TVET CURRICULUM DEVELOPMENT, ASSESSMENT AND CERTIFICATION COUNCIL (TVET CDACC)

Qualification Code	:	071606T4MCT
Qualification	:	Mechatronics Level 6
Unit Code	:	ENG/OS/MC/CR/04/6/A
Unit of Competency	:	Perform mechatronics systems instrumentation and control

WRITTEN ASSESSMENT

INSTRUCTIONS TO ASSESSOR:

1. Allocate **THREE** hours to the candidate to answer all the questions.
2. Marks for each question are indicated in the brackets.

SECTION A (40 MARKS)

1. State five categories of PPE (5 Marks)
   - ✓ ***Protective clothing***
   - ✓ ***Hand and arm protection***
   - ✓ ***Foot protection***
   - ✓ ***Head protection***
   - ✓ ***Hearing protection***
   - ✓ ***Eye and face protection***
   - ✓ ***Respiratory protection***
   - ✓ ***Equipment protecting against falls from a height***
2. Name two major types of control systems (2 Marks)
   - ✓ ***Open loop***
   - ✓ ***Close loop***
3. Highlight two comparison of a sensor and a transducer. (4 Marks)

Basis for Comparison	***Sensor***	***Transducer***
Definition	***Senses the physical changes occurs in the surrounding and converting it into a readable quantity.***	***The transducer is a device which, when actuates transforms the energy from one form to another.***
Components	***Sensor itself***	***Sensor and signal conditioning***
Function	***Detects the changes and induces the corresponding electrical signals.***	***Conversion of one form of energy into another.***
Examples	***Proximity sensor, Magnetic sensor, Accelerometer sensor, Light sensor etc.***	***Thermistor, Potentiometer, Thermocouple, etc.***

4. Explain what an operation and maintenance manual is. (2 Marks)

- ✓ ***Comprehensive document that provides all details necessary about a physical plant as well as individual pieces of equipment to help maintenance staff keep everything running smoothly***

5. List four major the components of a hydraulic system. (4 Marks)
   - ✓ ***Selector valve,***
   - ✓ ***hydraulic lines,***
   - ✓ ***actuating units,***
   - ✓ ***reservoir,***
   - ✓ ***pump***
6. Differentiate between positive and negative feedback (4 Marks)
   - ✓ ***Positive feedback-Feedback system where system output ad set point values are added as feedback is in phase with the input. The effect is to increase the system gain. However, gain can be too much leading to oscillatory circuit responses (instability)***
   - ✓ ***Negative feedback-Feedback system that occurs when output of system is fed back in a manner that tends to reduce fluctuations in the output. The system is stable***
7. State three functions of a controller in a control system (4 Marks)
   - ✓ ***Controllers improve the steady-state accuracy by decreasing the steady state error.***
   - ✓ ***As the steady-state accuracy improves, the stability also improves.***
   - ✓ ***Controllers also help in reducing the unwanted offsets produced by the system.***
   - ✓ ***Controllers can control the maximum overshoot of the system.***
   - ✓ ***Controllers can help in reducing the noise signals produced by the system.***
   - ✓ ***Controllers can help to speed up the slow response of an overdamped system.***
8. Define the following terms s used in instrumentation (4 Marks)
   a) Desired value
      - ✓ ***The value of the variable that the system is needed to maintain. Also called reference value.***
   b) Manipulated value
      - ✓ ***The value of variable that occurs when controlled variable has been influenced / manipulated to match the reference variable / desired value.***

9. Outline four significance of developing system models when designing control systems. (4 Marks)

- ✓ ***They help to document the entire system.***
- ✓ ***They help to make templates for the construction in the system.***
- ✓ ***They help in the visualization of the system.***
- ✓ ***The structural dimensions of a system can be specified.***
- ✓ ***Modeling is entirely accepted by the engineering technique.***

10. Outline two items that are found on a technical report. (2 Marks)

Title page, abstract, preface, dedication, acknowledgements, table of contents, List of tables ad figures, Nomenclature, introduction, Central chapters, conclusions, tables and figures, appendices, references, bibliography

11. Differentiate between the following terms as used in instrumentation systems. (4 Marks)

a) Resolution and accuracy.

