OCR
Oxford Cambridge and RSA

Wednesday 21 May 2025 – Morning

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873 Unit 4: Principles of electrical and electronic engineering

Time allowed: 1 hour 30 minutes
C304/2506

C304/2506

You must have:
- the Formula Booklet for Level 3 Cambridge Technical in Engineering (inside this document)
- a ruler (cm/mm)
- a scientific calculator

05822-04

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

Date of birth | D | D | M | M | Y | Y | Y | Y |

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working.
- Give your final answers to a degree of accuracy that is appropriate to the context.

INFORMATION
- The total mark for this paper is **60**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **16** pages.

ADVICE
- Read each question carefully before you start your answer.

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1 A student takes measurements on a battery.

(a) The battery provides current to resistor R_1.
An ammeter measures current through the resistor.
Complete the diagram below by adding a symbol for the ammeter and the connections needed to measure current through resistor R_1.

[2]

(b) The ammeter shows a current of 34 mA when a 220 Ω resistor is used.

(i) Calculate the voltage across the 220 Ω resistor.

voltage across 220 Ω resistor = ... V **[2]**

(ii) Calculate the power dissipated in the 220 Ω resistor.

power dissipated in the 220 Ω resistor = ... W **[1]**

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(c) The student changes the value of the resistor in the circuit and takes some more measurements.

(i) Complete the table of results below by calculating the missing values in the last **three** rows.

resistor value / Ω	current / mA	voltage across resistor / V	power dissipated in resistor / W
22	132	2.9	0.39
33	114	3.8	0.43
47	97	4.5	0.44
68		5.4	0.42
100	62		0.38
150	46	6.9	

.....

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.....

.....

[3]

(ii) The student was told that the internal resistance of the battery should be about 47 Ω. Explain how the student's results support what they were told about the battery.

.....

.....

.....

..... **[2]**

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2 A student investigates a circuit with an inductor, capacitor and resistor in series with an AC supply.

(a) Complete the circuit diagram to show how the inductor, capacitor and resistor should be connected to the AC supply.

AC generator 

[4]

(b) The student uses an inductor of value $L = 220\,\mu H$.

Calculate the reactance of the inductor, X_L, when the frequency of the AC supply is $f = 350\,Hz$.

$X_L =$ ..... Ω **[2]**

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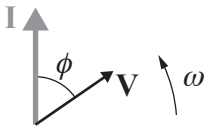
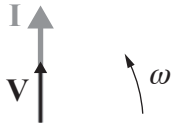
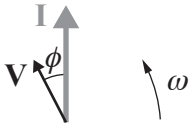
(c) The student investigates the effect of changing the frequency, f, of the AC supply on the phase angle, ϕ, between the voltage and current from the AC supply.

The values of the resistor, capacitor and inductor are as follows:

- $R = 3.3\,\Omega$
- $C = 3.2 \times 10^{-4}\,\text{F}$
- $L = 220\,\mu\text{H}$

Calculate the missing values to complete the table.

Include the units for your phase angles.

frequency f/ Hz	**reactance of inductor X_L/Ω**	**reactance of capacitor X_C/Ω**	**impedance of series RLC circuit Z/Ω**	**phase angle ϕ**	**phasor diagram**
100	0.14	5.0	5.9		
600	0.83	0.83		0°	
1450	2.0		3.7		

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[4]

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3 A series-wound DC motor is used to drive an electric scooter.

(a) The scooter uses a 24 V battery to supply electricity to the motor.

The armature has a resistance of 6.0 Ω and a field coil resistance of 0.5 Ω.

When the scooter is travelling at 15 mph the EMF generated in the armature, $E = 19$ V.

Use the equation for the DC series-wound motor to calculate the armature current, I_a.

$I_a =$ ..... A **[3]**

(b) The instructions for the scooter contain a warning that the motor should not be connected to the battery when the wheels are not in contact with the ground.

Explain the reason for the warning in the instructions by referring to the behaviour of a series-wound DC motor.

.....

.....

..... **[2]**

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(c) When users want to slow down the scooter, they operate a switch that disconnects the battery and connects the motor to a resistor.

The motor then behaves as a series-wound self-excited DC generator.

