Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

Semester II Examinations, 2005/2006

Exam Code(s) 1BS1, 1BO1, 1CS1, 1EL1, 1ER1, 1EV1, 1PT1

Exam(s) 1st Science

Module Codes EP101

Module(s) Experimental Physics

Paper No. ___________
Repeat Paper ___________ Special Paper ___________

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Instructions: Answer Question 1 (60 marks) and FOUR questions from the remainder (20 marks each). The total marks for the paper are 140.

Use a separate answer book for Question 1.

Duration THREE HOURS
No. of Answer Books ______

Requirements:
Handout Mathematical Tables
Statistical Tables ______
Graph Paper ______
Log Graph Paper ______

No. of Pages 6

Department Experimental Physics

Q.1 Answer **ALL** parts, each question carries 3 marks.

(a) Write down the units for the following quantities: pressure, force, work.

(b) Calculate the force necessary to keep an object of mass 20 kg moving in a circle of radius 8 m with a uniform speed of 6 m s^{-1}.

(c) A uniform metre stick has a 50 g mass suspended from its 10 cm mark. It is balanced horizontally when it is suspended by a string attached at the 35 cm mark. Calculate the mass of the metre stick.

(d) A section of steel rail is exactly 100 m in length when the temperature is 0 ^{O}C. What will be its length when the temperature increases to 35 ^{O}C?

(e) The Hubble space telescope, located at a distance of 598 km from the centre of the Earth, has a mass of 11,110 kg. Calculate the force of attraction exerted by the earth on the telescope.

(f) Calculate how much heat energy is required to increase the temperature of 0.50 kg of water from 20 ^{O}C to 85 ^{O}C, assuming no heat energy is lost to the surroundings.

(g) In a cycle race, a bicycle wheel, of diameter 80 cm, was measured to be rotating at 150 revolutions per minute. Calculate the speed of the cyclist in kilometres per hour.

(h) An iron anchor, of volume 0.5 m^3, is suspended beneath a boat on a lake. Calculate the buoyant force on the anchor.

(i) Calculate the intensity level (in decibels) of a sound wave of intensity 3.2×10^{-6} W m^{-2} relative to a reference level of 10^{-12} W m^{-2}.

(j) A guitar string has a length of 0.60 m and a mass per unit length of 5.0×10^{-3} kg m^{-1}. Calculate the fundamental frequency of vibration of the string when it is under a tension of 230 N.

(k) Calculate the magnitude of the electric field 25 cm from an isolated charge of +3.0 μC.

(l) A rechargeable battery has a rating of 700 mA h, meaning that it can deliver a current of 700 mA to an external circuit for one hour. (i) How much charge flows through the circuit if a current of 700 mA flows for 1.0 hours? (ii) If the potential difference between the terminals of the battery is constant at 1.2 V, how much energy does the battery deliver to the external circuit in this time?

(m) A battery has an electromotive force of 9.0 V. A current of 1.5 A flows when the battery is connected to an external circuit with a resistance of 5.0 Ω. Calculate the internal resistance of the battery.

(n) A transformer has 2000 turns in its primary coil and 100 turns in its secondary coil. If the primary coil is connected to the 220 V a.c. mains, what is the output voltage from the secondary coil?

(o) Calculate the velocity of light in water.

(p) A convex mirror, focal length – 46 cm, is used to form an image of an object placed 66cm in front of the mirror. Find the location and magnification of the image. Specify whether it is real or virtual, and upright or inverted.

(q) A near sighted person has a far point which is 120 cm in front of the eye. Calculate the power (in dioptres) of a spectacle lens, worn 1.5 cm in front of the eye, which would enable the person to focus on the Moon.

(r) The Sun radiates power into space at a rate of 3.8×10^{26} W. Calculate the rate by which it is losing mass, assuming that its size is not altering.

(s) Determine the age of a sample of bog oak, which has an activity of 0.121 Bq per gram of carbon. The half life of C^{14} is 5730 years, and the original activity was 0.23 Bq per gram of carbon.

(t) The work function for a fresh silver surface is 4.73 eV. Calculate the minimum frequency and maximum wavelength for a photon which will eject a photoelectron from the surface. In what part of the spectrum does the photon lie?