- ✓ ***Resolution is the smallest amount of an input signal change that can be reliably detected by an instrument.***
- ✓ ***Accuracy is the extent to which the value indicated by a measurement system or element might be wrong.***

b) Repeatability and reproducibility

- ✓ ***The term repeatability is used for the ability of a measurement system to give the same value for repeated measurements of the same value of a variable.***
- ✓ ***The term reproducibility is used describe the ability of a system to give the same output when used with a constant input with the system or elements of the system being disconnected from its input and then reinstalled.***

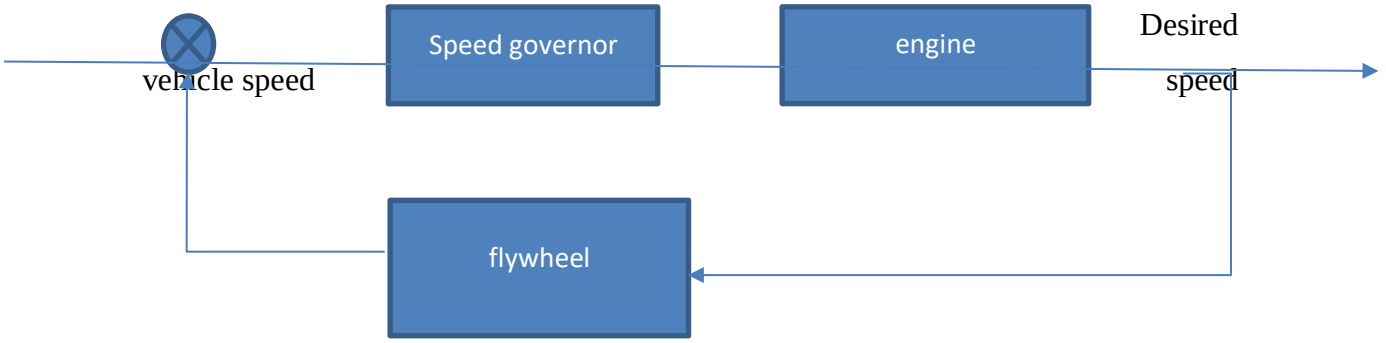
12. Highlight two importance of patenting. (2 Marks)

- ✓ ***It prevents duplicating other people's work or infringing someone else's patent.***
- ✓ ***Avoid wastage of time and money duplicating other people's work***
- ✓ ***Help keep an eye on trends in technology and emerging key players.***

SECTION B (60 MARKS)

13.

a) The government of Kenya wishes that all public service vehicles operate at 80km/h. With the aid of well labelled block diagram, explain the control system, given speed governor, engine and flywheel. (10 Marks)



- ✓ ***The governors are control mechanisms and they work on the principle of feedback control.***
- ✓ ***the speed governor controls the speed of the engine by regulating fuel intake***
- ✓ ***the speed of the engine determines the speed of the vehicle***
- ✓ ***the flywheel reflects the speed of the engine end gives a feedback to the governor***
- ✓ ***the governor the adjust the engine speed accordingly***

b) Explain how capacitive sensing works, and give an example of its application. (10 Marks)

- ✓ ***Based on capacitive coupling***
- ✓ ***Takes as input a human body or anything that is conductive / has dielectric different from air***
- ✓ ***Surface capacitance***
  - ✓ ***One side of dielectric is coated with conductive material (one plate)***

- ✓ ***Small voltage applied to this layer, creating a uniform electrostatic field***
- ✓ ***When a conductive material, e.g. a finger, touches the uncoated side, a capacitor is dynamically formed***
- ✓ ***Durable, low resolution (used in industrial controls and info kiosks)***

