Oxford Cambridge and RSA

Wednesday 15 January 2020 – Afternoon

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 plus your additional time allowance

You must have:

the Formula Booklet for Level 3 Cambridge Technical in Engineering (with this document)

a ruler (cm/mm)

a scientific calculator

Modified Enlarged 18 pt

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 [ ].

ADVICE

Read each question carefully before you start your answer.

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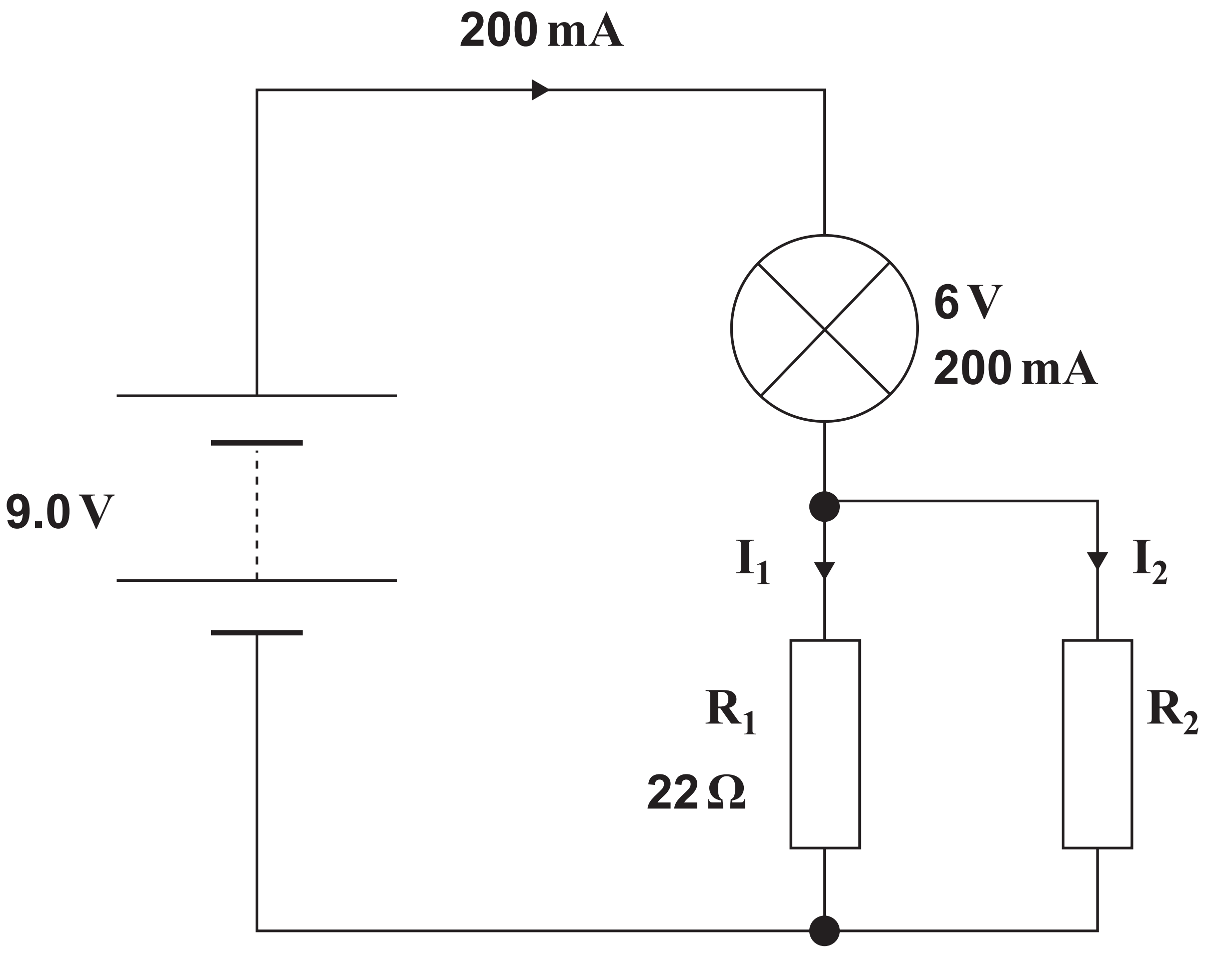
Answer ALL the questions.

