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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SUMMER EXAMINATIONS 2000

FIRST YEAR EXAMINATION IN
ENGINEERING AND
INFORMATION TECHNOLOGY

Experimental Physics EP101

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Time allowed : THREE hours.

Answer Question 1 and FOUR questions from the remainder. 50% of the marks for the paper are for Question 1, and the remaining 50% for the other four questions.

Use a separate answer book for Question 1

Numerical values of the required physical constants and relavant data are given at the end of the paper .

Q.1 Answer all parts (each part carries **one** mark)

(a) Which of the following are vectors and which scalars: Displacement, pressure, power, temperature, electric field strength, electric potential.

(b) Which of the following are written to three significant figures: 0.001, 1.230×10^{-2}, -0.0740, 3.78×10^{4}, and 0.87 ?

(c) A boat which can travel at 4 m s^{-1} in still water is headed directly across a river, 100 m wide, which is flowing at 3 m s^{-1}. When it reaches the other side of the river, how far downstream from its starting point is it?

(d) Convert (i) 1 litre (10^{3} cm^{3}) and (ii) 13.6 g cm^{-3} to SI units.

(e) Calculate the acceleration the Earth experiences due to the gravitational attraction of the Sun.

(f) A 4 kg rifle fires a 10 g bullet with a velocity of 800 m s^{-1}. Calculate the recoil velocity of the rifle.

(g) A 1 kg mass stretches a spring by 2.5 cm. The mass is pulled beyond its equilibrium point and oscillates. Determine the angular frequency of oscillation.

(h) A block of mass 2 kg slides a distance of 5 m down an inclined plane at an angle of 25°. The final speed is 5 m s^{-1}. How much energy is lost due to friction?

(i) How tall would a barometer, filled with copper sulphate solution of relative density 1.2, have to be in order to register a pressure of 1 atmosphere?

(j) A simple pendulum has length equal to 83 cm. What is the frequency of oscillation?

(k) A uniform metre stick of mass 25 g is suspended at the 30 cm mark. From where on the metre stick should we suspend a 40 g mass to keep the metre stick horizontal?

(l) Convert the pressure corresponding to 75.8 cm Hg to SI units.

(m) The temperature and pressure of the air in a balloon change from 22°C and 1 atm to 345 K and 5×10^5 Pa. What is the ratio of the final to the initial volume?

(n) When a piece of wood of volume 100 cm^3 is floated in a container, which had been filled to the brim with water, it caused 80 g of water to overflow. Calculate the density of the wood.

(o) A 2 kW heater is submerged in 1 kg of water at 20 °C. How long does it take for the water to reach the boiling point?

(p) 10 kJ of heat energy is added to 40 g of ice at 0°C. What is the final temperature of the ice/water

(q) A compact disc rotates at 500 revolutions per minute. Calculate the angular speed in $rad.s^{-1}$.

(r) For the wave $y(x,t) = 5 \sin (1.57x - 20t)$ where x and y are in metres and t in seconds what are: the amplitude, the wavelength, the frequency (f), and the speed of the wave?

(s) Calculate the location and size of the image of an object of height 3 cm placed on the axis of a concave mirror 20 cm in front of the mirror. The focal length of the mirror is 15 cm.

(t) What is the electrostatic force between a singly ionised calcium ion and an electron if the distance between them is 3.4 nm?

(u) An electron initially at rest is accelerated by the potential difference provided by two AA batteries (each of potential 1.5 V). What is the final speed of the electron?

(v) In order to store the most energy, should two identical capacitors of capacitance C be connected in parallel or in series across a potential V?

(w) Calculate the resistance of the piece of wire in a 100 W light bulb (the RMS mains voltage is 230 V).

(x) What is the time constant of a circuit consisting of a 2 μF capacitor in series with a 500 Ω resistor?

(y) A photocopier uses a convex lens to form an image of a sheet of paper. If the paper is placed 7.1 cm from the lens, how far from the lens must the image be formed if we want a magnification of 141%?

(z) When the light from a He-Ne laser (λ = 633 nm) is incident normally on a diffraction grating, the second order maximum is observed at an angle of 49.4 degrees from the straight through direction. Calculate the separation of the slits in the grating.

(A) Starting with 1.6 moles of a radioactive material, the half life of which is 2.6 years, how long does it take for 1.2 moles of the material to decay?

(B) An X-ray machine produces X-rays with minimum wavelength of 2.1×10^{-11} m. What is the voltage of the X-ray machine?

(C) How many protons, electrons and neutrons are there in a neutral atom of $^{57}Fe_{26}$?

(D) What is the energy in eV of a photon of green light of wavelength 500 nm.

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. Sketch also the distance-time graph in the special case where the initial speed is zero.

