2507/205
MEASUREMENT TECHNOLOGY
June/July 2022
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN AERONAUTICAL ENGINEERING
(AVIONICS OPTION)

MODULE II

MEASUREMENT TECHNOLOGY

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
    Answer booklet;
    Mathematical tables/Non-programmable scientific calculator.
    Drawing instruments;
This paper consists of EIGHT questions.
Answer any FIVE of the EIGHT questions in the answer booklet provided.
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.
Take:
    Electron charge $e = 1.6 \times 10^{-19} C$
    Electron mass $m = 9.1 \times 10^{-31} Kg$
    Acceleration due to gravity, $g = 9.81 \, m/s^2$
    Modulus of elasticity of steel, $E = 200 \, GN/m^2$
    Poisson's ratio of steel, $v = 0.29$

This paper consists of 6 printed pages.

Candidates should check the question paper to ascertain that
all the pages are printed as indicated and that no questions are missing.

    Turn over

1.   (a)   (i)   With the aid of a diagram, describe the operation of a mechanical tachometer.

                (ii)   State **two** demerits of the tachometer in a(i).

                                                           (7 marks)

       (b)   Draw a labelled diagram of a pressure measuring unit using Bellows and linear variable differential transformer and describe its operation.   (7 marks)

       (c)   A disc with 14 pattern points is coupled to a shaft whose speed is to be measured. A strosbescope directed to the disc produces 6200 flashes per minute. Determine the speed of the shaft in r.p.m, if the disc appears:

                (i)   stationary;
                (ii)   to move forward in the direction of rotation at 15 r.p.m;
                (iii)   to move backward in the opposite direction at 15 r.p.m.

                                                               (6 marks)

2.   (a)   (i)   State **two** merits of radiation methods of level measurements.

                (ii)   With the aid of a labelled diagram describe photoelectric method of liquid level measurement.   (7 marks)

       (b)   Figure 1 shows a diagram of an ultrasonic method of liquid level measurement. The transmitter/receiver unit, is placed at a distance d_1 from the liquid surface. The liquid falls to a new level after use and the distance from transmitter/receiver unit to new level is d_2. The time taken for the ultra sound to travel to and fro distance d_1 is 1.5 ms and d_2 is 18 ms. Taking the velocity of ultrasound as 1540 m/s, determine the height, h.   (5 marks)
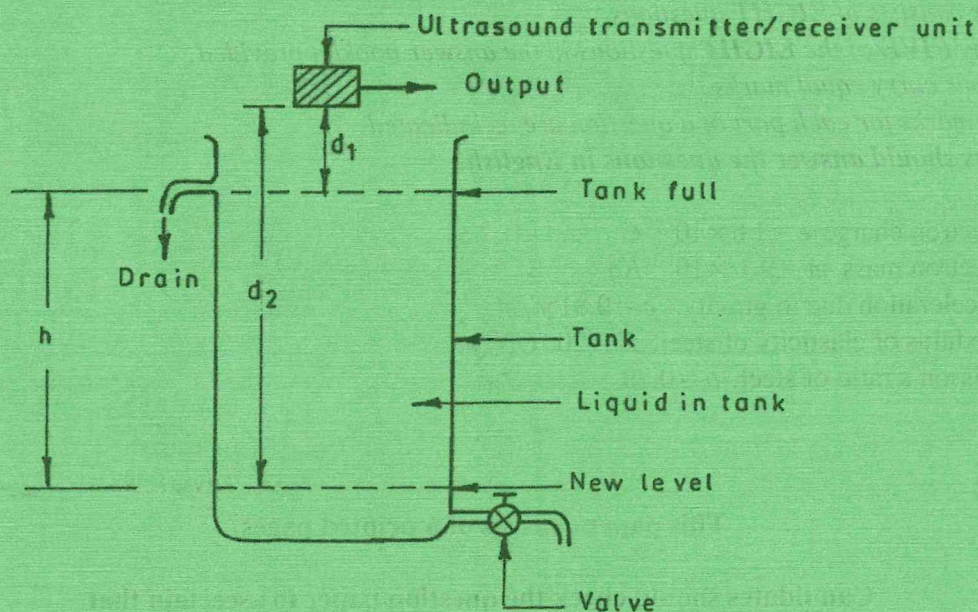

Fig. 1

(c) A vapour pressure thermometer filled with pure water has a sensing bulb of height 5 m connected to a Bourdon-tube pressure gauge through a capillary tube. Taking the vapour pressure of saturated steam at 200°C as 1555 kN/m², saturation temperature at 1,600 kN/m² as 201.4°C, saturation temperature at 1,700 kN/m² as 204.3°C and density of water as 1,000 kg/m³, determine the following when the bulb temperature is 200°C:

(i) pressure in capillary tube;
(ii) gauge pressure;
(iii) saturation temperature at gauge pressure;
(iv) error in temperature measurement due to head effect.

(8 marks)

3. (a) (i) State **two** advantages of venturi meters over orifice meters in flow measurements.

(ii) With the aid of a labelled diagram describe the operation of a nutating disc flow meter.

(8 marks)

(b) Draw a labelled diagram of a crystal hygrometer and describe its operation.

(6 marks)

(c) Three identical spheres are dropped at the same instant into three identical samples of oil contained in three identical tubes. The terminal velocities of the spheres are 0.92 cm/s, 0.58 cm/s and 0.32 cm/s respectively. The viscosity of the oil sample with sphere velocity of 0.92 cm/s is 4.8 x 10⁻³ m²/s.:

(i) Determine the viscosity of the other two oil samples;
(ii) Comment on the results from c(i).

(6 marks)

4. (a) (i) Distinguish between direct acting and reverse acting pneumatic controllers.

