Oxford Cambridge and RSA

Monday 17 January 2022 – 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
C304/2201

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

Please write clearly in black ink.

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 **20** pages.

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

FOR EXAMINER USE ONLY	
Question No	**Mark**
1	/9
2	/11
3	/9
4	/11
5	/10
6	/10
Total	**/60**

Answer **all** the questions.

1 The circuit diagram in **Fig. 1** shows a network of resistors.

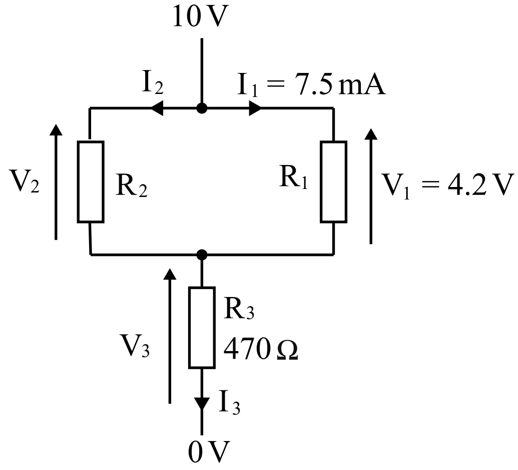

Fig. 1

(a) A voltmeter is used to measure the voltage V_1.

(i) Draw **on Fig. 1** to show how a voltmeter should be connected to measure the voltage V_1. **[1]**

(ii) A multimeter is used as a voltmeter to measure the voltage V_1.

Fig. 2a shows a multimeter with the dial in the off position.

Draw an arrow **on Fig. 2b** showing the correct position of the dial to precisely measure the voltage V_1.

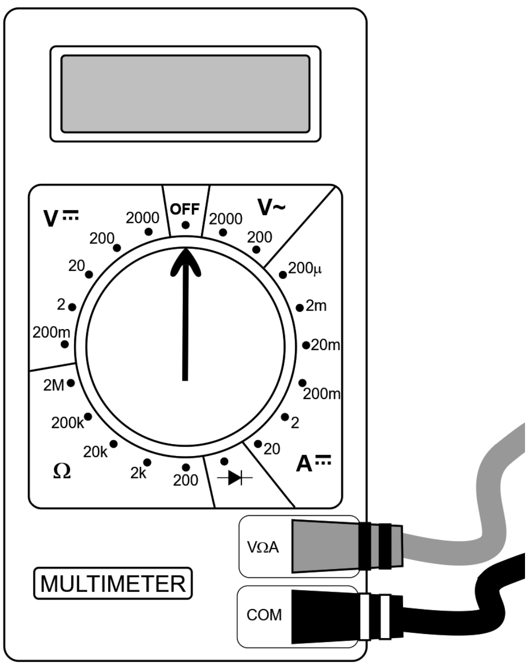

Fig. 2a

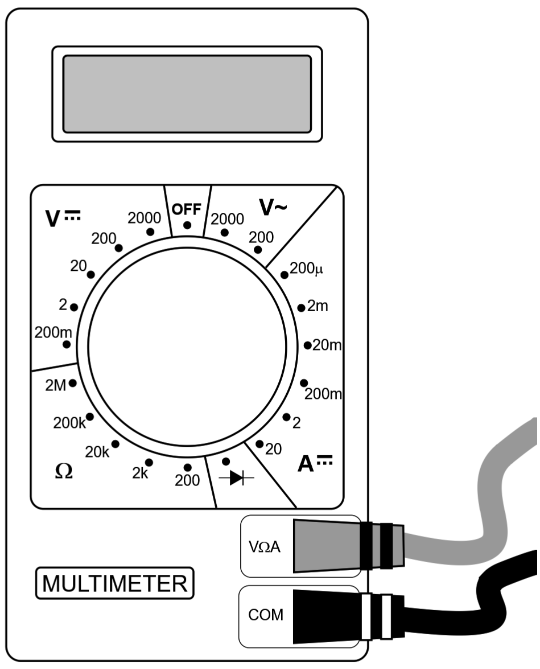

Fig. 2b

[1]

(b) Calculate the value of the resistor R_1.

R_1 = ... Ω **[1]**

(c) Calculate the voltage V_3.

V_3 = ... V **[1]**

(d) Calculate the current I_3.

I_3 = ... A **[1]**

(e) Calculate the value of the resistor R_2.

R_2 = ... Ω **[2]**

(f) Calculate the resistance of the network of resistors.

resistance of the network of resistors = ... Ω **[2]**

2 **(a)** A sine wave alternating current (AC) supply of frequency $f = 455$ kHz is connected in series with a resistor (R), a capacitor (C) and an inductor (L).

