Candidate Name	Centre Number	Candidate Number
		2

General Certificate of Education
Advanced

544/01

PHYSICS
ASSESSMENT UNIT PH4: OSCILLATIONS AND ENERGY

A.M. MONDAY, 21 January 2008
(1 hour 30 minutes)

For Examiner's use only.	
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Total	

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 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}

Examiner only

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

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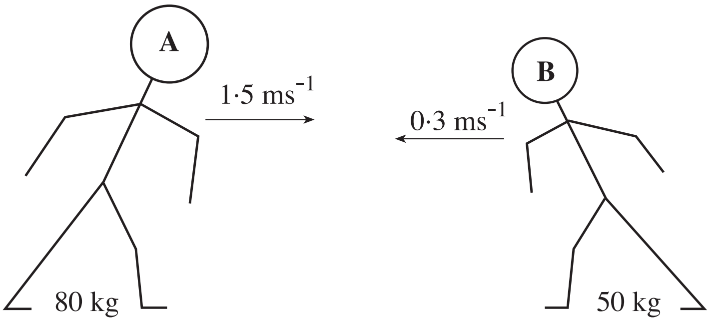
(b) Two ice skaters, **A** (of mass 80 kg) and **B** (of mass 50 kg), approach each other, as shown. As they collide **A** pushes **B** away from him, so that **A** is left stationary.



(i) Calculate the ***velocity*** of **B** after the collision. [3]

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(ii) (I) Show that kinetic energy is gained during the collision. [2]

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(II) Where has the extra kinetic energy come from? [1]

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(c) **A** and **B** now approach each other as before (see diagram), but hold on to each other when they collide. Calculate their velocity after the collision. [2]

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Turn over.

2. For one of the challenges in a science ‘project fair’, students are provided with stop-watches, rulers, string and standard (known) masses. The challenge is to find the mass of any bird which they see landing in a nearby tree.

One student sees a pigeon landing on the end of a very thin branch. He notes that 3 oscillations take place in a time of 1·95 s, as the bird bobs up and down because of the bendiness of the branch.

(a) After the pigeon has flown off, the student gently hangs a mass of 0·050 kg from the end of the branch, and measures its resulting downward displacement to be 0·035 m. Calculate the force per unit displacement (the ‘spring constant’, *k*) for the branch. [3]

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(b) By treating the bird on the branch as a mass-spring system, calculate a value for the mass of the bird. [3]

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(c) The student notes that the bird’s oscillations are *damped*.

(i) What **main** effect does the damping have on the oscillations? [1]

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(ii) Explain, in terms of forces, why the damping effect takes place. [1]

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(iii) Why is it clear that the damping is less than critical? [1]

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(d) Give one reason, other than experimental error, why the method may not yield the correct value for the pigeon’s mass. [1]

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3. In an experiment, a syringe with its outlet blocked contains $40 \times 10^{-6}\,m^3$ of air at an initial temperature of 25 °C. The syringe is then immersed in boiling water at 100 °C. The air expands to a volume of $50 \times 10^{-6}\,m^3$, pushing out the piston.

(a) Treating the air as an ideal gas, show that the air pressure is the same, or almost the same, before and after the expansion. [3]

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(b) In fact, the pressure is a steady 100 kPa throughout the expansion. Calculate the *work* done by the air in the syringe. [2]

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(c) (i) *The First Law of Thermodynamics* may be written in the form

$$Q = \Delta U + W$$

in which Q is the heat flowing into a system. Give the meanings of

(I) ΔU, ... [1]

(II) W. .... [1]

(ii) The initial internal energy of the gas in the syringe is 6·0 J. The final internal energy (after the gas has expanded) is 7·5 J. Calculate the heat input. [1]

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(d) In the last stages of the expansion of the gas, the **rate** of heat flow through the walls of the syringe into the gas becomes smaller and smaller. Use the thermal conductivity equation to explain why this should be the case. [2]