1 **The circuit diagram in Fig. 1 shows a circuit for operating a lamp at 6.0 V, 200 mA from a 9.0 V battery of negligible internal resistance.**

Fig. 1



(a) **Calculate the power dissipated by the lamp.**

P = ______________________________ W [1]

(b) Calculate the energy dissipated by the lamp in 3 minutes.

Give the correct units for your answer.

energy dissipated = ______________________________ [3]

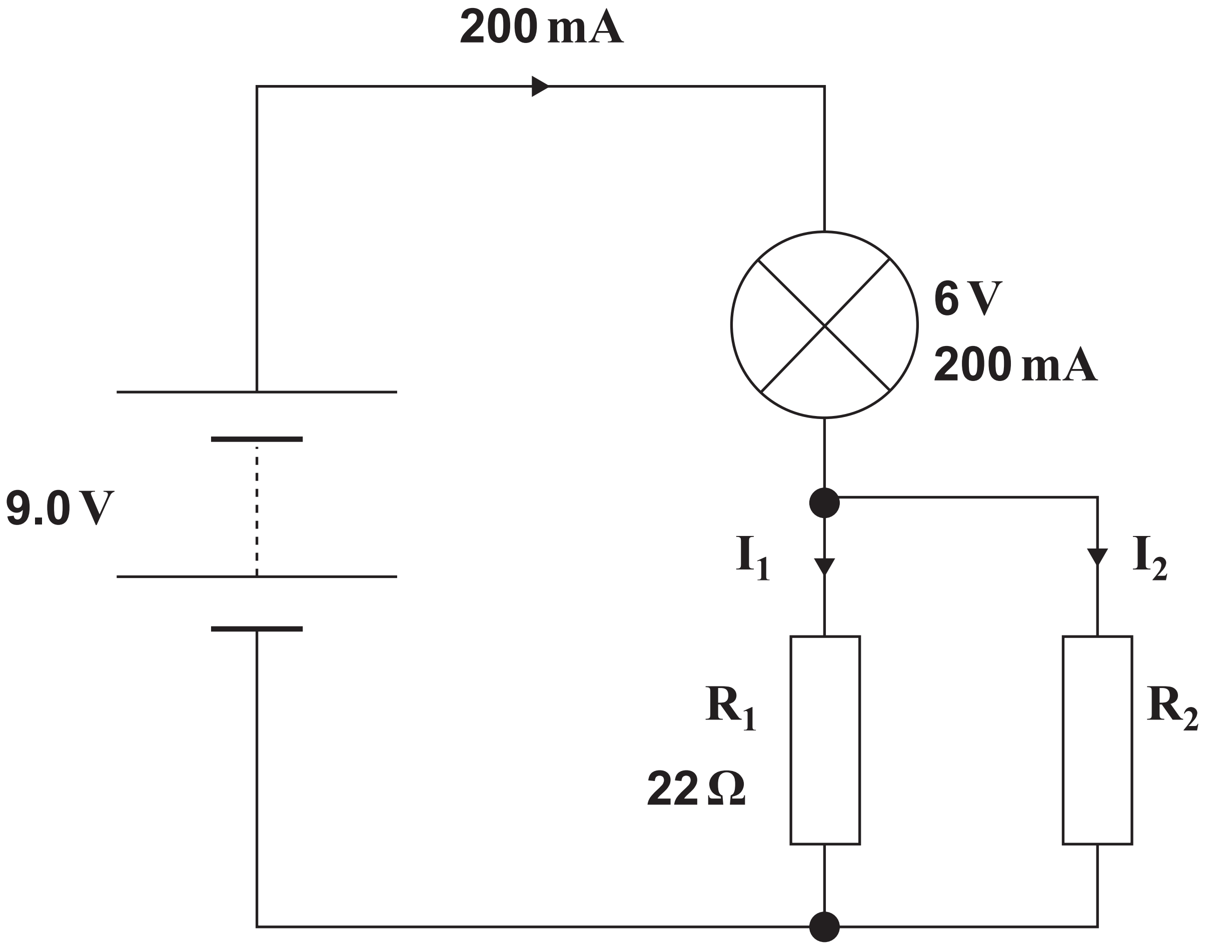
(c) Calculate the voltage across the resistor R_1.

voltage across R_1 = ____________________________ V [1]

(d) Calculate the current I_1.