- ✓ ***Projected capacitance***
  - ✓ ***The plate is etched with conductive lines, or uses two superimposed sub-plates of etched perpendicular lines to create a conductive grid***
  - ✓ ***Field projects outwards, and enables contactless operation***
  - ✓ ***Variations include mutual capacitance (allows multi-touch) and self-capacitance measuring versions***
- ✓ ***Examples: industrial sensing, touch screen interfaces***

14.

a) Two induction coils are wound on the same form as shown in Figure 1. Explain, in your own words, what causes the self-inductances L1 and L2, and the mutual inductance M. Explain the significance of the black dots shown in Figure 5.

(5 Marks)

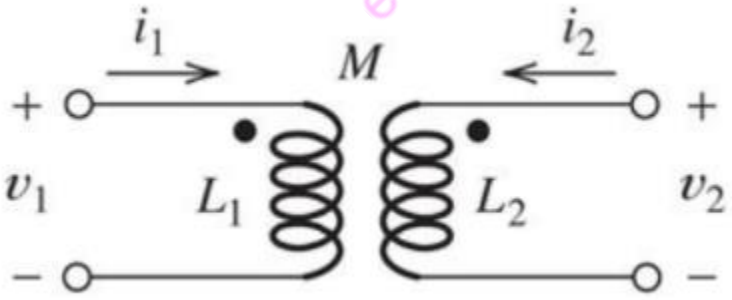
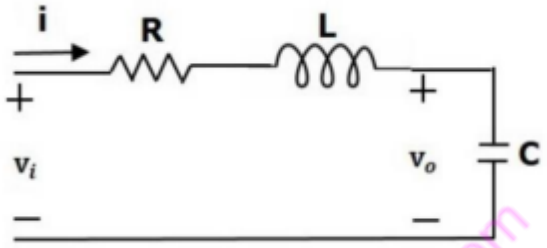


Figure 1

- ✓ **Sometimes several coils are wound on the same form so that magnetic flux produced nby one coil links the others**
- ✓ **Then a time-varying current flowing through one coil induces voltages in the other coils**
- ✓ **The self-inductances of the two coils are denoted as L1 and L2, respectively**

- ✓ **The mutual inductance is denoted as M, which also has units of Henries (H)**
- ✓ **The dots indicate if fields are aiding or opposing**

b) Consider the following electrical system as shown in the following figure. This circuit consists of resistor, inductor and capacitor. All these electrical elements are connected in series. The input voltage applied to this circuit is $\boldsymbol{vi}$ and the voltage across the capacitor is the output voltage $\boldsymbol{v_0}$



i. Develop second order differential equation equating the input and the output of the electrical system. (5 Marks)

- ✓ ***Mesh equation for this circuit is***

$$\boldsymbol{vi = Ri + L\frac{di}{dt} + vo}$$

- ✓ ***Substitute, the current passing through capacitor*** $\boldsymbol{i = c\frac{dvo}{dti}}$ ***in the above equation***.

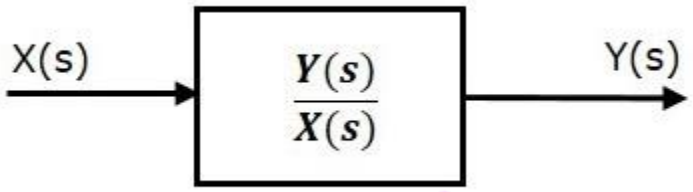
- ✓ $\Rightarrow vi = RC\frac{dvo}{dt} + LC\frac{d^2vo}{dt^2} + vo$
- ✓ $\Rightarrow \frac{d^2vo}{dt^2} + \left(\frac{R}{L}\right)\frac{dvo}{dt} + (\frac{1}{LC})vo = (\frac{1}{LC})vi$
- ✓ *The above equation is a second order* ***differential equation***.