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta \theta}{\Delta x}$$

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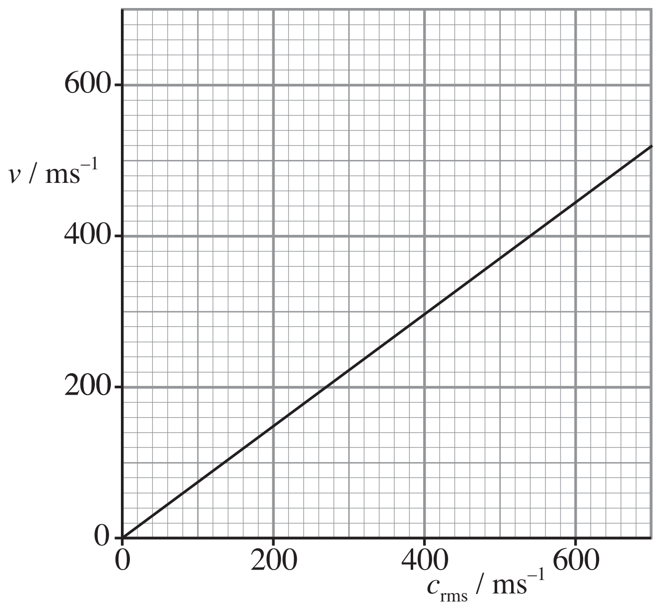
Examiner only

4. *(a)* For monatomic gases (gases whose molecules consist of single atoms) there is a simple relationship between the speed of sound, v, in the gas, and the r.m.s. speed, c_{rms}, of the molecules.



The relationship is given alongside as a graph. Write it as an equation, giving the value of any constant. [2]

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(b) The speed of sound in a particular monatomic gas at a temperature of 288K is found to be 320 ms^{-1}. Using the graph and the appropriate *kinetic theory* formula, find the *density* of the gas if its pressure is 100 kPa. [4]

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(c) Use the *ideal gas equation* to calculate the number of moles in $1{\cdot}0\,\mathrm{m}^3$ of gas at a temperature of 288 K and a pressure of 100 kPa. [2]

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(d) Use your answers to *(b)* and *(c)* to find the relative molecular mass, M_r of the monatomic gas. [2]

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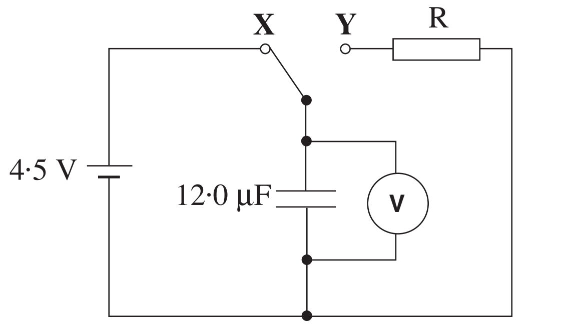
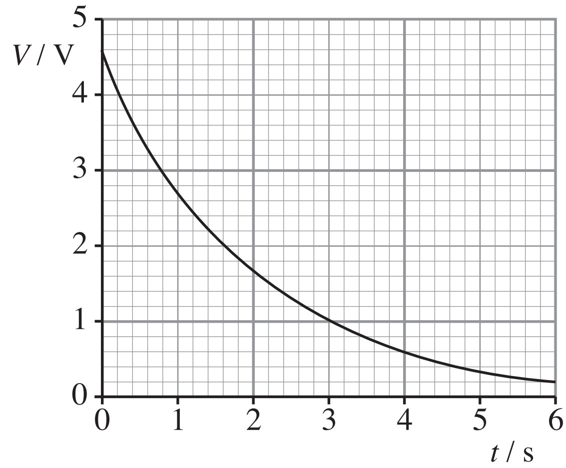
5. *(a)* A 12.0 μF capacitor is charged by connecting it to a 4·5V battery, as shown. Then at time $t = 0$ the connection is moved from **X** to **Y**, so that the capacitor discharges through the resistor. Readings from the voltmeter are used to plot the graph.





(i) Show clearly that the *time constant* is approximately 2·0 s. [2]

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(ii) Hence calculate the resistance of the resistor. [1]

