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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER II (SUMMER) EXAMINATION 2001

FIRST SCIENCE EXAMINATION

Experimental Physics

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Time allowed: THREE hours.

Answer Question 1 (30 marks) and FOUR questions from the remainder (10 marks each). 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. [1 mark per question]

(a) Express a speed of 20 m s^{-1} in miles per hour.
(1 mile = 1760 yards, 1 inch = 2.54 cm)

(b) An object is thrown vertically upwards from the surface of the Earth. It reaches a maximum height, then falls back down again. Sketch on a graph how the velocity varies with time, from the time that the object is thrown until it reached the surface again (Numerical values are not required)

(c) A stone is fired vertically upwards and reaches a height of 7 m before falling back. What was the initial velocity of the stone?

(d) A swimmer can swim at a speed of 1 m s^{-1} relative to the water. What is the shortest time for this swimmer to go from one bank of a river to the other bank, if the river is 100 m in width and the river water flows at a rate of 1 m s^{-1} relative to the bank?

(e) A uniform metre stick hangs in a horizontal fashion when suspended from the 35 cm mark if a 100 g mass is suspended from the 5 cm mark. What is the mass of the metre stick?

(f) A simple mass-on-a-string pendulum has a period of 1 s. If the length of the string is doubled, what is the new period?

(g) A 100 cm^3 block of ice (mass density 917 kg m^{-3}) floats in a vessel of water (mass density 1000 kg m^{-3}). What volume of ice is above the level of the water?

(h) In question (g), if the level of the water fills the containing vessel to the brim, what volume of water, if any, will spill from the vessel when the ice melts?

(i) What is the temperature on the Fahrenheit scale when the temperature on the Celsius scale reads 20°?

(j) A steel wire 2 m in length and with a cross-sectional area of 2 mm^2 is used to suspend an object of mass 50 kg from the ceiling. Calculate the increase in the length of the wire when the object is suspended from it.

(k) A train is sounding a whistle at 1 kHz. Calculate the change in the frequency of the whistle observed by a passenger standing on a station platform as the train passes through at 50 m s^{-1}.

(l) Calculate the electrostatic force between two electrons which are separated by 1.0 mm. Is the force attractive or repulsive?

(m) A 220 Ohm resistor is rated to dissipate a maximum of 0.25 W. What is the maximum voltage and current that the resistor can carry?

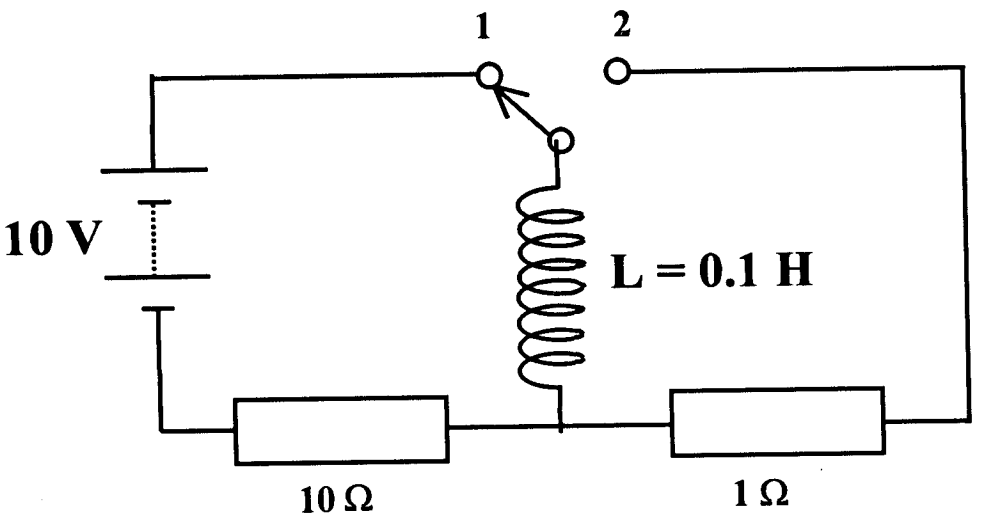
(n) What is the resistance of a electric kettle element working at 220 V rms in which 0.5 kg of water is heated from 20 °C to 100 °C in 3 minutes?