(ii) With the aid of a labelled diagram, explain the principle of force-balance pneumatic controller.

(8 marks)

(b) A load cell, made of a solid cylinder of steel, has four strain gauges bonded to it and connected to form four arms of a bridge. A load applied to the cell produces a per unit change in resistance of 9.2×10^{-6}. Taking the stress produced by the load as 0.83×10^6 N/m^2, strain as 4.2×10^{-6}, output voltage as 0.35 μV and diameter of cell as 50 mm, determine the:

(i) effective area of the cell;
(ii) load applied;
(iii) gauge factor;
(iv) sensitivity of the cell.

(8 marks)

(c) Describe the calibration of a resistive load cell and sketch the calibration curve.

(4 marks)

5. (a) (i) State **two** demerits of potentiometric accelerometers.

(ii) With the aid of a labelled diagram, explain the principle of operation of a piezoelectric accelerometer.

(8 marks)

(b) Describe each of the following photo-detectors:

(i) photoconductive;
(ii) photovoltanic.

(6 marks)

(c) An accelerometer has a seismic mass of 0.06 kg and its natural frequency is 40 Hz. The displacement of the mass is 0.05 mm. Determine the:

(i) spring constant;
(ii) maximum velocity;
(iii) maximum acceleration.

(6 marks)

6. (a) (i) Distinguish between dead time and recovery time as applied to Geiger-miller counter.

(ii) With the aid of a labelled diagram explain the operation of a semiconductor x-ray detector.

(9 marks)

(b) (i) Explain the effect of boundary between two material media on the propagation of ultrasound waves.

(ii) With the aid of sketches distinguish between longitudinal and shear ultrasonic waves. (7 marks)

(c) The anode and cathode of an X-ray tube are 30 cm apart and the anode potential is 1.2 kV. Neglecting fringing effects, determine the:

(i) velocity with which the electrons strike the anode;
(ii) transit time of the electrons from cathode to anode.

(4 marks)

7. (a) Define each of the following terms with respect to measurement systems:

(i) reproducibility;
(ii) dead zone;
(iii) sensitivity.

(3 marks)

(b) The output voltage of an audio power amplifier is 15 V when delivering power of 25 W to a load and 8 V when delivering power of 16 W to a load.
Determine the:

(i) Value of load resistance in each case;
(ii) Open circuit voltage of the amplifier;
(iii) Output impendance of the amplifier.

(10 marks)

(c) (i) With the aid of a response curve explain time-delay with reference to measuring instruments.

(ii) A pyrometer is calibrated to measure temperatures from 400°C to 1,000°C. If the dead zone of the pyrometer is 0.125 per cent, determine the temperature change that may occur without being detected. (7 marks)

8. (a) (i) State **two** demerits of stroboscopic method of measuring the angular speed of a shaft.

(ii) Draw a labelled diagram of a dc tachogenerator and describe its operation.

(8 marks)

(b) Figure 2 shows a sketch of an inclined tube manometer. Obtain the expression of the differential pressure in terms of density of liquid, acceleration due to gravity and the height, h_2. (6 marks)
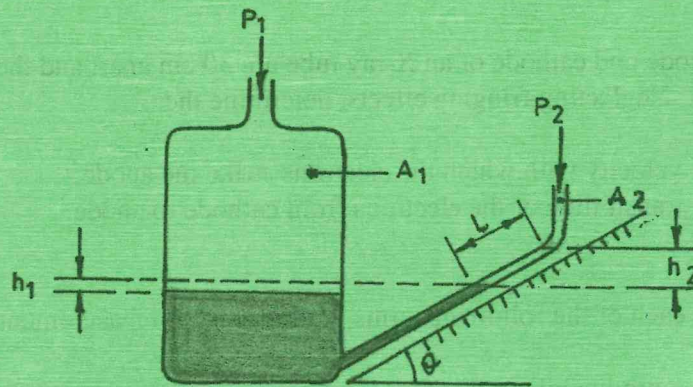

Fig. 2

(c) Figure 3, shows a diagram of a tank of mass 5000 kg supported on three interconnected hydraulic load cells, each 160 mm diameter equally spaced about the centre, C. The tank contains a liquid of mass 38 kg. Determine the:

(i)   total force exerted on the load the cells;
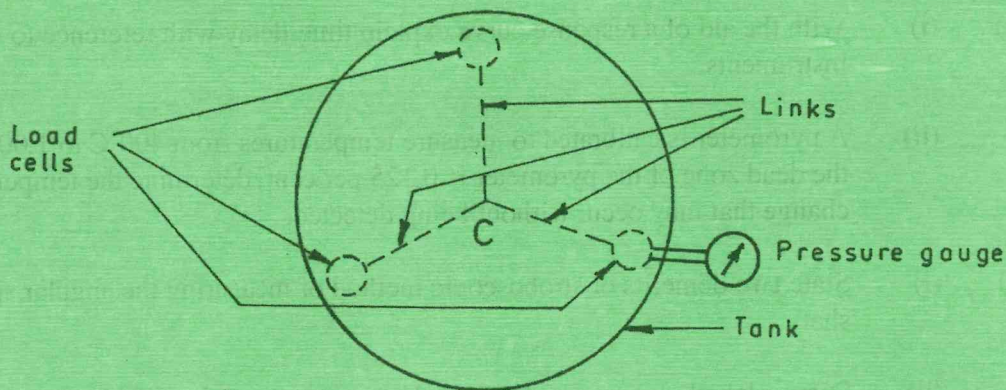(ii)   effective area of load cells;
(iii) pressure indicated by the pressure gauge.

(6 marks)

Fig. 3

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