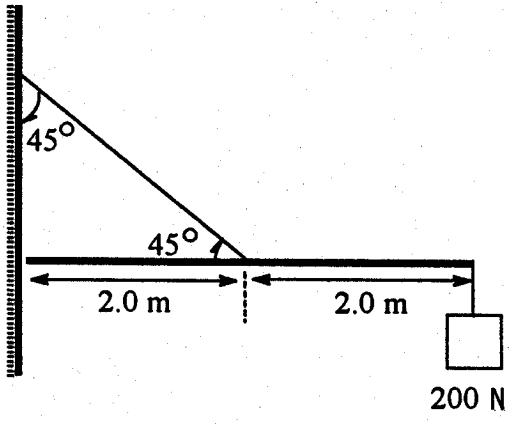
A stone is thrown vertically upwards with an initial speed of 29.4 m s^{-1} from the top of a tower 34.3 m high. Find the time taken to reach the maximum height and the total time which elapses before the stone hits the ground.

Make a rough plot of the velocity of the stone as a function of time.

Q. 3 Define the terms weight, coefficient of friction, torque, principle of moments.

State the conditions for a solid object to be in static equilibrium

A beam is supported as shown by a cable attached to the midpoint of the beam and to the wall. Find the vertical and horizontal components of the force exerted by the wall on the beam. The weight of the bar is 300 N.



Q. 4 Answer each of the following

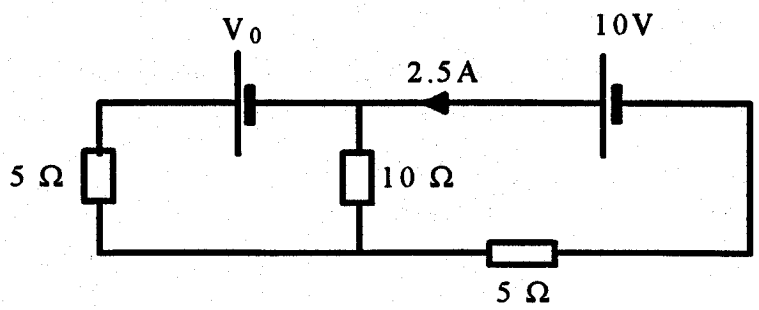
(a) Define the terms *strain, Young's modulus of rigidity, coefficient of linear expansion.* Calculate the force required to stretch a steel specimen 3 m long and 1.5 mm diameter by the same amount as it would expand due to a rise in temperature of 50 °C.

(b) Explain, in relation to sound waves, the terms *standing wave, Doppler shift, resonance.* An organ pipe, closed at one end, is 60 cm long. A sound source of variable frequency is placed at the open end and the frequency is varied from 50 Hz to 500 Hz. At what frequencies will the organ pipe resonate ?

Q.5 Answer each of the following

(a) State Kirchhoff's rules for the analysis of electrical circuits.

Find the value of the unknown voltage V_0 in the circuit shown below.



(b) Explain what is meant by the EMF and internal resistance of a cell.

A cell is connected in series with an ammeter (of negligible resistance) and a 4 Ω resistor. The ammeter reads 0.6 A. When an additional 4 Ω resistance is added in series, the current falls to 0.36 A. Calculate the EMF and internal resistance of the cell.

Q.6. State Snell's Laws for the refraction of light between two optical media of refractive indices n_1 and n_2.

Describe what is meant by total internal refraction and derive the equation for the critical angle of incidence between two optical media. Explain clearly, on a diagram, which medium has the greater refractive index. Describe one application of total internal reflection.

A narrow beam from a laser pointer enters a cubical glass block (measuring 10 cm on an edge) at the centre of a face and at an angle of incidence of 75 degrees. The plane of incidence is parallel to an edge of that face. Calculate, and show on a diagram, the exact path of the light beam through the block.

Q. 7 Explain what is meant by (I) the impedance of a capacitor, (ii) the coefficient of self-inductance L of an inductor, (iii) the resonant frequency of an LC circuit.

A series LCR circuit, with C = 1.5 μF, l = 0.1 H, and R = 20Ω, is connected to an AC source (frequency = 400 Hz), and the resulting peak current is 2.05 A. Calculate

(a) the reactances of L and C at 400 Hz,

(b) the total AC impedance of the circuit at 400 Hz,

(c) the peak voltage of the AC source, and

(d) the resonant frequency of the circuit.

Q.8 Explain what is meant by the photo-electric effect, and write down Einstein's equation for the phenomenon, explaining clearly all the terms in the equation.

Describe Millikan's experiment to study the photo-electric effect and explain how a value of Planck's constant h can be found from these measurements.

Explain the operation of the photomultiplier tube for the detection of light.

PHYSICAL CONSTANTS and DATA

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