ii. Develop the transfer function for the system. (5 Marks)

- ✓ ***If $x(t)$ and $y(t)$ are the input and output of an LTI system, then***
- ✓ ***the corresponding Laplace transforms are $X(s)$ and $Y(s)$.***

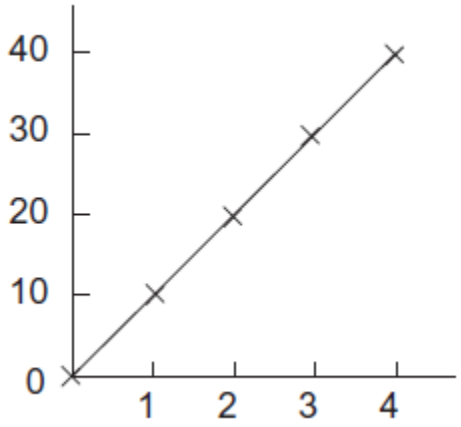
Therefore, the transfer function of LTI system is equal to the ratio of Y(s) and X(s).

- ✓ ***i.e., $transfer\ Function = \frac{Y(s)}{X(s)}$***
- ✓ ***The transfer function model of an LTI system is shown in the following figure.***
- ✓



c) A spring balance has its deflection measured for a number of loads and gave the following results. Determine its sensitivity. (5 Marks)

Load in kg	0	1	2	3	4
Deflection in mm	0	10	20	30	40



shows the graph of output against input.

- ✓ ***The graph has a slope of 10 mm/kg and so this is the sensitivity. (show working)***

15.

a) A pressure measurement system (a diaphragm sensor giving a capacitance change with output processed by a bridge circuit and displayed on a digital display) is stated as having the following characteristics. Explain the significance of the terms:

(10 Marks)

Range: 0 to 125 kPa and 0 to 2500 kPa

Accuracy: $\pm 1\%$ of the displayed reading

Temperature sensitivity: $\pm 0.1\%$ of the reading per ℃

- ✓ ***The range indicates that the system can be used to measure pressures from 0 to 125 kPa or 0 to 2500 kPa.***
- ✓ ***The accuracy is expressed as a percentage of the displayed reading,***
- ✓ ***thus, if the instrument indicates a pressure of, say, 100 kPa then the error will be*** $\pm \mathbf{1}\ \boldsymbol{kPa}$.
- ✓ ***The temperature sensitivity indicates that if the temperature changes by 1*** ℃ ***the displayed reading will be in error by*** $\pm \mathbf{0.1}\%$ ***of the value.***
- ✓ ***Thus, for a pressure of, say, 100 kPa the error will be*** $\pm \mathbf{0.1}$ ***kPa for a 1*** ℃ ***temperature change.***

b) A platinum resistance coil is to be used as a temperature sensor and has a resistance at 0 ℃ of 100 Ω. It forms one arm of a Wheatstone bridge with the bridge being balanced at this temperature and each of the other arms also being 100 Ω. If the temperature coefficient of resistance of platinum is $0.0039\ K^{-1}$, what will be the output voltage from the bridge per degree change in temperature if the supply voltage is 6.0 V? (5 marks)

The variation of the resistance of the platinum with temperature can be represented by:

$$R_t = R_0(1 + \alpha t)$$

where R_t is the resistance at t °C, R_0 the resistance at 0°C and α the temperature coefficient of resistance. Hence:

$$\text{Change in resistance} = R_t - R_0 = R_{0\alpha}t$$

Thus, for a one degree change in temperature:

$$\text{Change in resistance} = 100 \times 0.0039 \times 1 = 0.39\ \Omega$$

Since this resistance change is small compared to the 100 Ω, the approximate equation for the output voltage can be used. Hence, the change in output per degree change in temperature is:

$$\delta V_o \approx V_s\left(\frac{\delta R_1}{R_1 + R_2}\right) = \frac{6.0 \times 0.39}{100 + 100} = 0.012\text{V}$$

c) List five elements of a close loop system. (5 Marks)