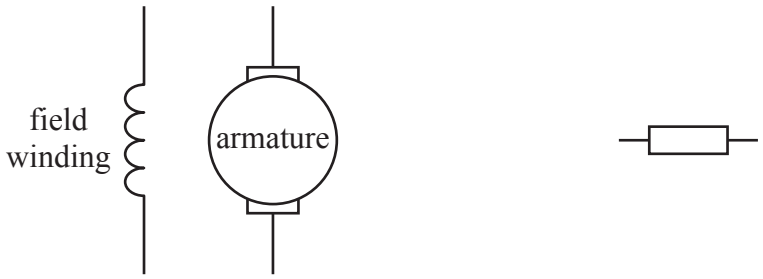
(i) Explain the difference between a motor and a generator.

.....

.....

..... **[2]**

(ii) Complete the diagram to show how the armature and field winding of the series-wound self-excited DC generator should be connected to the resistor.



[1]

(iii) Complete the sentences to explain how the series-wound DC generator is used to slow down the scooter.

Choose words from the following list.

Each word may be used once, more than once or not at all.

decreases **increases** **maintains** **oscillates**

Connecting the resistor to the generator causes a large current to flow through the field winding, which ..... the EMF generated in the armature and the voltage from the generator causing heating of the resistor. This ..... the torque required to turn the generator and decreases the speed of the scooter.

[2]

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4 A farm is supplied with electricity using a single phase 3-wire system.

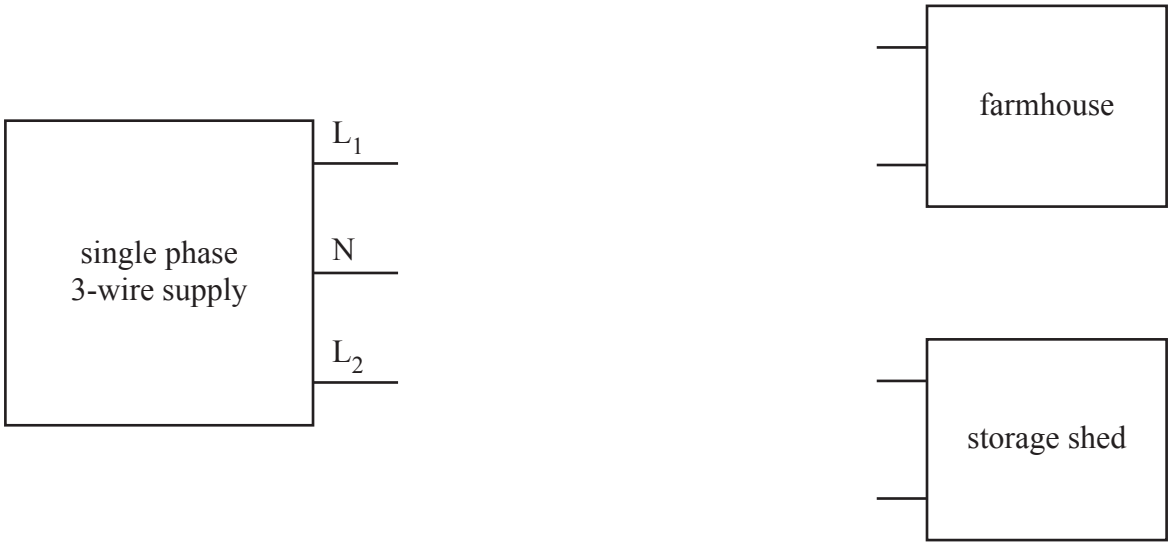
The electricity supply has a neutral wire, N, and two live wires, L_1 and L_2.

The voltage between a live wire and the neutral wire is 230 V AC.

One of the live wires is used to supply 230 V AC electricity to the farmhouse where the people live.