Q.2 Sketch the general form of the speed-time graph for motion with uniform acceleration in a straight line. Hence, or otherwise, derive the three formulae connecting initial speed, final speed, distance travelled, acceleration, and time. **[6 marks]**

Explain what is meant by the terms force and kinetic energy and state the units in each case. **[4 marks]**

As it prepares for take-off, an aeroplane (of total mass 6×10^5 kg) is initially moving down the runway at 4.5 m s^{-1}. The pilot pulls the throttle, giving the plane a constant acceleration of 1.8 m s^{-2}. The plane then travels a distance of 1700 m down the runway before lifting off. Calculate the speed of the plane when it lifts off and the time taken from the beginning of the acceleration until it becomes airborne. **[7 marks]**

Calculate the increase in the kinetic energy during the acceleration phase. **[3 marks]**

Q.3 (a) Explain what is meant by (i) the principle of the conservation of momentum, and (ii) inelastic collision. **[3 marks]**

A railway carriage of mass 1800 kg and travelling at 8 m s^{-1}, collides with a second carriage of mass 1500 kg, which is travelling at 2 m s^{-1} in the same direction. After the collision, the carriages are coupled together and move as a unit. Calculate the velocity of this combined unit after the collision. Calculate also how much mechanical energy is lost in the collision. **[7 marks]**

(b) Describe briefly the three mechanisms by which heat energy can be transported. **[3 marks]**

Explain what is meant by the thermal conductivity of a material and the U-Value of an insulating medium. **[3 marks]**

A room is maintained at a temperature of 20 ^{O}C while the outside air temperature is −5 ^{O}C. Calculate the rate at which heat energy flows through a window, which consists of a single pane of glass with a thickness of 4 mm and a total area of 6 m^2. **[4 marks]**

Q.4 State clearly the Universal Gas Law for ideal gases, explaining all the terms used. Indicate briefly the assumptions used in deriving the formula. **[4 marks]**

Describe an experiment to measure the variation with temperature of the pressure (at constant volume) of a fixed mass of gas and show how this leads to the Kelvin scale of temperature. **[5 marks]**

Show how, for situations where the mass of gas does not remain constant, the gas law can be expressed in the form $\rho = C\frac{P}{T}$, where ρ is the density, P is the pressure, T is the Kelvin temperature, and C is a constant for the gas in question. **[4 marks]**

Use this result to calculate how much air will leave a lecture theatre, with a volume of 600 m^3, when the pressure and temperature change from their STP values (101 kPa, 0 ^oC) to the new values of 103 kPa and 25 ^oC. **[5 marks]**

Determine the value of the constant C for nitrogen gas (N_2). **[2 marks]**

Q.5 (a) Define, with the use of appropriate sketches, the terms: wavelength, period, frequency, and amplitude of a sinusoidal wave. **[4 marks]**

(b) Sketch the two lowest-frequency standing wave modes for a cylindrical air-filled tube that is open at one end and closed at the other end. **[2 marks]**

(c) Briefly describe an experiment, using standing waves in a resonance tube, to measure the speed of sound in air at room temperature. **[6 marks]**

(d) A person carries out an experiment in a warm room with a 512 Hz tuning fork and a cylindrical resonance tube of variable length that is closed at one end and open at the other end. The tube is filled with air at room temperature. The two shortest lengths that they find resonance for are 18.0 cm and 52.0 cm.
(i) Calculate the wavelength of the sound waves in the tube. **[2 marks]**
(ii) Calculate the speed of sound in air at room temperature. **[2 marks]**
(iii) Explain what change would occur to the resonance lengths if room temperature decreased. **[4 marks]**

Q.6 (a) Write down an expression for the magnetic force acting on a current-carrying wire in a magnetic field, clearly stating what each of the terms in the expression represent. Draw a careful sketch showing the direction of the magnetic force for a case where the current is perpendicular to the magnetic field. **[3 marks]**

(b) With the aid of an appropriate diagram, explain the principle behind the operation of a moving coil galvanometer. **[7 marks]**

(c) Show, including circuit diagrams and values of resistances used, how a moving coil galvanometer with an internal resistance of 50 Ω and a full scale deflection of 0.10 mA may be used to make:
(i) an ammeter with a full scale deflection of 5.0 A. **[5 marks]**
(ii) a voltmeter with a full scale deflection of 10 V. **[5 marks]**

Q.7 (a) Describe Thomas Young's experiment, and explain why this was considered a crucial test of the wave nature of light. **[4 marks]**

Two slits, 0.25 mm apart, are illuminated coherently by monochromatic light. Fringes separated by 0.88 mm are observed on a screen, which is 40 cm from the slits. What is the wavelength of the light used? **[6 marks]**

(b) In relation to light waves, explain briefly what is meant by random and linear polarisation, and briefly describe two methods to produce a linearly polarised light beam. **[4 marks]**

