



UNIVERSITI TUN HUSSEIN ONN MALAYSIA

**FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017**

COURSE NAME : INSTRUMENT
COURSE CODE : BDT 40602
PROGRAMME : 3 BDC
EXAMINATION DATE : JUNE 2017
DURATION : 2.5 HOURS
INSTRUCTION : ANSWER **FOUR (4)** QUESTIONS ONLY

TERBUKA

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

- Q1** (a) The airspeed indicator (ASI) in an aircraft cockpit consists of differential pressure gauge that measures the dynamic pressure and deflects an indicator hand proportionally to the pressure difference. Describe the principle operation of an airspeed indicator (ASI) with relevant sketches to clarify your explanation. (5 marks)
- (b) Differentiate various airspeed designations used in pitot-static calibration. (4 marks)
- (c) Outline the calibration procedure for pitot-static probe to account for compressibility error and density error. (6 marks)
- (d) A high speed subsonic Jetstar business jet is flying at a pressure altitude of 10 km ($P = 2.65 \times 10^4 \text{ N/m}^2$). A pitot tube on the wing tip measures a pressure of $4.5 \times 10^4 \text{ N/m}^2$. Assume $\gamma = 1.4$ and specific gas constant, $R = 287 \text{ J/kg.K}$ for normal air.
- (i) Calculate the Mach number at which the aircraft is flying. (3 marks)
- (ii) If the ambient air temperature is 230 K, calculate the true airspeed and the calibrated airspeed for the aircraft. (7 marks)
- Q2** (a) List **TWO (2)** technical importance of air temperature reading during flight. (2 marks)
- (b) Describe the operation principle of total air temperature probe and its main source of error. (8 marks)
- (c) Outline and describes **THREE (3)** methods used by the pilot to obtain static air temperature from total air temperature reading. (5 marks)
- (d) Consider a platinum resistance thermometer connected as one arm of a Wheatstone bridge as shown in **Figure Q2**. The fixed resistance in the circuit are 200Ω each, and the input voltage is 10 V. At 0°C , the circuit is balanced and at this temperature, the thermometer has a resistance of 200Ω . If the temperature coefficient of resistance of platinum is 0.004°C^{-1} , determine the change in output voltage for a 1°C change in the temperature. (10 marks)
- Q3** (a) Inertial measurement units (IMUs) are widely used for navigation and control purposes on unmanned autonomous vehicles. Explain the primary function of IMU in navigation and control of unmanned autonomous vehicles. (3 marks)
- (b) List all available direct measurement from the IMU. (4 marks)

- (c) Differentiate different sensors used in the development of MEMS inertial measurement units (IMU). Briefly explain the main function, variable measurement produced and disadvantages of each individual sensor. (10 marks)
- (d) Given the disadvantages of using individual sensor packages, an efficient sensor fusion algorithm is needed to provide the optimal estimation of the vehicle attitude. Extended Kalman filters are frequently used in nonlinear estimation problems, especially attitude estimation problems of rigid bodies like an aircraft. Write the propagation (or state) equation and measurement equation if Euler angles are chosen as the system states for the attitude estimation problem. (8 marks)
- Q4** (a) The automatic flight controller or autopilot has been in existence for about 50 years. List **TWO (2)** major reasons to use autopilot in aircraft flight operation. (4 marks)
- (b) An autopilot is a control system that uses control loops such the inner loop and outer loop control. Compare the differences between inner loop control and outer loop control in terms of function, system architecture and types (modes). (6 marks)
- (c) Describe the principle of operation for an automatic landing system. (4 marks)
- (d) Describe in detail the automatic landing sequence for a Boeing aircraft. (11 marks)
- Q5** (a) Describe **TWO (2)** methods to induced magnetism in an unmagnetized iron bar. (4 marks)
- (b) Describe and explain the design of a vertical card type compass. (4 marks)
- (c) Discuss and interpret the effect of linear acceleration and turning maneuvers to the accuracy of direct reading compass. (8 marks)
- (d) Explain the operating principles and the construction of rate gyro and rate integrating gyro. (4 marks)
- (e) Gyroscopes have two basic properties (rigidity and precession) that are unique to a rotating mass. Establish the relationship between precession and rigidity of a gyroscope. (5 marks)

-END OF QUESTION-

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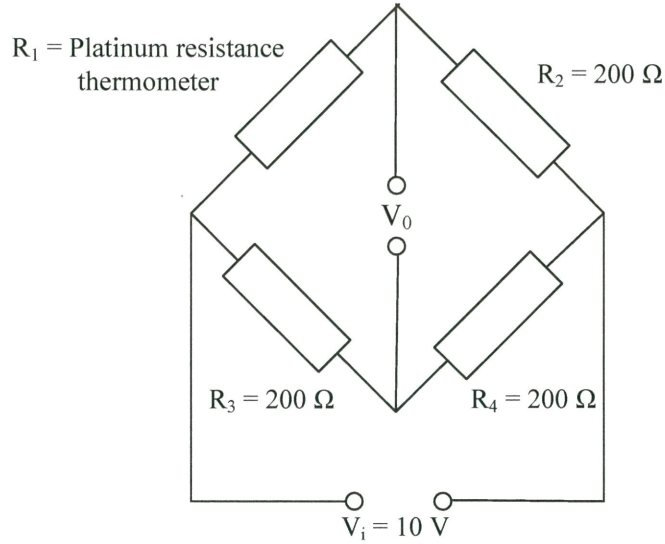


Figure Q2 Platinum resistance thermometer attached to a Wheatstone bridge.

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A Key Equations

The relevant equations used in this examination are given as follows:

1. Continuity equation:

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \quad (1)$$

2. Isentropic flow:

$$\frac{P_2}{P_1} = \left(\frac{\rho_2}{\rho_1}\right)^\gamma = \left(\frac{T_2}{T_1}\right)^{\gamma/\gamma-1} \quad (2)$$

3. Bernoulli equation for steady incompressible flow:

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2 \quad (3)$$

4. The speed of sound:

$$a = \sqrt{\gamma RT} \quad (4)$$

5. Mach Number:

$$M = \frac{V}{a} \quad (5)$$

6. Measurement of airspeed (incompressible flow):

$$V_1 = \sqrt{\frac{2(P_0 - P)}{\rho}} \quad (6)$$

where, P_0 is total pressure and P is static pressure.

7. Measurement of airspeed (subsonic compressible flow):

$$\frac{T_0}{T_1} = 1 + \frac{\gamma - 1}{2} M_1^2 \quad (7)$$

$$\frac{P_0}{P_1} = \left(1 + \frac{\gamma - 1}{2} M_1^2\right)^{\gamma/(\gamma-1)} \quad (8)$$

$$\frac{\rho_0}{\rho_1} = \left(1 + \frac{\gamma - 1}{2} M_1^2\right)^{1/(\gamma-1)} \quad (9)$$

$$V_1^2 = \frac{2a_1^2}{\gamma - 1} \left[\left(\frac{P_0}{P_1}\right)^{(\gamma-1)/\gamma} - 1 \right] \quad (10)$$

$$V_{cat}^2 = \frac{2a_s^2}{\gamma - 1} \left[\left(\frac{P_0 - P_1}{P_s} + 1\right)^{(\gamma-1)/\gamma} - 1 \right] \quad (11)$$

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8. Electrical resistance thermometer:

$$R_t = R_0(1 + \alpha T) \quad (12)$$

9. Wheatstone bridge:

$$\Delta V_0 = V_i \left(\frac{\Delta R_1}{R_1 + R_2} \right) \quad (13)$$