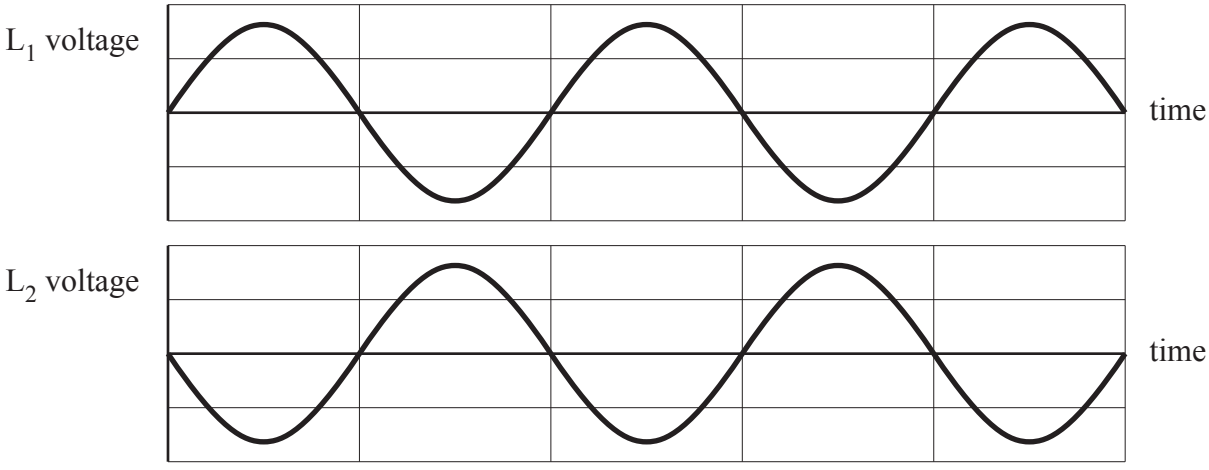
The other live wire is used to supply 230 V AC electricity to the storage shed for fridges that keep the produce fresh.

(a) Show how L_1, L_2 and N should be connected to the farmhouse and to the storage shed.



[2]

(b) The graphs below show how the voltages of L_1 and L_2 vary with time.



State the phase difference between L_1 and L_2.

..... **[1]**

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(c) The fridges and power supply are protected by a circuit breaker.

Explain how the circuit breaker protects the power supply and fridges.

.....

.....

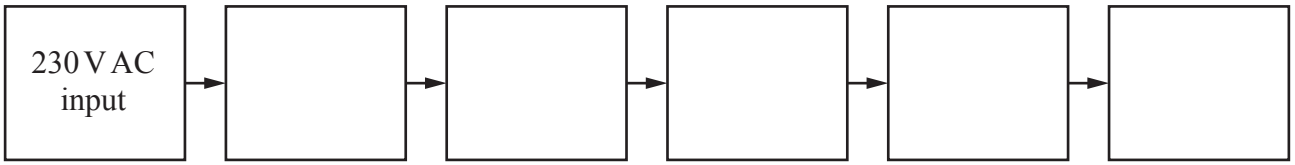
..... **[2]**

(d) The fridges are controlled by an electronic circuit that operates from 5 V DC.

Complete the block diagram of a stabilized power supply for the electronic circuit.

Choose from the terms below.

DC output	**rectifier**	**smoothing circuit**	**stabilising circuit**	**star**	**transformer**



[5]

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5 An engineer is building an op-amp inverting amplifier to amplify the signal from a force sensor.

The op-amp inverting amplifier has a voltage gain of –20.

The equation of the amplifier is given by:

$$Voltage\ Gain = \frac{V_{out}}{V_{in}} = -\frac{R_F}{R_{in}}$$

(a) The input voltage of the amplifier, $V_{in} = 160\,\text{mV}$.

Calculate the output voltage of the amplifier, V_{out}.

V_{out} = ... V **[3]**

(b) The engineer uses a feedback resistor, $R_F = 100\,\text{k}\Omega$.

Calculate the value of the input resistor, R_{in}, in ohms.

R_{in} = ... Ω **[2]**

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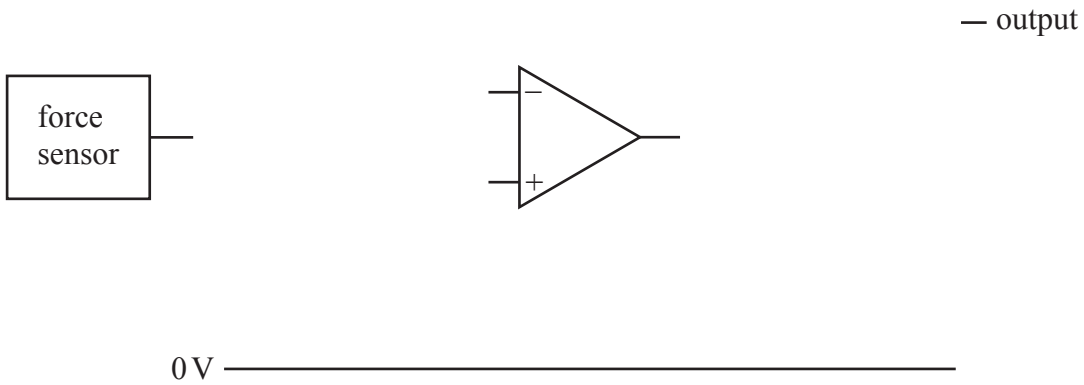
(c) Complete the circuit diagram of the op-amp inverting amplifier.

