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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER 2 (SUMMER) EXAMINATIONS 1998-99

Applied Physics & Electronics – Paper 1
Physics & Computing – Paper 1

EP313: Materials and Instrumentation

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Answer THREE questions	Time allowed: TWO hours

Q.1 Outline the principles of a strain gauge.

Define what is meant by the gauge factor, G, and prove that it is given by the following equation:

$$G = 1 + 2\nu + (1/\varepsilon_L)(\Delta\rho/\rho)$$

where ν is Poisson's ratio, ε_L is the longitudinal strain, and ρ is the resistivity.

Show that $G \approx 2$ for most metals.

Indicate how torque measurements are made using strain gauges.

Q.2 Describe, using a diagram, the operation of a silicon photodiode. Sketch the characteristic curves (I vs V) for a range of illuminations.

Starting with the modified Shockley equation, show:

(a) In the short circuit current mode, that the photocurrent is directly proportional to the illumination.
(b) In the open circuit voltage mode, that the voltage produced is proportional to the logarithm of the illumination.

Illustrate, using load lines on the characteristic curves, the two modes (a) and (b) above.

Show, using a characteristic curve, how to obtain the correct load resistor for optimum energy transfer when using the photodiode as a solar cell.

Q.3 Outline the source and properties of Johnson (thermal), shot and flicker noise, giving equations for the first two.

Define the signal-to-noise ratio (SNR logarithmic) and also the noise figure for an amplifier.

Derive the expression for the SNR of a voltage source, when delivering no current.

If this voltage source is fed to an amplifier, with a very high input impedance (R_{in}) and having noise power densities of e_n (V $Hz^{-1/2}$) and i_n (A $Hz^{-1/2}$), derive the equation for the noise figure of the amplifier.

Q.4 State clearly what is meant by the term surface energy.

Use a simple atomic model to obtain an expression for the surface energy density of a metal in terms of Young's Modulus, E, and the separation of the atoms in the metal. In the derivation you may assume that the ideal fracture stress is approximately E/π.

Calculate the ideal fracture stress of iron, given an atomic separation of 0.3 nm and a surface energy density of 2.1 J m^{-2}.

Q.5 Write detailed notes on *three* of the following topics.

(a) Characterising engineering materials.

(b) Defects in crystal structures and their effects.

(c) The linear variable differential transformer.

(d) Temperature sensors.