(o) Calculate the velocity of a proton which has been accelerated through an electric field of 10 kV.

(p) Calculate the force per unit length acting between two long straight, parallel, wires which are 1.0 cm apart and each carrying a current of 1.0 A, in the same direction.

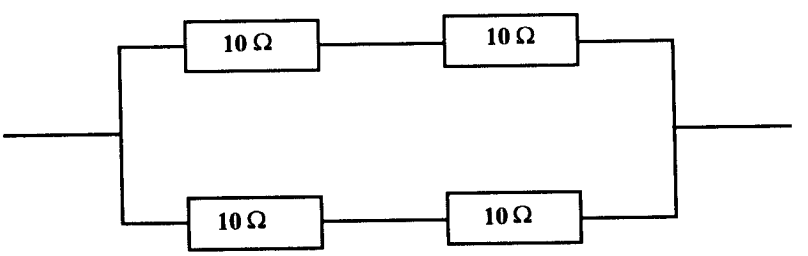
(q) Calculate the total current drawn by a 1 kW kettle, a 700 W electric iron, and a 500 W electric toaster simultaneously connected to the 220 V rms A.C. mains supply.

(r) In the circuit shown, the switch is changed from position 1 to position 2 so that current in the inductor now flows through the 1 Ω resistor. The inductor has negligible resistance. Calculate the time for the current in the inductor to fall to 0.37 A.



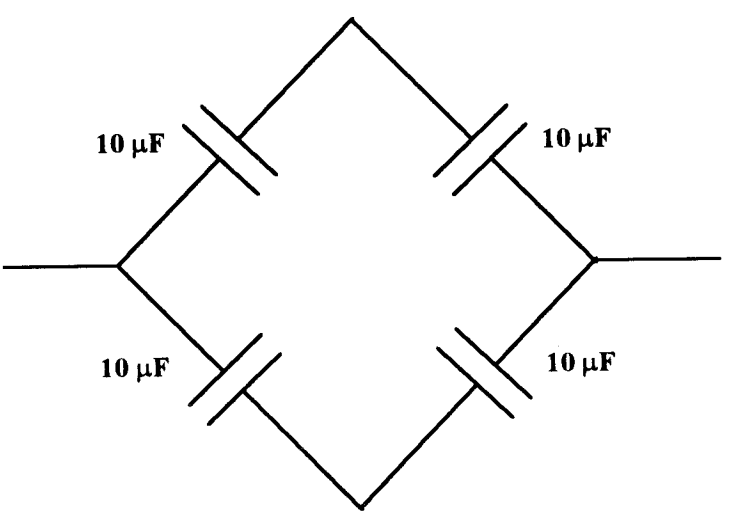
(s) The effective resistance of the circuit given below is.

(a) 1 Ω
(b) 5 Ω
(c) 10 Ω
(d) 100 Ω



(t) The effective capacitance of the circuit given below is.

(a) 1 μF
(b) 5 μF
(c) 10 μF
(d) 100 μF



(u) At what distance from a concave mirror of 30 cm focal length should an object be placed to produce an image magnified by 2 and inverted ? Sketch the ray diagram.

GD 759

(v) A transmission diffraction grating has 600 lines/mm. At what angle to the normal will the first order fringe appear, when light of wavelength 600 nm is incident normally on the grating.

(w) Calculate the separation of fringes produced on a screen at a distance of 5 m from two slits, that are spaced 0.8 mm apart, when they are coherently illuminated by a sodium lamp (λ = 600 nm).

(x) Calculate the critical angle for total internal reflection for light travelling from beneath the water surface in an open tank.