(i) Draw a diagram of the circuit.

Label all components.

[2]

(ii) The value of inductor $L = 240$ μH.

Calculate the reactance X_L of the inductor when the frequency $f = 455$ kHz.

$X_L =$ .... Ω **[3]**

(iii) The reactance of the capacitor $X_C = 910$ Ω when the frequency $f = 455$ kHz.

Calculate the value of the capacitor (C).

Give the units for your answer.

$C =$ .... **[3]**

(iv) The value of the resistor $R = 330\ \Omega$.

Calculate the impedance (Z) of the circuit at a frequency of 455 kHz.

$Z =$ .... Ω **[2]**

(v) Calculate the amplitude of the current in the circuit when it is supplied with a sine wave of amplitude 15 V at a frequency of 455 kHz.

Use the equation $I = \frac{V}{Z}$

$I =$ .... A **[1]**

3 An electric food mixer uses a shunt-wound DC motor.

(a) Draw **on Fig. 3** to show how a field winding and armature should be connected to a 14.4 V power supply in a shunt-wound DC motor.

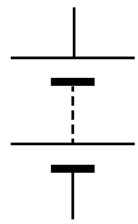

Fig. 3

[2]

(b) Complete the sentences in the paragraph below by choosing the most appropriate words from the list.

Use each word once, more than once or not at all.

constant

increased

infinite

reduced

zero

A shunt-wound DC motor maintains a fairly constant speed regardless of load.

When the motor is running with no load, it spins at high speed.

When a load is applied to the motor, the speed reduces, and the EMF generated in the armature is ……………………….................... .

This means that the current in the armature is increased and so the torque is ……………………….................... .

The current in the field winding is ……………………….................... .

All of this keeps the load speed of the motor close to its no-load speed.

[3]

(c) The shunt-wound motor has a field winding resistance (R_f) of 48 Ω and an armature winding resistance (R_a) of 18 Ω.

(i) Calculate the current in the field winding (I_f) when 14.4 V is supplied to the motor.

I_f = ... A **[1]**

(ii) The motor operates from a 14.4 V power supply (V).

When the motor is turning at high speed, it produces a back EMF (E) of 12.2 V.

Calculate the armature current (I_a) in the motor.

Use the equation $V = E + I_aR_a$

I_a = ... A **[2]**

(iii) Calculate the total current (I_t) drawn from the power supply when the motor is turning at high speed.

I_t = ... A **[1]**

4 (a) The block diagram and circuit diagram for a power supply are shown in **Fig. 4**.

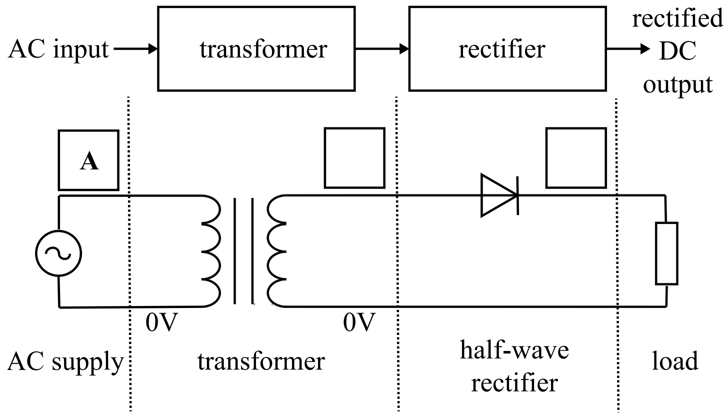

Fig. 4

Graphs **A-E** in **Fig. 5** show how voltage can change over time.

In **Fig. 4**, the letter **A** indicates that **Graph A** shows the way that voltage changes over time at this point in the circuit.

Fill in the **two** blank boxes ☐ **in Fig. 4** to show which graph (**B**, **C**, **D** or **E**) represents the way that voltage changes over time at each point in the circuit.

