998

Ollscoil na hÉireann, Gaillimh

*National University of Ireland, Galway*

**Semester II Examinations, 2004/2005**

| | |
|---|---|
| Exam Code(s) | 2BM121 |
| Exam(s) | 2nd Mechanical Engineering |
| Module Code(s) | ME215 |
| Module(s) | Instrumentation |
| Paper No. | 1 |
| Repeat Paper | Special Paper |
| External Examiner(s) | Professor J. Fitzpatrick |
| Internal Examiner(s) | Professor J.F. McNamara |
| | Dr. D. Apatsidis |
| | Dr. T. Joyce |

Instructions: Answer 5 questions in total, including a maximum of 3 questions from Section A.
All questions will be marked equally.

| | |
|---|---|
| Duration | 3hrs |
| No. of Answer Books | 1 |
| **Requirements**: | |
| Handout | |
| MCQ | |
| Statistical Tables | |
| Graph Paper | |
| Log Graph Paper | |
| Other Material | |

| | |
|---|---|
| No. of Pages | 5 including cover |
| Department(s) | Mechanical and Biomedical Engineering |
| Course Co-ordinator(s) | Dr. D. Apatsidis, Dr. T. Joyce |

# SECTION A

1. A hollow shaft is to be designed to measure the torque of an engine. The shaft has an outer radius of 2cm and an inner radius of 1.5cm. It is 30cm long and made from steel with E = 200GPa and $\nu = 0.27$. If the angular deflection is 10°, use the given formulae to determine the applied torque. **(7)**

$$T = \frac{\pi G\left(R_o^4 - R_i^4\right)}{2L}\phi$$

$$G = \frac{E}{2(1+\nu)}$$

What is a LVDT? **(2)**

Describe its essential features. **(4)**

Explain its operation. **(4)**

Name three advantageous features of the LVDT for its use as a transducer. **(3)**

2. Describe the essential features of a stylus profilometer or 'talysurf'. **(3)**

Describe the principle of operation of such a device. **(5)**

Include in your description the selection of cut-off and give a typical value of cut-off. **(3)**

Define the traverse length. **(1)**

Name and define three internationally recognized surface roughness parameters, including Ra. **(8)**

3. Describe the principle of operation of a positive displacement flow meter. **(4)**

Name three specific types of positive displacement flow meters. **(3)**

Two different sorts of flow-obstruction meters are known as a Venturis and orifice plates. List two advantages each for Venturis and orifice plates, plus one disadvantage of each which could influence the choice of their use in a mechanical engineering situation. **(6)**

All flow obstruction meters are based on Bernoulli's equation which can be written as:

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+h_1=\frac{P_2}{\rho g}+\frac{V_2^2}{2g}+h_2$$

Consider a horizontal pipe, initially of 80mm constant diameter, which then expands out to 150mm constant diameter. If the absolute pressure at the smaller diameter is 0.3MPa, and the volume flow rate is $0.1\text{m}^3/\text{s}$, calculate the fluid velocity at the two sections of constant diameter, plus the absolute pressure in the section with the greater diameter. Assume the fluid is water with a density of $1000\text{kg/m}^3$ that it is incompressible and that friction effects can be ignored. **(7)**

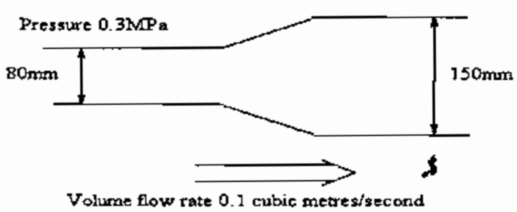


*Figure 3*

4. **(a)** A bimetallic strip is an example of a device which measures temperature by a mechanical effect. When subjected to a change in temperature, the bimetallic strip bends and the radius of curvature r is given by the following equation:

$$r = \frac{t\left\{3(1+m)^2 + (1+mn)[m^2 + (1/mn)]\right\}}{6(\alpha_2 - \alpha_1)(T - T_0)(1+m)^2}$$

where t = combined thickness of the bonded strip;

m = ratio of thicknesses of low to high expansion materials;

n = ratio of moduli of elasticity of low to high expansion materials;

$\alpha_1$ = lower coefficient of expansion per °C;

$\alpha_2$ = higher coefficient of expansion per °C;

T = temperature and

$T_0$ = initial bonding temperature.