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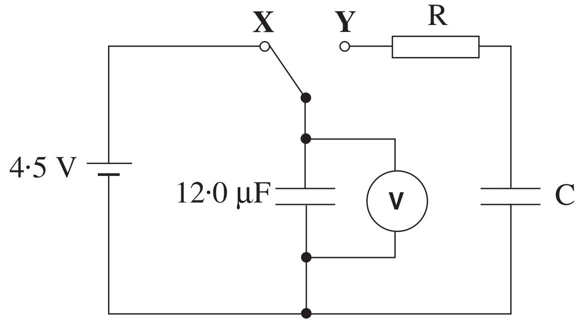
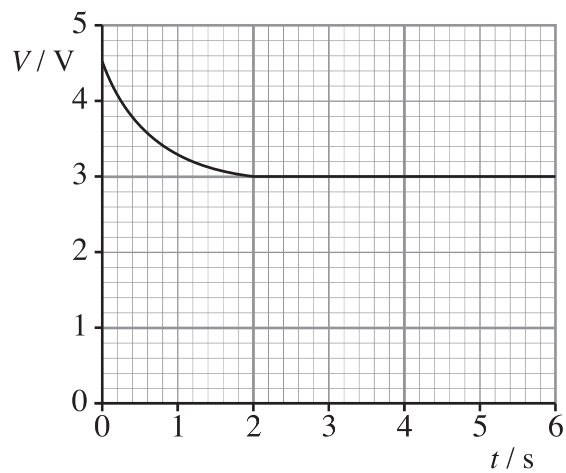
(b) The experiment is now repeated, but with the extra capacitor, C (initially uncharged).





Examiner only

(i) Calculate the *charge* on either plate of the 12·0 μF capacitor when the voltmeter reading has become steady. [1]

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(ii) Show that there must now be a charge of 18 μC on either plate of capacitor C. [1]

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(iii) Calculate the capacitance of C. (In the final steady state, the p.d.s across the two capacitors are equal.) [1]

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(iv) Calculate the energy stored in the 12·0 μF capacitor at time $t = 0$. [2]

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(v) Show that the total energy stored in the capacitors finally is less than this. [1]

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(vi) Suggest what happens to the missing energy. [1]

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Examiner only

6. This question is about a car of mass 1200 kg. Take the resistive forces as negligible.

(a) (i) Define *power.* [1]

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(ii) Calculate the mean power needed

(I) to accelerate the car from rest, along a straight level road, to a speed of $12{\cdot}0\ \text{ms}^{-1}$ in a time of $9{\cdot}0\,\text{s}$, [3]

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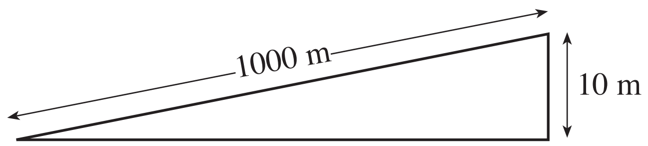
(II) to enable the car to climb the gradient shown at a steady speed of $12{\cdot}0\,\text{ms}^{-1}$. [3]



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

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(ii) The car is travelling at $12{\cdot}0\,\text{ms}^{-1}$ when it starts to descend a hill.

(I) It descends with the brakes off and the engine producing no power. Calculate the car's speed when it has lost 3·0 m of height. Show your reasoning clearly. [3]

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Examiner only

(II) Suppose that the driver had applied her brakes, bringing the car to a stop after descending through the same vertical distance (3·0 m). The brakes consist of pads which press against steel discs attached to the car's wheels. If the total mass of steel in the discs is 12·0 kg, and the specific heat capacity of steel is 450 J kg^{-1} K^{-1}, calculate a value for the temperature rise of the discs during the braking. [4]

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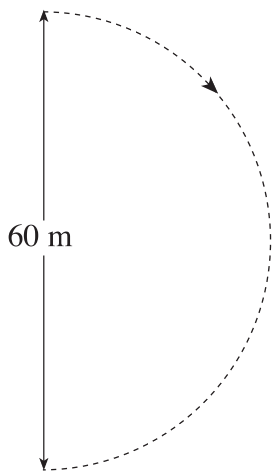
(c) The car is driven at a steady 12·0 ms^{-1} around a semicircular bend (see diagram) on a level motorway slip-road.



(i) Calculate the resultant force on the car. [2]

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(ii) Discuss how this resultant force arises. [2]

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7. *(a)* A signal generator is set to produce a sinusoidal alternating voltage of 5·0 V r.m.s. and frequency 100 Hz.

