

LOCATION: SWANSEA

LLEOLIAD: ABERTAWE

LEVEL 4

LEFEL 4

**EXAMINATION PERIOD
AUGUST 2020**

**CYFNOD ARHOLIADAU
AWST 2020**

**MODULE CODE: M4X00386
ENGINEERING SCIENCE 2**

TIME: 2 HOURS

ANSWER ALL QUESTIONS

Equipment or materials required – Calculator.

FORMULAE BOOKLET FOR ELECTRICAL ENGINEERING
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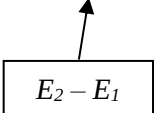
$Q = CV$	$Q = It$	$V = IR$	$V = V_0 e^{-\frac{t}{RC}}$	$I = I_0 e^{-\frac{t}{RC}}$
$Q = Q_0 e^{-\frac{t}{RC}}$	$P = IV$	$P = I^2 R$	$P = \frac{V^2}{R}$	$E = \frac{1}{2} CV^2$
$E = \frac{1}{2} QV$	$\rho = \frac{RA}{l}$	$R_T = R_1 + R_2 + R_3$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	$V = \varepsilon - Ir$
$V_{rms} = \frac{V_0}{\sqrt{2}}$	$I_{rms} = \frac{I_0}{\sqrt{2}}$	$V_{rms} = I_{rms} R$		

FORMULAE BOOKLET FOR THERMODYNAMICS

- **BASIC CONCEPT:**

The change in the energy content of a body or any other system is equal to the difference between the energy input and the energy output, and the energy balance is expressed as:

$$\Delta E = E_{in} - E_{out}$$



WORK:

Work done **by** the system is considered: **POSITIVE**

Work done **on** the system is considered: **NEGATIVE**

HEAT:

Heat transfer **into** the system is considered: **POSITIVE**.

Heat transfer **out** of the system is considered: **NEGATIVE**.

- **CLOSED SYSTEMS:**

Non-flow energy equation:

$$\Delta U = Q - W$$

- **ENTHALPY:**

$$H = U + P.V \quad (J)$$

Where:

- U = internal energy
- P = pressure
- V = volume

- **FLOW WORK:**

The **flow work**, or **flow energy**, or again **displacement energy**:

$$W_{flow} = P \times V$$

- **OPEN SYSTEMS / Steady-flow systems**

✓ Mass Balance:

$$\sum_{in} \dot{m} = \sum_{out} \dot{m} \quad (kg/s)$$

✓ Energy Balance:

$$\dot{Q} - \dot{W} = \sum_{out} \dot{m} \cdot \left(h + \frac{1}{2} \cdot c^2 + g \cdot z \right) - \sum_{in} \dot{m} \cdot \left(h + \frac{1}{2} \cdot c^2 + g \cdot z \right)$$

- **CONTINITY OF MASS FLOW:**

$\dot{m}$ = mass flow in kg/s

A = cross sectional area in m^2

v = specific volume in m^3/kg

c = velocity in m/s

Consider the volume of substance passing the section per second = $\dot{V}$ in m^3/s

$$\dot{V} = \dot{m} \cdot v \quad \text{also} \quad \dot{V} = A \cdot c \quad (\text{Continuity equation})$$

Therefore:

$$\dot{m} \cdot v = A \cdot c$$

From which

$$\dot{m} = \frac{A \cdot c}{v}$$

- **OPEN SYSTEMS / Unsteady-flow systems**

✓ Mass Balance:

$$m_i - m_e = m_2 - m_1$$

Where:

- i = inlet, and e = exit.
- 1 = initial state, and 2 = final state of the control volume.
- Often one or more terms in this equation are zero.

✓ Energy Balance: (when kinetic and potential energy changes associated with the control volume and fluid streams are negligible)

$$Q - W = \sum_{out} mh - \sum_{in} mh + (m_2 u_2 - m_1 u_1)$$

- **IDEAL GAS:**

We defined an **ideal gas** as a gas whose temperature, pressure, and specific volume are related by:

$$P \cdot v = R \cdot T$$

where:

- R is the gas constant (kJ/kg.K) or (kPa.m³/kg.K)
- P the absolute pressure (kPa)
- T the absolute temperature (K)
- v is the specific volume (m³/kg)

The change in internal energy or enthalpy for an **ideal gas** during a process from state 1 to state 2 are defined as:

$$u_2 - u_1 = c_v(T_2 - T_1) \quad (\text{kJ/kg})$$

$$h_2 - h_1 = c_p(T_2 - T_1) \quad (\text{kJ/kg})$$

where:

- c_v is the specific heat at constant volume
- c_p is the specific heat at constant pressure

Reminder:

$$^{\circ}C = K - 273$$

$$K = ^{\circ}C + 273$$

ELECTRICAL ENGINEERING

1. QUESTION ONE (10 marks)

- a) Define the following:
- i. Power [2]
 - ii. Capacitance [2]
- b) Calculate the charge passing a given point in 25 s when a current of 0.22 A is flowing [2]
- c) Figure 1 shows the circuit in question 1 where internal resistance is **not** neglected.
Given that the reading on A_1 is 2.5 A and $R_1 = 4.R_2$, what is the reading on A_2 ? [4]

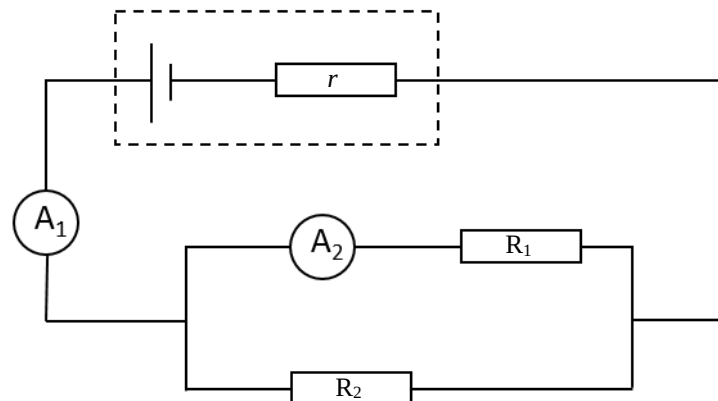


Figure 1

2. QUESTION TWO (20 marks)

Figure 2 shows an ac waveform that is displayed on an oscilloscope screen.

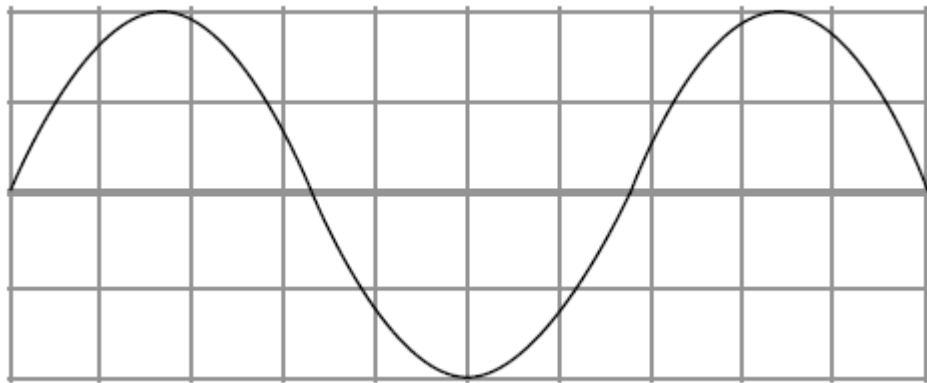


Figure 2

- a) The time base of the oscilloscope is set at 2.5 ms per division and the y-gain at 1.5 V per division.
- Calculate the frequency of the waveform [2]
 - Calculate the peak voltage [2]
 - Calculate the period [2]
 - Calculate the rms voltage [2]
- b) State and explain the effect on the oscilloscope if the time base is switched off [2]
- c) In the UK, domestic users are supplied with mains electricity at a *root mean square voltage* of 230 V.

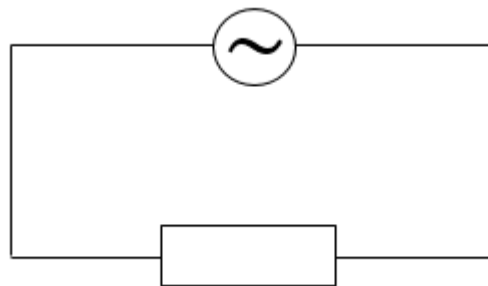


Figure 3

- State what is meant by root mean square voltage [2]
- Calculate the peak value of the supply voltage [2]
- Calculate I_{rms} if the peak current is 7.5A [2]
- Using your answer to (iii), if V_{rms} is 110 V, calculate the peak voltage and the value of resistor R [4]

