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NATIONAL UNIVERSITY OF IRELAND
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SEMESTER I (WINTER) EXAMINATIONS 2000-2001

Second Science Examination
Experimental Physics - (EP 211, 212)

Experimental Physics

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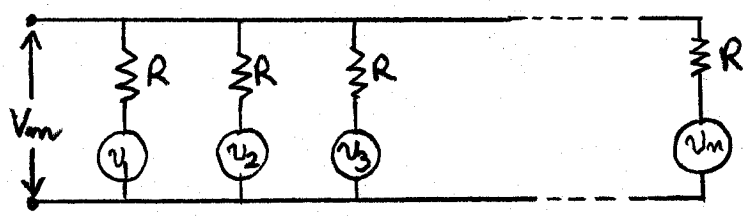
Time allowed : THREE hours.
Answer FIVE questions at least TWO from each section.
Use separate answer books for each section.

SECTION A

Q.1 State the superposition principle as used in circuit analysis. For the circuit below use the superposition principle to find the voltage V_m produced by the array of n voltage sources and equal resistances. What function is performed by this circuit?

Design an operational amplifier circuit which will perform the same function.



Q.2 Derive the differential equation (governing equation) for the current i in a series LCR circuit. From this equation obtain the characteristic equation and derive the equations for the roots s_1 and s_2. Give the condition, the relationship between R, L and C, for the roots to be real and distinct and verify that the problem below satisfies this condition.

Continued.....

A series LCR circuit has values of L = 1 H, R = 4 Ω and C = 1/3 F. If the capacitor is given an initial charge of 10 V derive the equation for how the current changes with time. Sketch the graph of this equation.

Q.3 Draw the circuit for a simple half wave rectified power supply with capacitive smoothing and connected to a load resistance of R_L. Sketch the waveforms for the transformer secondary voltage, the transformer secondary current and the output voltage.

Derive the equation for the percentage ripple if the frequency is f. List ways in which the ripple can be reduced.

Q.4 Using Coulomb's Law derive the expression for the electric field at a distance y from an infinitely long line of charge of linear charge density λ C m^{-1}. Now state Gauss's Law and use it to derive the same relationship.

An electron is placed at a distance of 2 cm from a long line of charge density 5 nCm^{-1}. Calculate the acceleration of the electron.

(Constants: Mass of electron = 9.11 x 10^{-31} kg, permittivity constant ε_0 = 8.85 x 10^{-12} Fm^{-1}, magnitude of electron charge e = 1.60 x 10^{-19} C).

SECTION B

Q.5 Answer *All* parts:

(a) A projectile is launched with initial speed v_0 at an angle ϕ with respect to the horizontal. Show that the horizontal range of the projectile is given by

$$R = \frac{v_0^2}{g}\sin 2\phi$$

Use the fact that $2\sin\phi\cos\phi = \sin 2\phi$ and ignore air resistance.

(b) Using the result of part (a) find the launch angle if $v_0 = 40ms^{-1}$ and $R = 141.2m$.

(c) Distinguish between an inertial and a non-inertial frame of reference. Give one example of each.

(d) A plane moves with an air speed of 480 $hour^{-1}$. The pilot sets out for a destination 810 km to the north but discovers that the plane must be headed 21° east of north to fly there directly. The plane arrives in 1.9 hours. What was the vector wind velocity ?

Q.6 Answer *All* parts:

(a) What is meant by the potential energy of a system ? Potential energy can only be defined for what kind of force ?

(b) Write down an equation which describes conservation of energy for a system of particles. Define each term in the equation.

(c) A stone is dropped from rest 2.2 m above the ground. Using conservation of energy find the speed of the stone when it is at a height of 1.1 m. Ignore frictional drag.

(d) A stone of weight w is thrown vertically upward into the air with an initial speed v_0. Air drag force f dissipates an amount fy of mechanical energy as the stone travels a distance y. Show that

(i) the maximum height reached by the stone is

$$h = \frac{v_0^2}{2g(1+\frac{f}{w})}$$

(ii) the speed of the stone just before impact with the ground is

$$v = v_0\left(\frac{w-f}{w+f}\right)^{1/2}$$

Q.7 Answer *All* parts:

(a) An ambulance siren emits a sound at frequency f_0. You measure the frequency to be $f > f_0$. What is the motion of the ambulance relative to you ? Justify your answer using basic physics (not the Doppler equation).

(b) You are given four tuning forks. The fork with the lowest frequency vibrates at 500 Hz. By using two tuning forks at a time, the following beat frequencies are heard: 1, 2, 3, 5, 7, and 8 Hz. What are the possible frequencies of the other three tuning forks ?

(c) Define *sound intensity level (SL)*. If two sounds differ in SL by 3 dB what is the ratio of their intensities ? Write down the SL and intensities for sounds at the thresholds of human hearing and pain.

(d) You are standing at a distance D from an isotropic source of sound waves. You walk 51.4 m toward the source and observe that the sound intensity level of these waves has increased by 3 dB. Calculate the distance D.

Q.8 Answer *All* parts:

(a) Define moment inertia of an object. A cylinder of radius R, mass M, and moment of inertia I_C rolls without slipping at linear speed v. Determine the ratio of the rotational kinetic energy about its central axis to the translational kinetic energy of the cylinder given that $I_C = \frac{1}{2}MR^2$, about the centre of mass.

(b) A sphere, a cylinder, and a hoop, each of mass M, roll without slipping down the same incline. Which will get to the bottom first and which last ? Justify your answer with physical arguments. Moments of inertia, about the centre of mass, a sphere, cylinder and hoop each of mass M and radius R are:

$$I_S = \frac{2}{5}MR^2,\ I_C = \frac{1}{2}MR^2;\ \text{and}\ I_H = MR^2$$

(c) The length of the day (T) is increasing at the rate $\frac{dT}{dt}$ of about 2 ms/century. This is primarily due to frictional forces generated by movement of water in the world's shallow seas as a response to the tidal forces exerted by the Sun and Moon.

(i) What is the angular acceleration $\frac{d\omega}{dt}$ of the Earth ?

(ii) At what rate $\frac{dK_{rot}}{dt}$ is the Earth losing rotational kinetic energy (K_{rot})?

(iii) What is the magnitude of the tangential force, at latitudes 60° N and 60° S, applied by the seas on the seabed ?

$M_{Earth} = 5.98 \times 10^{24}$ kg.

Consider the Earth as a sphere of radius $R_{Earth} = 6.37 \times 10^6$ m.

[HINT: tangential acceleration is given by: $\vec{a}_T = \vec{\alpha} \times \vec{R}$]