- ✓ ***Comparison element***
- ✓ ***Control law implementation element***
- ✓ ***Correction element***
- ✓ ***Process***
- ✓ ***Measurement element***

16.

a) Measurement signals often have to be transmitted over quite large distances from the place of measurement to a display unit and/or a process control unit. Discuss five methods used for such transmission. (10 Marks)

- ✓ ***Analogue voltage transmission***
  - ✓ ***Analogue voltage signals can suffer corruption due to induced noise and the resistance of the connecting cables can result in attenuation of the voltage; the voltage drop across the output being reduced by that across the line resistance. Such effects can be reduced by the use of signal amplification and shielding with the connecting cables. However, because of these problems, such signals are not generally used for large distance transmission.***
- ✓ ***Current loop transmission***
  - ✓ ***The attenuation which occurs with voltage transmission can be minimised if signals are transmitted as varying current signals. This***

form of transmission is known as current loop transmission and uses currents in the range 4 mA to 20 mA to represent the levels of the analogue signal.

- ✓ ***Digital voltage signals***
  - ✓ ***Digital signals can be transmitted over transmission lines using either serial or parallel communication. With serial communication, the sequence of bits used to describe a value is sent in sequence along a single transmission line. With parallel transmission, each of the bits is sent along a separate parallel transmission line. For long-distance communication, serial communication is used.***
- ✓ ***Pneumatic transmission***
  - ✓ ***Pneumatic transmission involves converting the sensor output to a pneumatic pressure in that range 20 to 100 kPa or 20 to 180 kPa. The lower limit gives the zero-sensor signal and enables the zero value to be distinguished from a break in the circuit. Such pressure signals can then be transmitted though plastic or metal piping, the distances being limited to about 300 m because of the limitations of speed of response at larger distances.***
- ✓ ***Fibre-optic transmission***
  - ✓ ***An optical fibre is a light conductor in the form of a long fibre along which light can be transmitted by internally being reflected of the sides of the fibre. The light sources used are LEDs or semiconductor laser diodes. Digital electrical signals are converted into light pulses which travel down the fibre before being detected by a photodiode or phototransistor and converted back into an electrical signal.***

b) In carrying out the maintenance of a measurement system, the most important aid is the *maintenance manual*.

i. Describe five information contained in a maintenance manual.

(5 Marks)

- ✓ ***A description of the measurement system with an explanation of its use.***

- ✓ ***A specification of its performance.***
- ✓ ***Details of the system such as block diagrams illustrating how the elements are linked; photographs, drawings, exploded views, etc. giving the mechanical layout; circuit diagrams of individual elements; etc.***
- ✓ ***Preventative maintenance details, e.g. lubrication, replacement of parts, cleaning of parts and the frequency with which such tasks should be carried out.***
- ✓ ***Breakdown/corrective maintenance details, e.g. methods for dismantling, fault diagnosis procedures, test instruments, test instructions, safety precautions necessary to protect the service staff and precautions to be observed to protect sensitive components. With electrical systems the most commonly used test instruments are multi-range meters, cathode ray oscilloscopes and signal generators to provide suitable test signals for injections into the system.***
- ✓ ***Spare parts list.***

ii. Identify five activities carried out during maintenance. (5 Marks)

- ✓ ***Inspection to determine where potential problems might occur or where problems have occurred. This might involve looking to see if wear has occurred or a liquid level is at the right level.***
- ✓ ***Adjustment, e.g. of contacts to prescribed separations or liquid levels to prescribed values.***
- ✓ ***Replacement, e.g. routine replacement of items as part of preventative maintenance and replacement of worn or defective parts.***
- ✓ ***Cleaning as part of preventative maintenance, e.g. of electrical contacts.***
- ✓ ***Calibration. For example, the calibration of an instrument might drift with time and so recalibration becomes necessary.***