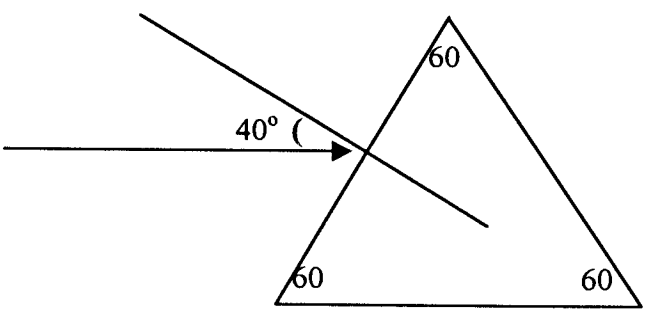
(y) How does the atomic number of a nucleus change with the emission of (i) and α-particle, (ii) a β-particle, and (ii) a γ ray. ?

(z) The work function of caesium metal is 2.14 eV. What is the longest wavelength of light that can cause photoelectrons to be emitted from its surface ?

(A) What is the maximum frequency of X-rays produced when 80 keV electrons strike a heavy metal target ?

(B) How many carbon atoms are there in 80 g of ^{12}C ?

(C) White light is incident from the left, as shown, at the mid–point of one side of an equilateral prism made from flint glass. The refractive index of the glass varies smoothly from a value of 1.664 in the blue to 1.640 in the red. Copy the figure into your answer book and <u>sketch</u> the <u>approximate</u> path followed by the red and blue components in the incident beam until they leave the prism.



(D) A sample containing 100 μg of a certain radioactive isotope was observed over a period of time. 16 μg decayed in the first 3 hours and an additional 59 μg decayed in the following 21 hours.
The amount remaining after a <u>further</u> 24 hours was
(a) 10 μg (b) 12.5 μg (c) 6.25 μg (d) 3.125 μg (e) 0.5 μg.

Q.2 Write down the laws governing linear motion under constant acceleration. [1½ marks]

Define the coefficient of friction between two surfaces in contact. [½ mark]

A body of mass m is at rest on an inclined plane, which makes an angle θ with the horizontal. Illustrate on a sketch the various forces acting on the body, and write down expressions for these forces. [2 marks]

The drivers of two cars, travelling at 20 m s^{-1} on a road that has a covering of ice, see a steep incline ($\theta = 20^{\circ}$) ahead. One driver decides to stop before she reached the incline. How far ahead should she apply full brakes so that her car will stop before she reaches the incline? [2 marks]

The driver in the second car decides to drive up the incline. However, as he attempts to do so, his car slows down and eventually stops. He immediately turns off the engine and applies full brakes, the car slides backwards down the incline. How far will it slide in 5 seconds? [2 marks]

If he restarts the engine and attempts again to drive up the incline, what change if any, occurs to the downward slide? *Briefly* explain your answer. [2 marks]

(μ, the coefficient of friction between tyre and icy road has value 0.1)

Q.3 Write down the formula for the centripetal force acting on a body of mass m to keep it moving at velocity v in a circle of radius r. Make a sketch to illustrate the direction of the force. [1 mark]

A satellite is to be placed in a circular orbit a distance r from the centre of the Earth. Derive a formula for the orbital speed of the satellite. [2 marks]
Also, derive a formula for the orbital period. [1 mark]

Explain what is meant by a geostationary satellite. [1 mark]
How far above the surface of Earth must such a satellite be placed? [2 marks]

A space probe is to be sent to explore the outer planets of the solar system.. What minimum velocity must be given to this probe in order for it to break free of the gravitational force of the Earth? [3 marks]

Q.4 Write down the Ideal Gas formula. [1 mark]

Derive an expression relating the mass density of a gas to the pressure, temperature, and molar mass of the gas. [1 mark]
Using this formula calculate the mass density of air (80% nitrogen molecules, 20% oxygen molecules) at standard temperature and pressure. [3 mark]

State Archimedes principle. [1mark]

A hot air balloon has a volume of 2000 m^3. If the air in the balloon is at 40°C while the air outside is at 0°C, what mass can be lifted by the balloon? [4 marks]

Mass number of nitrogen 14, mass number of oxygen = 16)

