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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER I EXAMINATIONS 2002 -2003

Second Science Examination
Experimental Physics - (EP211, EP212)

Experimental Physics

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Time allowed: THREE hours.
Answer FIVE questions, at least TWO from each section.

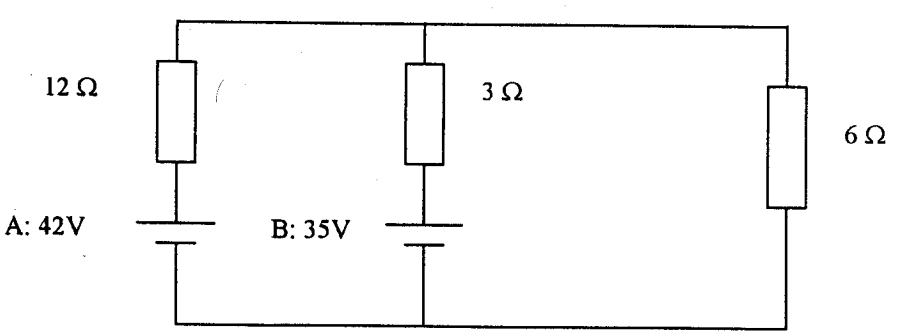
Use separate answer books for each section.

SECTION A

Q.1 State the Superposition Principle as used in circuit analysis. [2 marks] In using this principle, state clearly what are meant by removing a current source and removing a voltage source. [1 mark]

Two batteries A [emf = 42 V] and B [emf = 35 V], of internal resistance 12 ohm and 3 ohm respectively, are connected in parallel across a 6 ohm load resistance as shown below. Using superposition, calculate the current in this load resistor. [5 marks]

Using this result, now calculate the current provided to the load by each battery. [2 marks]



Q.2 Outline the properties of an ideal differential operational amplifier. [1 mark]

State the two summing point constraints applied to the non-inverting input of an operational amplifier when using negative feedback. [2 marks]

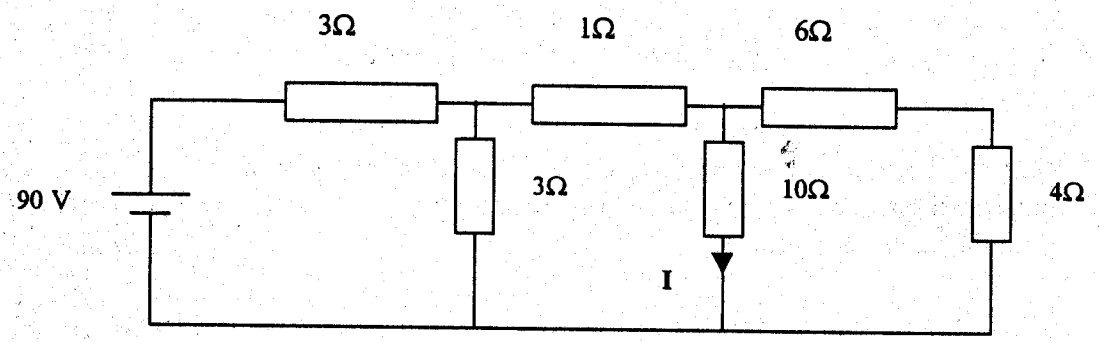
Using the summing point constraints, derive the equations relating output voltage to input voltage for an operational amplifier configured as:
(a) an integrator [1.5 marks]
(b) a differentiator. [1.5 marks]

An operational amplifier integrator, employing a resistor of 5 kΩ and a capacitor of 1 μF, has an input voltage given by v = 10 Sin (500t) Volts. Calculate the expression for the output signal. [2 marks]

Sketch the waveforms of the input and the output voltages. [2 marks]

Q.3. Derive the equations for a current divider circuit and for a voltage divider circuit. [2,2 marks]

Using network reduction techniques and the current divider equation, calculate the current I in the circuit shown below. [6 marks]



Q.4 Define what is meant by an electric field and give two equivalent SI units used in its measurement. [2, 0.5, 0.5 marks]