[2]

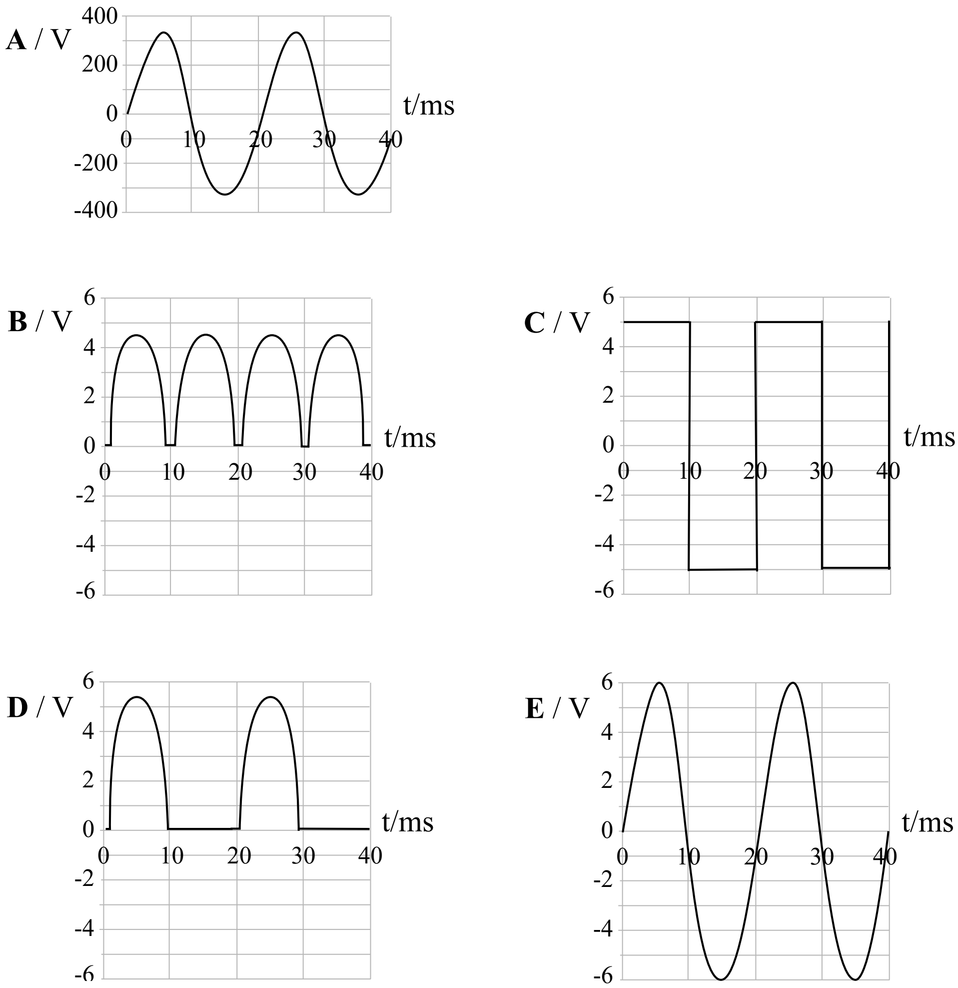

Fig. 5

(b) An incomplete block diagram of a stabilised power supply is shown in **Fig. 6**.

(i) Add the names of the **two** missing blocks to complete the stabilised power supply.

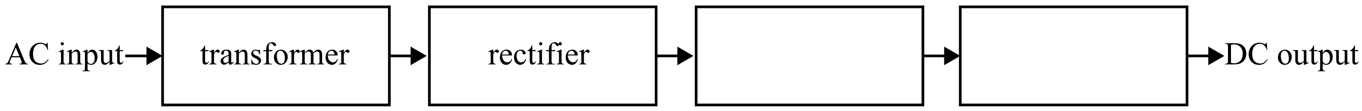

Fig. 6

[2]

(ii) A stabilised power supply has good load regulation.

Explain what is meant by good load regulation.

....

....

....

.... **[2]**

(c) An LED is used to show that the DC output of a 3.3 V power supply is operating.

(i) Complete **Fig. 7** to show how an LED and current limiting resistor can be used to show that the power is operating.

Label the parts in your diagram.

Fig. 7

[3]

(ii) Explain the function of the current limiting resistor in **Fig. 7**.

....

....

....

.... **[2]**

5 **(a)** The table shows the input voltage (V_{in}), output voltage (V_{out}) and voltage gain of three different amplifiers.

Complete the table with the missing values.

Use the equation: Voltage Gain = $\frac{V_{out}}{V_{in}}$

Input voltage (V_{in})	**Output voltage (V_{out})**	**Voltage gain**
3.0	1.5	
-2.5		3
	6	-1.5

[3]

(b) Calculate the resistors for a non-inverting operational amplifier, constructed from an operational amplifier (op-amp) with a voltage gain of 1.5.

Use the equation: Voltage Gain = $1 + \frac{R_F}{R_2}$

R_F = ... kΩ

R_2 = ... kΩ

[2]

(c) Complete **Fig. 8** to show a non-inverting amplifier.