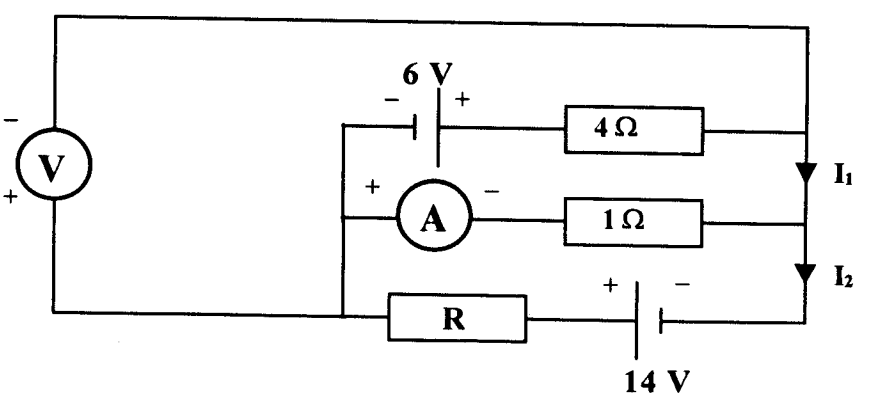
Q.5 For standing waves, define the terms node and anti-node. [2 marks]

Derive an expression for the frequencies of standing waves on a stretched string, such as a guitar string. [3 marks]

Why does the tension and mass per unit length of the string affect the resonant frequencies. [1 marks]
A string fixed at both ends has consecutive standing wave modes for which the distances between adjacent nodes are 18 cm and 16 cm respectively.
(i) What is the minimum possible length of the string? [2 marks]
(ii) If the tension in the string is 10 N and the mass per unit length is 4 g/m, what is the fundamental frequency for the minimum length string. [2 marks]

Q.6 Write down Kirchhoff's Current and Voltage Laws for electrical currents and voltages in circuits. [2 marks]

Explain what physical quantities are being conserved in the two cases. [2 marks]
In the circuit given below, the voltmeter reads 2 V, and the ammeter reads 2 A. (the current flow is from + to –). Use this information to determine the currents I_1, I_2 and the unknown resistance R. [2,2,2 marks]



Hint: The current through a perfect voltmeter, and the voltage dropped across a perfect ammeter are both zero.

Q.7 Write down the rules for ray tracing and the convention of signs used in the formation of images by thin lenses. Using ray diagrams, show one example each of how a convex lens may be used to form (i) a real image, and (ii) a virtual image. [4 marks]

Derive the formula relating the object distance, the image distance, and the focal length for the thin lens. [3 marks]

A 35 mm slide has a picture area of 24 mm x 36 mm. What focal length of slide projector lens must be used to produce an image that fills a 2.4 m x 3.6 m screen located 10 m from the lens of the projector. [3 marks]

Q.8 Answer *both* of the following:

(a) Derive the Bragg X-rays reflection formula. [2 marks]
In a silver bromide crystal, the atoms are arranged in parallel planes 0.288 nm apart. X-rays are incident at 15.5° to the surface, and a first order maximum is observed in the diffracted beam at the same angle to the surface. Calculate the wavelength of the X-rays used. [3 marks]

(b) Explain what is meant by the activity of a radioactive sample. Write down the relationship between the decay constant and the half life of a radioactive sample. Calculate the activity in Becquerels of a 100 μg sample of ^{131}I, if the half life is 8 days. [5 marks]

Q.9 Write detailed notes (1-2 pages at most) on *one* of the following topics: [10 marks]

(1) Hubbles' Law.
Include a discussion of the physical effects that Hubble used to establish his Law, and explain why Hubbles' Law **does not** mean that we are at the centre of the Universe.

(2) The importance of chaos in our daily life.

(3) Our ionizing radiation environment.
Topics should include: the percentage contributions from different sources, the radon problem, cosmic rays, internal radioactivity, medical applications and nuclear discharges.

(4) Radiocommunication.