Show the connections to the force sensor and the output.

Label the resistors R_F and R_{in}.



[5]

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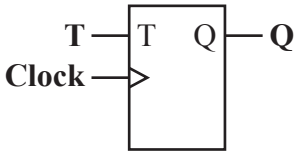
6

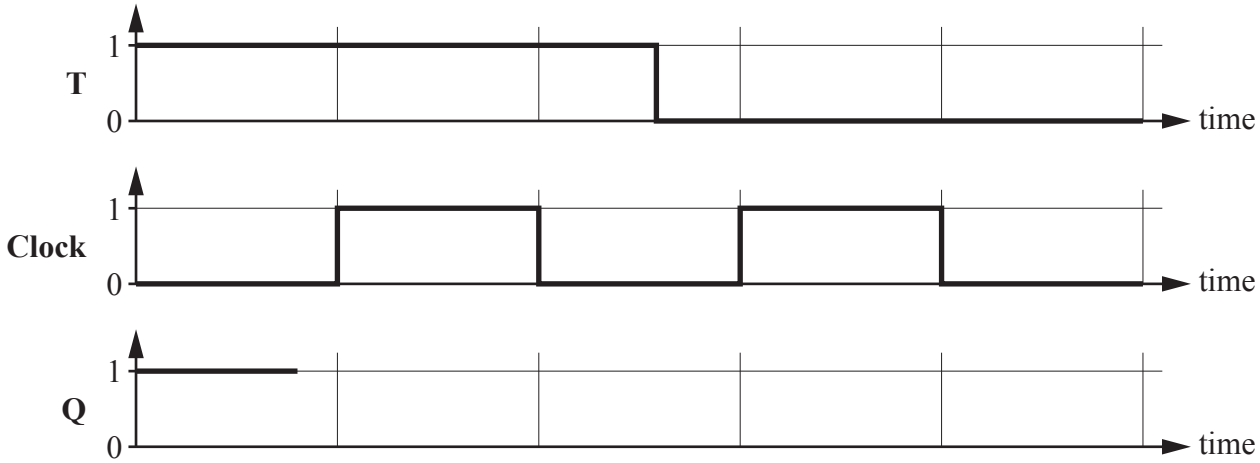
(a) The circuit symbol for a rising edge triggered T-type flip-flop is shown below.



A timing diagram shows the how the logic levels at **T**, **Clock** and **Q** vary with time.

The **T** and **Clock** signals have been completed; **Q** starts at logic 1.

Complete the timing diagram below to show how **Q** varies with time.



[2]

(b) An OR gate with output **Q** and inputs **A** and **B** is used in a circuit.

(i) Draw the circuit symbol for an OR gate.

[1]

(ii) Complete the truth table for an OR gate.

A	B	Q

[2]

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(iii) Which of the following is the correct Boolean expression for an OR gate?

Tick (✓) **one** box.

Q = A · B ☐

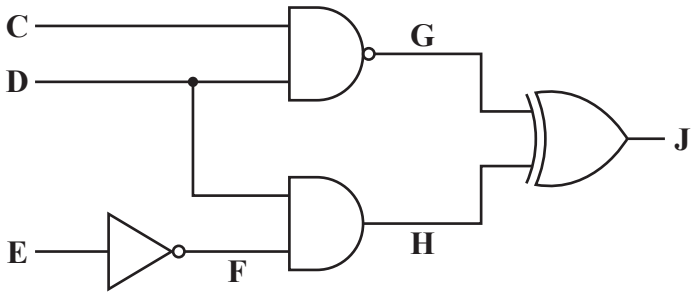
Q = A + B ☐

Q = A ⊕ B ☐

Q = $\overline{\mathbf{A \cdot B}}$ ☐

[1]

(c) A logic circuit is shown below.



Complete the truth table for the logic circuit.

C	D	E	F	G	H	J
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

[4]

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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