3. QUESTION THREE (20 marks)

- a) A $720\ \mu\text{F}$ capacitor is charged fully from a $24\ \text{V}$ battery. At time $t = 0$ the capacitor begins to discharge through a resistor. When $t = 25\ \text{s}$ the energy remaining in the capacitor is one quarter of the energy it stored at $24\ \text{V}$.
- Determine the pd across the capacitor when $t = 25\ \text{s}$. [2]
 - Show that the time constant of the discharge circuit is $36\ \text{s}$. [2]
 - Calculate the resistance of the resistor [2]
- b) Figure 3 shows a capacitor which was charged to a pd of $12\ \text{V}$ and discharged through a $750\ \text{k}\Omega$ resistor.
- Calculate the initial discharge current [3]
 - Use the graph to determine the time constant of the circuit, giving the answer to an appropriate number of significant figures [5]
 - Calculate the capacitance of the capacitor [3]
 - Calculate how long it took for the capacitor to lose 75% of its initial voltage [3]

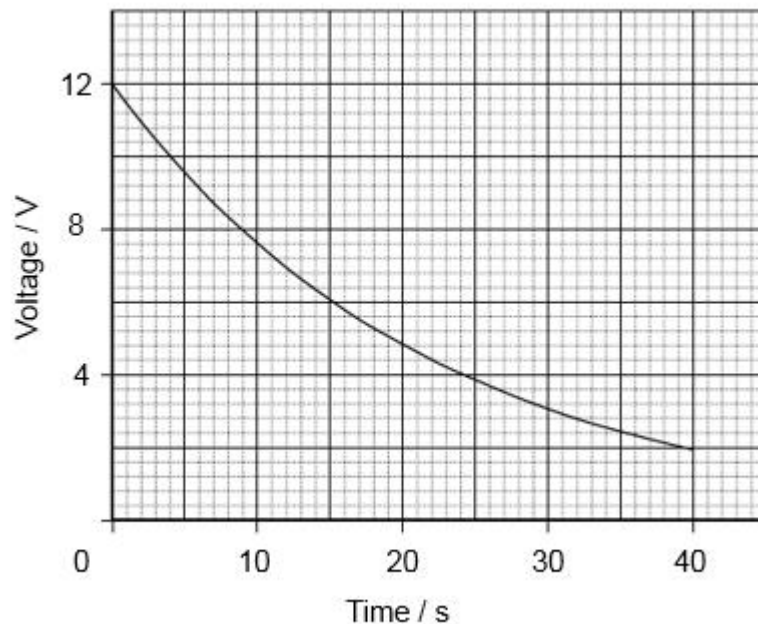


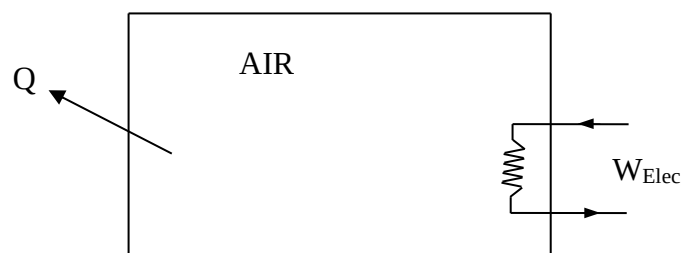
Figure 3

THERMODYNAMICS

4. QUESTION FOUR / Closed System (16 marks)

A rigid container equipped with a resistance heater contains 2 kg of air. The resistance heater is switched on for 28 minutes. Determine,

- i. The change of specific internal energy in kJ/kg during this time; knowing that the air container loses 3 MJ of heat while 1.8 kW of power is applied to the resistance heater. [12]
- ii. The final air temperature if the initial air temperature in the container is 10°C. [4]



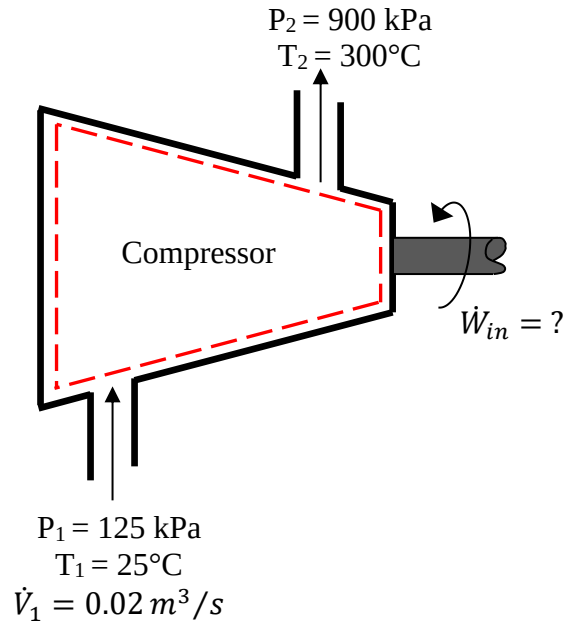
Assumptions:

- Air is considered as an ideal gas.
- Gas constant and specific heats values can be found in Table A-2.