Derive an expression for the electric field produced by an electric dipole at a distance r along the perpendicular to the line joining the two charges. Show clearly the direction of the electric field. [7 marks]

SECTION B

Q.5 A jet of water flows at a speed of 40 ms^{-1}, and at an angle of 60° with respect to the horizontal, from a hosepipe resting on the ground. Find:

(a) the time taken for the water to reach maximum height
(b) the maximum height reached by the water
(c) the horizontal distance travelled by the water before it hits the ground
(d) the time taken for the water to hit the ground
(e) the speed of the water when it hits the ground [7 marks]

An airport terminal has a moving sidewalk, to speed passengers through a long corridor. Peter walks through the corridor, but not on the sidewalk, and covers the distance in 150s. Paul stands on the moving sidewalk, but does not walk, and takes 70s to reach the end. Mary not only uses the sidewalk, but walks on it. Assuming that Peter and Mary walk at the same speed, calculate how long it takes Mary to reach the end of the corridor. [3 marks]

Q.6 State the Work-Energy Theorem and the Impulse-Momentum Theorem. Which theorem is represented by a vector equation? [3 marks]

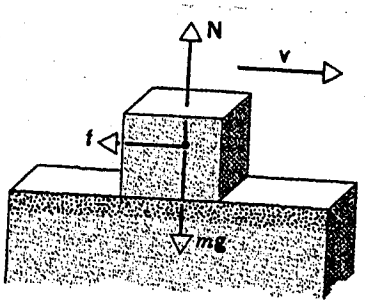
For a two-particle system, with mass m_1 at position x_1, and mass m_2 at position x_2, write down an expression for the position of the centre of mass of the system. [1 marks]

By what fraction is the kinetic energy of a neutron (mass m_1) decreased in a head-on collision with an atomic nucleus (mass m_2) initially at rest? Find the fractional decrease in the kinetic energy of the neutron when it collides in this way with a lead nucleus, a carbon nucleus and a hydrogen nucleus (assume that the ratio of nuclear mass to neutron mass is 206 for lead, 12 for carbon and 1 for hydrogen). [6 marks]

Q.7 Give an example of an inertial reference frame and a non-inertial reference frame. [2 marks]

Explain what are meant by the terms (a) inertial mass, (b) coefficient of static friction. [2 marks]

In the figure below, the block undergoes a displacement in the direction indicated by the velocity vector **v**. With reference to the laws of vector multiplication, identify which of the forces shown is doing work (**N** is the normal force, **mg** is the gravitational force and **f** is the frictional force). [2 marks]

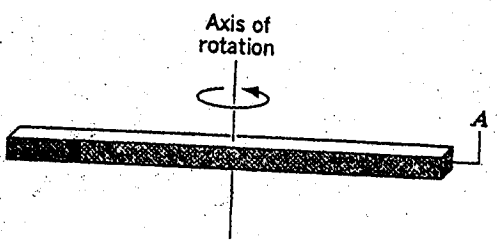


A 136 kg crate is at rest on a floor. A man attempts to push it across the floor by applying a horizontal force of 412 N. Show that the crate does not move if the coefficient of static friction between the crate and the floor is 0.37. If a second man helps by pulling upwards on the crate what minimum vertical force must he apply so that the crate starts to move across the floor? [4 marks]

Q.8 Write down the equations for rotational motion with constant angular acceleration, and write down the rotational analogue for Newton's second law. [3 marks]

Show that the moment of inertia I of a thin rod of cross-sectional area A and length L, rotated about an axis through it centre (see figure), is given as

$$I = \frac{1}{12} ML^2$$



where M is the total mass of the rod. [5 marks]

The flywheel of an engine is rotating at 25.5 rad s^{-1}. When the engine is turned off, the flywheel decelerates at a constant rate and comes to rest after 19.7 s. Calculate the angular acceleration of the flywheel (in rad s^{-2}) and calculate the angle (in rad) through which the flywheel rotates in coming to rest. [2 marks]