its equilibrium position.

(e) (i) Using a measurement from the diagram, find the mean speed of the sphere as it goes from **P** to **Q**. [2]

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(ii) Use the appropriate s.h.m. formula to find the **maximum** speed of the sphere. [2]

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(iii) Explain why you would expect the answers to *(e)*(i) and *(e)*(ii) to be close. [2]

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(f) (i) Label with a letter **R** on the diagram the position of the sphere when its acceleration is a maximum in an upward direction. [1]

(ii) Calculate the magnitude of this upward acceleration using an s.h.m. formula. [2]

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(iii) Hence find the force, F_s, which the **spring** exerts on the sphere when it is in position **R**. [3]

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7. *(a)* The internal energy of an ideal (monatomic) gas is given by the equation

$$U = \frac{3}{2}nRT.$$

(i) State the meaning of *n*. [1]

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(I) Use the ideal gas equation and the kinetic theory formula $pV = \frac{1}{3}Nm\overline{c^2}$ to show that an equivalent formula is

$$U = N \times \frac{1}{2}m\overline{c^2}$$

[2]

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(II) Explain the meaning of this equivalent formula in terms of molecules. [2]

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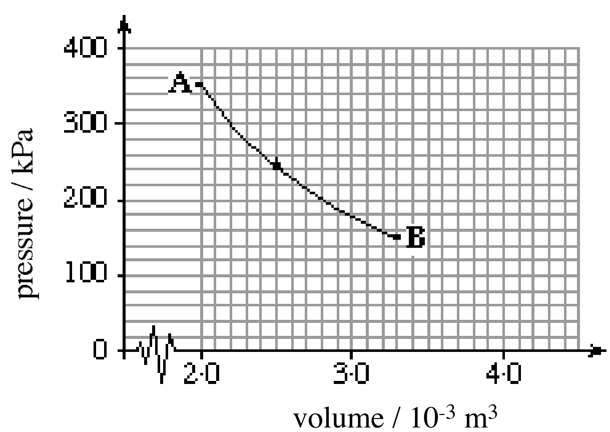
(b) A sample of helium gas in state **A** (see diagram) is at a temperature of 420 K. It expands to state **B**, pushing out a piston.



(i) (I) Estimate the work done by the gas during the process **AB** shown on the graph giving your method clearly. [3]

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(II) Comment on the accuracy of your method. [1]

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(ii) Use the *ideal gas equation* to find

(I) the number of moles of helium, [2]

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(II) the temperature of the helium at **B**. [2]

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(iii) Hence calculate the change in internal energy of the gas during the process **AB**. [2]

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(iv) The process **AB** is a rapid one, and a negligible amount of heat flows into or out of the gas. Explain carefully whether your answers to *(b)*(i) and *(b)*(iii) are consistent with the *The First Law of Thermodynamics*. [3]

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(c) (i) Draw on the graph grid on page 12 a line representing a process **AC** in which the gas is initially in state **A** and loses internal energy without any work being done. [1]

(ii) In what form, in this case, does energy leave the gas? [1]

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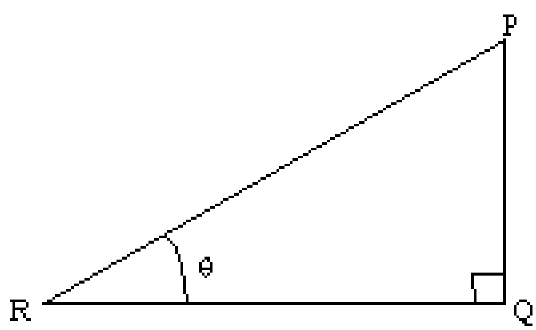
Mathematical Data and Relationships

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 $= \pi r^2 = \dfrac{\pi d^2}{4}$

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 $\log_{10}$.]

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

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