5. QUESTION FIVE / Opens System, Steady-Flow Process (16 marks)

An adiabatic air compressor compresses 0.02 m³/s of air at 125 kPa and 25°C to 900 kPa and 300°C. Determine:

- i. The specific work required by the compressor in kJ/kg. [8]
- ii. The power required to drive the air compressor in kW. [8]



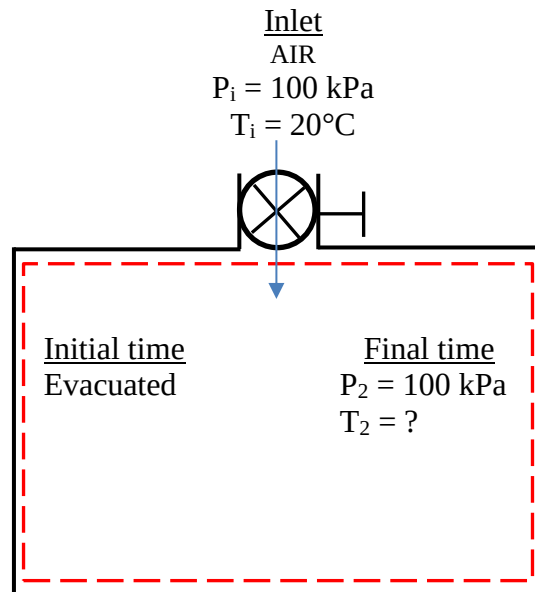
Assumptions:

- Air can be considered as an ideal gas.
- Gas constant and constant specific heat values can be found in Table A-2.
- Kinetic and potential energy changes are negligible.
- The device is adiabatic and thus heat transfer is negligible.

6. QUESTION SIX / Open System, Unsteady-Flow Process (18 marks)

An insulated rigid tank is initially evacuated. A valve is opened, and atmospheric air at 100 kPa and 20°C enters the tank until the pressure in the tank reaches 100 kPa, at which point the valve is closed. Determine,

- i. the final temperature of the air in the tank, [14]
- ii. the specific volume of the tank. [4]



Assumptions:

- Air can be considered as an ideal gas.
- Constant specific heat values can be found in Table A-2.
- Reminder: the change in internal energy or enthalpy for an ideal gas during a process from state a to state b are defined as:

$$u_b - u_a = c_v(T_b - T_a) \quad (\text{kJ/kg})$$

$$h_b - h_a = c_p(T_b - T_a) \quad (\text{kJ/kg})$$
- Kinetic and potential energy changes are negligible.
- There are no work interactions involved.
- The device is adiabatic and thus heat transfer is negligible.

TABLE A-2

Ideal-gas specific heats of various common gases

(a) At 300 K

Gas	Formula	Gas constant, R kJ/kg · K	c_p kJ/kg · K	c_v kJ/kg · K	k
Air	—	0.2870	1.005	0.718	1.400
Argon	Ar	0.2081	0.5203	0.3122	1.667
Butane	C ₄ H ₁₀	0.1433	1.7164	1.5734	1.091
Carbon dioxide	CO ₂	0.1889	0.846	0.657	1.289
Carbon monoxide	CO	0.2968	1.040	0.744	1.400
Ethane	C ₂ H ₆	0.2765	1.7662	1.4897	1.186
Ethylene	C ₂ H ₄	0.2964	1.5482	1.2518	1.237
Helium	He	2.0769	5.1926	3.1156	1.667
Hydrogen	H ₂	4.1240	14.307	10.183	1.405
Methane	CH ₄	0.5182	2.2537	1.7354	1.299
Neon	Ne	0.4119	1.0299	0.6179	1.667
Nitrogen	N ₂	0.2968	1.039	0.743	1.400
Octane	C ₈ H ₁₈	0.0729	1.7113	1.6385	1.044
Oxygen	O ₂	0.2598	0.918	0.658	1.395
Propane	C ₃ H ₈	0.1885	1.6794	1.4909	1.126
Steam	H ₂ O	0.4615	1.8723	1.4108	1.327

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