Label the input, output, R_F and R_2.

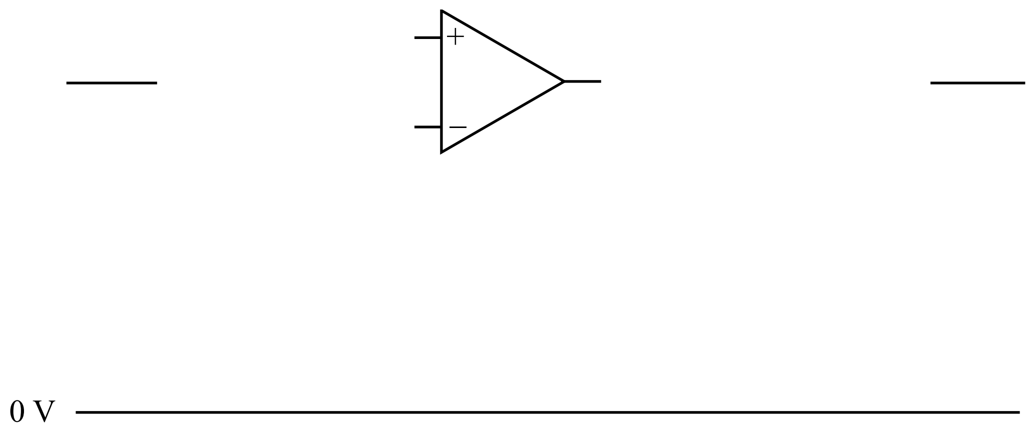

Fig. 8

[5]

6 **(a)** The circuit symbol for a T-type flip-flop is shown in **Fig. 9**.

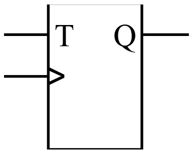

Fig. 9

Draw a line to join the start of each sentence to the most appropriate end of sentence about the behaviour of a T-type flip-flop.

There will be some end of sentences without a connecting line.

Start of sentence	End of sentence
	...Q changes.
When a T-type flip-flop is triggered and T is low, ...	
	...Q stays the same.
	...T changes.
When a T-type flip-flop is triggered and T is high, ...	
	...the clock is $\overline{T}$.

[2]

Question 6(b) begins on page 14

(b) A partially complete truth table for a logic gate is shown below.

A	**B**	**Q**
0	0	1
		0
		0
		0

(i) Complete the truth table by filling in columns **A** and **B**.

[1]

(ii) Name the logic gate described by the truth table.

.... **[1]**

(iii) Draw the circuit symbol for the logic gate described by the truth table.

Label the inputs **A** and **B** and label the output **Q**.

[1]

(iv) Put a (ring) around the correct Boolean expression for the logic gate described by the truth table.

$\mathbf{Q = A + B}$ $\quad$ $\mathbf{Q = \overline{A + B}}$ $\quad$ $\mathbf{Q = A \cdot B}$ $\quad$ $\mathbf{Q = \overline{A \cdot B}}$ $\quad$ $\mathbf{Q = A \oplus B}$

[1]

(c) **Fig. 10** shows a logic gate circuit.

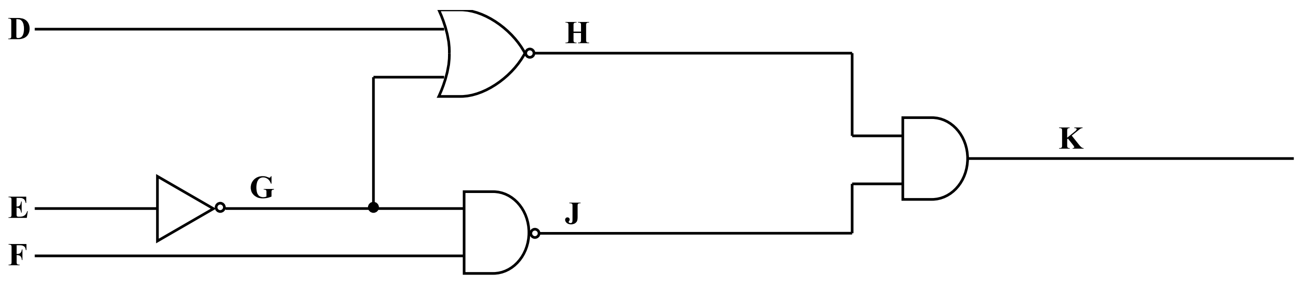

Fig. 10

Complete the truth table for this circuit.

D	E	F	G	H	J	K
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

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question numbers must be clearly shown – for example, 1(d) or 6(c).