Sunlight, with an intensity of 1250 W m^{-2}, is passed through two linear polarising filters whose transmission axes are at an angle of 50^{O} to each other. What is the intensity of the transmitted sunlight? **[6 marks]**

Q.8 Discuss briefly why some atomic nuclei are unstable and are subject to different types of radioactive decay. **[4 marks]**

Explain what is meant by nuclear binding energy, and sketch the form of the curve showing binding energy per nucleon as a function of atomic number, labelling the important features of the curve. **[6 marks]**

Write down, explaining the meaning of the symbols used, the relationship between the half life and the decay constant of a radioactive nuclide. **[4 marks]**

Calculate the number of atoms in a 100 μg sample of ^{131}I, and hence calculate the activity of the sample, in Becquerels, given that it has a half life of 8 days. **[6 marks]**

PHYSICAL CONSTANTS and DATA

Absolute zero of temperature, 0 K		=	–273 ºC
Acceleration due to gravity, g		=	9.81 m s^{-2}
Atomic mass unit, 1 u		=	1.6606 x 10^{-27} kg
Atomic mass of copper		=	63.54 kg $kmol^{-1}$
Avogadro's number, N_A		=	6.02 x 10^{26} $kmol^{-1}$, 6.02 x 10^{23} mol^{-1}
Boiling point of nitrogen		=	77 K
Boltzmann's constant, k		=	1.38 x 10^{-23} J K^{-1}
Coefficients of linear thermal expansion of	brass	=	18 x 10^{-6} K^{-1}
	steel	=	12 x 10^{-6} K^{-1}
Density of air at STP (0 ºC, 1 atm)		=	1.28 kg m^{-3}
Densities of	copper	=	8960 kg m^{-3}
	lead	=	11350 kg m^{-3}
	mercury	=	13600 kg m^{-3}
	steel	=	7800 kg m^{-3}
	water	=	1000 kg m^{-3}
Distance (mean) Earth to Sun		=	1.5 x 10^{11} m
Distance (mean) Earth to Moon		=	3.84 x 10^{8} m
Electron volt, 1 eV		=	1.60 x 10^{-19} J
Electronic charge, e		=	1.60 x 10^{-19} C
Gas constant, R		=	8314 J K^{-1} $kmol^{-1}$, 8.314 J K^{-1} mol^{-1}
Gravitational constant, G		=	6.67 x 10^{-11} N m^2 kg^{-2}
Mass of the electron, m_e		=	9.1 x 10^{-31} kg
Mass of the neutron, m_n		=	1.6749 x 10^{-27} kg
Mass of the proton, m_p		=	1.6726 x 10^{-27} kg
Mass of the Earth		=	5.98 x 10^{24} kg
Mass of the Moon		=	7.35 x 10^{22} kg
Mass of the Sun		=	2.0 x 10^{30} kg
Melting points of	lead	=	328 ºC
	mercury	=	–39 ºC
Permeability of vacuum, μ_o		=	4π x 10^{-7} H m^{-1}
Permittivity of vacuum, ε_o		=	8.85 x 10^{-12} F m^{-1}
$k = 1/(4\pi\varepsilon_o)$		=	9 x 10^{9} N m^2 C^{-2}
Planck's constant, h		=	6.63 x 10^{-34} J s
Radius of the Earth		=	6.4 x 10^{6} m
Radius of the Moon		=	1.74 x 10^{6} m
Radius of the Sun		=	7 x 10^{8} m
Refractive indices of	glass	=	1.50
	water	=	1.33
Resistivity of nichrome		=	1.0 x 10^{-6} Ω m
Specific heat capacity of	copper	=	389 J kg^{-1} K^{-1}
	lead	=	125 J kg^{-1} K^{-1}
	mercury	=	140 J kg^{-1} K^{-1}
	water	=	4180 J kg^{-1} K^{-1}
	ice	=	2092 J kg^{-1} K^{-1}
Specific latent heats of fusion of	lead	=	21 x 10^{3} J kg^{-1}
	water	=	335 x 10^{3} J kg^{-1}
Specific latent heats of evaporation of	nitrogen	=	2 x 10^{5} J kg^{-1}
	water	=	2.26 x 10^{6} J kg^{-1}
Speed of light in vacuum, c		=	3 x 10^{8} m s^{-1}
Speed of sound in air (15 ºC)		=	340 m s^{-1}
Standard atmospheric pressure		=	1.01 x 10^{5} Pa
Thermal conductivities of	glass	=	0.9 W m^{-1} K^{-1}
	copper	=	398 W m^{-1} K^{-1}
Young's modulus for steel		=	2.1 x 10^{11} N m^{-2}