Mechanical properties of two commonly used thermal materials are given below:

| Material | Thermal coefficient of expansion per °C | Modulus of elasticity GN/m$^2$ |
|---|---|---|
| Invar | $1.7 \times 10^{-6}$ | 147 |
| Yellow brass | $2.02 \times 10^{-5}$ | 96.5 |

A particular bimetallic strip is constructed of strips of yellow brass and Invar bonded together at 30°C. Each has a thickness of 0.3mm. Calculate the radius of curvature when a 6.0cm strip is subjected to a temperature of 100°C. **(5)**

Aside from the bimetallic strip, name one other example of a device which gives a temperature measurement by a mechanical effect. **(1)**

For this device, name four benefits of using it in a mechanical engineering context. **(4)**

**(b)** Another method of measuring temperature is by electrical effects. One such device is the resistance temperature detector (RTD). Describe the functional principle on which this sensor relies. **(2)**

RTD devices have electrical circuits incorporated into their design, which are connected to the RTD sensor by means of additional wires. These wires have their own resistance, which may affect the readings from the sensor. Three different bridge arrangements have been devised in the past to minimize such effects.

Name these three arrangements. **(3)**

Give a description of how these arrangements work to minimize secondary resistance effects. **(5)**

## SECTION B

**5.** All electrical instrumentation devices rely on an electrical analogue of any physical property that is measured. In this way there have been two types of mechanical and electrical analogies may be defined.

Name and explain these two analogies. **(4)**

What are the corresponding mechanical and electrical equivalents for each of these analogies? **(6)**

What is meant by the term 'attenuation' in the context of signal amplification and how can this attenuation be accounted for? **(2)**

For the circuit illustrated in Figure 5 and the three signals (i), (ii) and (iii), determine which signal is undesirably attenuated and by how much? **(8)**

(i) Initial recorded signal (electrocardiogram) from heart (V) = 1 mV

(ii) Input resistance of amplifier ($R_i$) = 1 MΩ

(iii) Resistance of overlying skin ($R_s$) = 100 kΩ

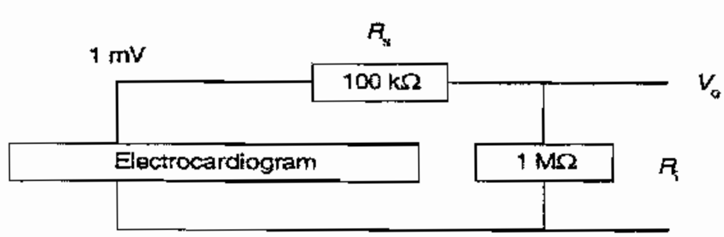


*Figure 5*

6. Describe the functional principles of both Transmission Electron Microscopes (TEM) and Scanning Electron Microscopes (SEM). **(4)**

What are the three main differences? **(6)**

What are the definitions of resolution power and magnifying power? **(2)**

In a TEM the resolution is greater when the wavelength ($\lambda$) of the illumination source is smaller. Wavelength is given by the following function:

$$\lambda = [ h / (m v) ]$$

where h is the Planck constant, m the mass of the electron and v the velocity with which the electron travels in the TEM's vacuum chamber. Velocity of the electron is calculated using the following function:

$$v = [ (2eV) / m ]^{-1/2}$$

where e and m are the charge and the mass of the electron, respectively, and V is the accelerating voltage of the electron.

Two TEM systems have voltages $V_1 = 120kV$ and $V_2 = 150kV$ respectively. Determine the most accurate of these two systems and by how much. **(6)**

What would be a typical resolution of a modern TEM system? **(2)**

7. When measuring strain, is it more advantageous to do so over a greater or smaller length and why? **(2)**

What is meant by 'base length' and 'strain sensitivity'? **(2)**

Describe how using brittle clear coatings on samples can provide a method for monitoring strain. What are the advantages of such methods? **(6)**

Describe the function of the Pirani gauge for measuring pressure. **(4)**

Describe the function of the Knudsen gauge for measuring pressure. **(4)**

What are the advantages relative to each other? **(2)**