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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SPRING EXAMINATION 1998

Jm0010

FIRST YEAR EXAMINATION IN MEDICINE

Experimental Physics

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Time allowed : Three hours.

Answer question 1 (35 marks) and THREE questions from the remainder. **There are SEVEN questions in total in this paper.** The total marks for the paper are 70.

Use a separate answer book for Question 1

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

Q.1 Answer all parts.

(a) What are the SI units of acceleration, force and momentum ?

(b) Express 0.000 240 m in terms of μm (microns)

(c) Convert a speed of 60 mph to units of m s^{-1} (1 mile = 1609 m)

(d) How long would it take light to reach the moon from the earth ?

(e) A car at rest accelerates at a rate of 2 m s^{-2} for a time of 4 s. How far will it have travelled in this time ?

(f) An object moves in a circular path of radius 40 cm at a constant speed of 20 m s^{-1}. What is its centripetal acceleration ?

(g) A 70 kg man runs up stairs (3 m high) in a time of 2 s. How much work is done and what is his power during the ascent ?

(h) If electricity costs 8 p per kWh, how much does it cost to run a 100 W light bulb for 24 hours?

(i) Bone has a compressional strength of 1.7×10^8 N m^{-2}. How much force could be applied to the femur, diameter 2.8 cm, before fracture would occur ?

(j) Normal body temperature is 98.6 ^{0}F. Calculate what this is on the Celsius scale.

(k) If a steel bridge of length 1280 m goes from a temperature of -12 ^{0}C to 38 ^{0}C, what would be the increase in its length ?

(l) A spherical balloon of radius 50 cm and filled with air is submerged in water in order to raise a submerged object. What is the upthrust produced ? (Ignore the weight of air).

(m) What is the total pressure acting on a diver at a depth of 5 m ? (atm. pressure = 1.013×10^5 N m^{-2})

(n) Calculate the heat required to convert 4.5 kg of ice at 0 ^{0}C to water at 0 ^{0}C

(o) What is the force between two electrons separated by a distance of 5 nm ?

(p) Calculate the electric field strength and indicate the direction of the field at a distance of 10 cm from a charge of + 2 C.

(q) Indicate the direction of the field at a point along a line that bisects perpendicularly the line joining the two charges of a dipole.

(r) What is the energy stored in a capacitor of 1 μF charged to a voltage of 200 V ?

(s) A defibrillator is designed to deliver 500 J through a capacitor at a voltage of 400 V. What is the value of the capacitance inside the defibrillator ?

(t) The defibrillator of part (s) above discharges through a skin resistance of 10 Ω. How long does the discharge last ?

(u) What is the initial value of the current which flows through the electrodes in the defibrillator described in parts (s) and (t) ?

(v) A long straight wire, carrying a current I, is placed in a magnetic field of strength B. What is the magnitude and direction of the force acting on the wire ? Illustrate your answer with a sketch.

(w) A laser has a wavelength of 600 nm (600×10^{-9} m). What is the frequency of the laser light in Hz ?

(x) An organ pipe has one open and one closed end. Sketch the fundamental and the first three harmonic standing waves in the pipe.

(y) What is the ratio in sound intensity between a sound of 50 dB(A) and 60 dB(A) ?

(z) Light is incident from air onto glass (n = 1.4). What is the angle of incidence where all the light will be reflected from the glass ?

(A) An object is placed 50 cm away from a single lens with a focal length of 25 cm. Where is the image located and what is the magnification of the object ?

(B) Sketch a schematic diagram of a helium atom. Give an indication of scale on your figure.

(C) What are the different characteristics of α, β and γ radiation ?

(D) Light of a wavelength of 400 nm is incident on a metal surface with a work function of 2.3 eV. What is the maximum energy of the photo-electrons being emitted ?

Q.2 State the conditions necessary for the equilibrium of a rigid body.

The upper arm is held vertically by the side of the body while the lower arm is held horizontally. The lower arm has a weight of 12 N and its centre of gravity is at a distance of 15 cm from the elbow pivot. The main tendon from the biceps acts vertically upward from a position 5 cm from the elbow pivot. Calculate the tensional force in the tendon and the reactional force of the elbow pivot.

Now repeat the calculation with a mass of 5 kg placed in the hand at a distance of 35 cm from the elbow.