(i) Calculate

(I) the peak voltage, [1]

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(II) the periodic time. [1]

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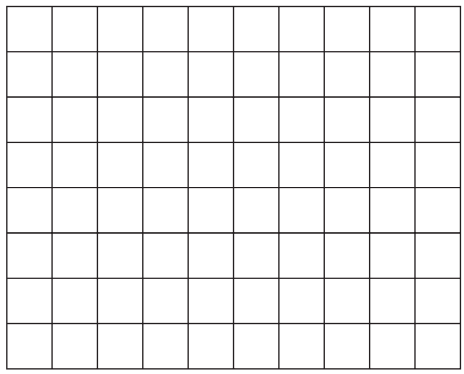
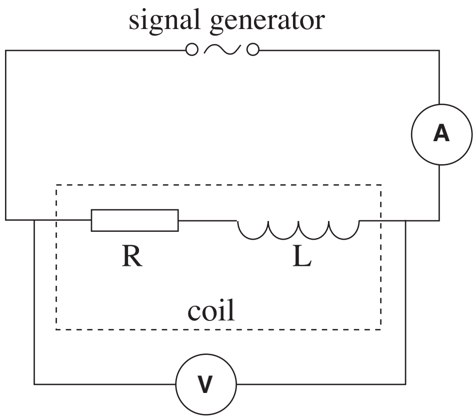
(ii) The signal generator is now connected to the *y*-input of an oscilloscope. The *y*-gain is set to 2·0 V per screen division, and the time-base to 2·0 ms per screen division. Sketch a trace which might be seen on the screen. (Assume both positive and negative peaks are visible.) [3]



(b) A coil of insulated wire behaves as an inductance, *L*, in series with a resistance, *R*.

(i)



State how the *impedance* of the coil at 100 Hz can be found using the circuit alongside. (The meters are calibrated to read r.m.s. values.) [2]

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(ii) The impedance, *Z,* of the coil is given by the equation

$$Z^2 = X_L^{\ 2} + R^2.$$

Derive this formula, using a labelled phasor (vector) diagram. Take the phasors to be rotating anticlockwise. [3]

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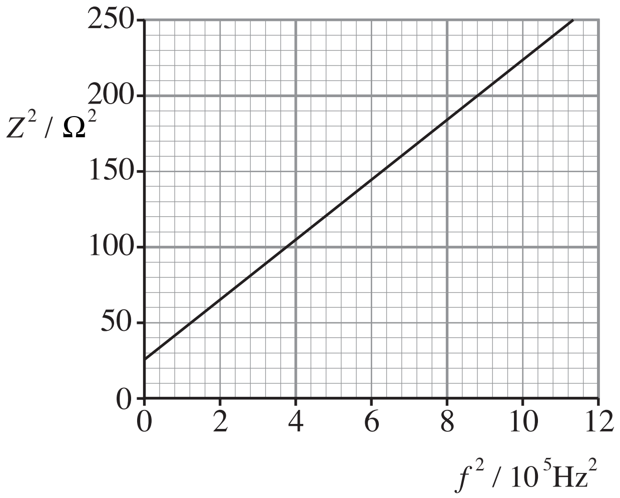
(iii) The formula given in *(b)*(ii) may also be written as

$$Z^2 = 4\pi^2 L^2 f^2 + R^2.$$

Using the circuit of *(b)*(i), *z* is found at a number of frequencies, *f*, and a graph is plotted of Z^2 against f^2. Showing your working, calculate



(I) The coil's resistance, *R*, [2]

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(II) The coil's inductance, *L*. [4]

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(iv) These values can be checked by a different method. A 0·10 μF capacitor is connected in series with the coil, in the circuit of *(b)*(i). The signal generator output voltage is kept at a constant 5·0 V r.m.s., and the frequency is varied. It is found that a maximum current, of 1·0 A r.m.s., occurs at a frequency of 10·6 kHz. Showing your working clearly, calculate values for

(I) *R*, [1]

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(II) *L*. [3]

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Turn over.

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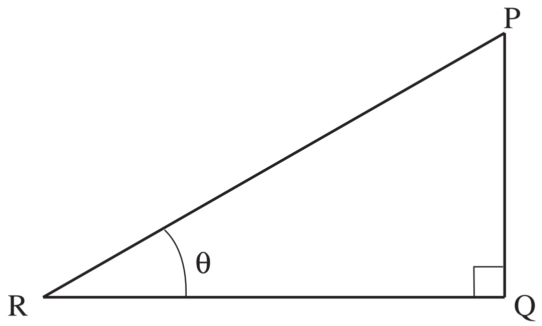
Mathematical Data and Relationships

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



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

$$PR^2 = PQ^2 + RQ^2$$

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 $\log_{10}$.]

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

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

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

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

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

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