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NATIONAL UNIVERSITY OF IRELAND
GALWAY

SUMMER EXAMINATIONS 2000

3rd year B. Sc. Unit EP313: Materials and Instrumentation

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Answer THREE questions	Time allowed: TWO hours

Q.1 A position sensor consists of a linear potentiometer with a total resistance R_P and having a voltage V_S placed across it. If x is the fractional displacement of the sliding contact prove that the output is given by $V_O' = xV_S$ for the unloaded situation.

If the potentiometer is loaded with a resistance R_L prove that the output is now given by

$$V_L = xV_S/[1+x(1-x)R_P/R_L]$$

(Use the Thevenin equivalent in place of the potentiometer, or other method).
Now calculate an expression for the error function N(x) and show, in the case where $R_P << R_L$, that N(X) has a maximum value of $(0.15\ R_P/R_L)V_S$ which occurs when $x = 2/3$. Calculate the maximum error, as a percentage of the span, when $R_P/R_L=0.5$.

Q.2 Outline the principle of the resistive 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 $G = 2$ for most metals.

A beam of cross section 2 cm x 2 cm is bent from being straight into an arc of a circle of radius 2 m. If a strain gauge of unstrained resistance 100 ohm is present on the convex surface calculate the change in resistance produced. (Use $G = 2$ and assume the central plane of the beam does not change in length).

Q.3 Sketch the model used to describe an electronic balance force measurement system employing high gain negative feedback but without modifying or interfering inputs. Use it to prove that the output voltage is given by the equation

$$V_{out} = KK_AF_{in}/(1 + KK_AK_F)$$

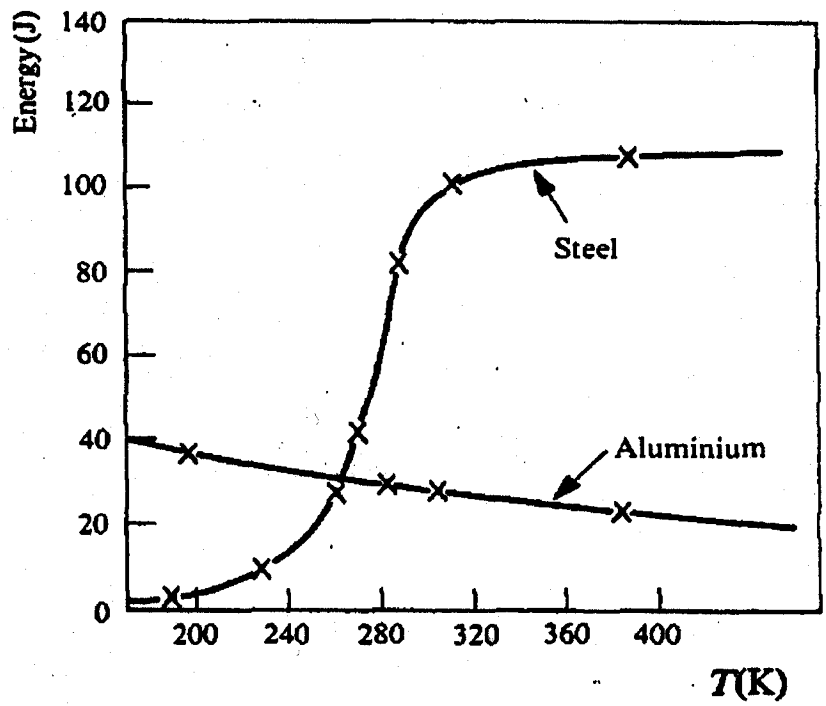
where F_{in} = input force
K = sensitivity of the sensing element
K_A = amplifier gain
K_F = feedback gain.

Explain the situation where the amplifier gain is made very large.

Explain, without calculation, how the effect of a modifying input is changed when using high gain negative feedback.

Q.4 (a) Sketch a stress-strain graph for a ductile and a brittle metal. You should refer to this graph in doing the following:
(i) Define ductility and how it is quantified, and the criterion for a brittle material.
(ii) Define the yield strength, σ_y, the tensile strength, and the fracture strength.
(iii) Distinguish between the engineering stress and strain and the true stress and strain.

(b) Describe, with the aid of a diagram, the Charpy test. How is the notch toughness quantified ? A notch test for aluminium and mild steel is shown opposite. Estimate the ductile-to-brittle transition temperature of mild steel. For what range of temperatures is mild steel brittle and for what range is it ductile ?



Q.5 Answer two of the following, using diagrams where appropriate.
a) Describe the linear variable differential transformer (LVDT) position sensor.
b) Derive the condition for maximum power transfer from a Thevenin source (Thevenin impedance Z_{th}) into load of impedance Z_L.
c) Give a brief description of the metallic bond. State the two physical properties of metals which follow from this bonding type. Sketch the structure of graphite. What types of bonds are involved and how do they determine the physical behaviour of graphite ?
d) The melting temperatures of copper and nickel are 1085 °C and 1453 °C. Draw the copper-nickel phase diagram, discuss the changes in phases as the wt% of nickel is increased at constant temperature, and state the lever rule.