Q.3 Describe what is meant by heat convection and heat radiation. Include in your answer a description of black body radiation and the greenhouse effect.

A cabin wall is made of wood 5 cm thick and has an area of 12 m^2. If the outside temperature of the wall is 0 ^{0}C and the inside surface is at 20 ^{0}C, at what rate is heat lost through the wall? (Thermal conductivity of wood = 0.08 W m^{-1} K^{-1}).

Q.4 Describe, using diagrams, the following;

(a) The sphygmomanometer.
(b) Ballistocardiography.
(c) The forces on the spinal column when lifting a weight in the bent position.

Q.5 Answer **all** parts

(a) Describe the mechanism of generation of the action potential in nerve conduction. Indicate relative sizes of the potential differences involved.
(b) How do nerves indicate the strength of a stimulus.
(c) Describe, in physical terms, how demyelination affects the conduction of action potentials.

Q.6 Answer **all** parts

(a) Outline a number of measures that are taken to prevent the risk of electric shock from electrical equipment.
(b) Indicate the effects on the human body of an increasing electric current passing through it.
(c) What measures can you, as a medical person, take to minimize the risk to the patient of receiving an electric shock ?

Q.7 Describe, using diagrams where appropriate, the operation of

(a) a spectacle lens
(b) a flexible endoscope
(c) the human ear.

PHYSICAL CONSTANTS and DATA

Absolute zero of temperature, 0 K		=	-273 °C
Acceleration due to gravity, g		=	9.81 m s^{-2}
Atomic mass unit, 1 u		=	1.6606×10^{-27} kg
Atomic mass of copper		=	63.54 kg $kmol^{-1}$
Avogadro's number, N_A		=	6.02×10^{26} $kmol^{-1}$, 6.02×10^{23} mol^{-1}
Boiling point of nitrogen		=	77 K
Boltzmann's constant, k		=	1.38×10^{-23} J K^{-1}
Coefficients of linear thermal expansion of	brass	=	18×10^{-6} K^{-1}
	copper	=	17×10^{-6} K^{-1}
	steel	=	12×10^{-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		=	1.5×10^{11} m
Distance (mean) Earth to Moon		=	3.84×10^{8} m
Electron volt, 1 eV		=	1.60×10^{-19} J
Electronic charge, e		=	1.60×10^{-19} C
Gas constant, R		=	8314 J K^{-1} $kmol^{-1}$, 8.314 J K^{-1} mol^{-1}
Gravitational constant, G		=	6.67×10^{-11} N m^2 kg^{-2}
Mass of the electron, m_e		=	9.1×10^{-31} kg
Mass of the neutron, m_n		=	1.6749×10^{-27} kg
Mass of the proton, m_p		=	1.6726×10^{-27} kg
Mass of the Earth		=	5.98×10^{24} kg
Mass of the Moon		=	7.35×10^{22} kg
Mass of the Sun		=	2.0×10^{30} kg
Melting points of	lead	=	328 °C
	mercury	=	–39 °C
Permeability of vacuum, μ_o		=	$4\pi \times 10^{-7}$ H m^{-1}
Permittivity of vacuum, ε_o		=	8.85×10^{-12} F m^{-1}
$1/(4\pi\varepsilon_o)$		=	9×10^{9} N m^2 C^{-2}
Planck's constant, h		=	6.63×10^{-34} J s
Radius of the Earth		=	6.4×10^{6} m
Radius of the Moon		=	1.74×10^{6} m
Radius of the Sun		=	7×10^{8} m
Refractive indices of	glass	=	1.50
	water	=	1.33
Resistivity of nichrome		=	1.0×10^{-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	=	21×10^{3} J kg^{-1}
	water	=	335×10^{3} J kg^{-1}
Specific latent heats of evaporation of	nitrogen	=	2×10^{5} J kg^{-1}
	water	=	2.26×10^{6} J kg^{-1}
Speed of light in vacuum, c		=	3×10^{8} m s^{-1}
Speed of sound in air (15 °C)		=	340 m s^{-1}
Standard atmospheric pressure		=	1.01×10^{5} Pa
Thermal conductivities of	iron	=	81 W m^{-1} K^{-1}
	copper	=	398 W m^{-1} K^{-1}
Young's modulus for steel		=	2.1×10^{11} N m^{-2}