I_1 = ____ mA [1]

This is a copy of Fig. 1



(e) Calculate the value of the resistor R_2.

R_2 = ______________________________ Ω [2]

(f) Calculate the total resistance of R_1 and R_2 in parallel.

total resistance of R_1 and R_2 =

______________________________________ Ω [1]

(g) Draw ON Fig. 1 on PAGE 6 to show how a voltmeter should be connected to measure the terminal voltage of the battery. [1]

2 **A sine wave alternating current (AC) supply with a frequency f = 250 kHz is connected in series with a resistor R = 4.7 kΩ and a capacitor C = 220 pF.**

(a) (i) **Draw a diagram of the circuit. Label all components with their values. Use the space below. [3]**

(ii) Calculate the reactance, X_C, of the capacitor C.

X_C = ______________________________ Ω [3]

(iii) Calculate the impedance, Z, of the series resistor and capacitor circuit at 250 kHz.

Z = ______________________________ Ω [2]

(iv) Calculate the phase difference, ϕ, in degrees between the voltage signal across the circuit and the current signal through the circuit.

Use the equation $\cos \phi = \frac{R}{Z}$

ϕ = ______________________________ ° [2]

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3 An electric train uses series-wound DC motors.

(a) Complete Fig. 2 to show how the field winding and armature in a series-wound DC motor should be connected to a 315 V power supply. Label all of the parts of the motor. [2]

Fig. 2

(b) Suggest why the train uses series-wound DC motors rather than shunt-wound DC motors.

____

____

____

____ [2]

(c) The series-wound motor has a field winding resistance (R_f) of 0.63 Ω and an armature winding resistance (R_a) of 0.42 Ω.

(i) Calculate the resistance (R_t) of the DC series-wound motor.

R_t = ______________________________ Ω [1]

(ii) The motor operates from a 315 V power supply (V).

When the motor is turning quickly, it produces a back EMF (E) of 141 V.

Calculate the armature current (I_a) in the DC series-wound motor.

I_a = ____ A [2]

(iii) When the train starts to climb a small hill, the gradient of the hill makes the train and motor slow down, even though the electrical supply to the motor remains the same.

Explain what happens to the armature current as the train and motor slow down.

____

____

____

____

____

____ [3]

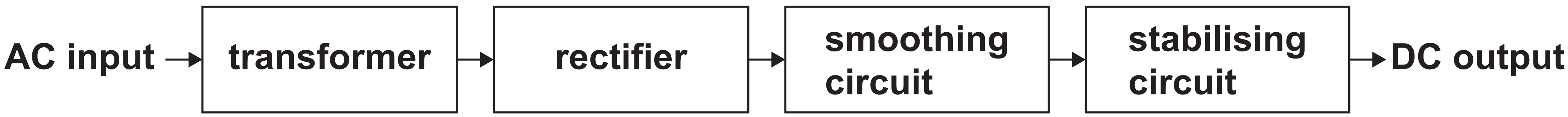
4 The block diagram of a stabilised power supply is shown in Fig. 3 opposite.

(a) A rectifier is used as part of the stabilised power supply.

(i) Complete Fig. 4 below to show how alternating current (AC) can be converted to half-wave direct current (DC) of the correct polarity using a SINGLE diode as a half-wave rectifier. [3]

Fig. 4

Fig. 3


AC input
transformer
rectifier
smoothing circuit
stabilising circuit
DC output

(ii) Explain how the half-wave rectifier works.

____

____

____

____ [2]

(b) The stabilising circuit in Fig. 3 provides good load regulation.

Explain what load regulation means.

____

____

____

____ [2]

(c) Complete the paragraph below using the most appropriate word in each gap.

Choose words from the following list.

Each word may be used once, more than once or not at all. [3]

high

low

series

no

parallel

phase

Fuses are used to protect power supplies and electrical devices. A fuse is connected in __________________________ with the power supply and the electrical device.
If a fault occurs in the electrical device and it draws too much power then __________________________ current flows through the fuse causing it to get very hot and melt. After the fuse has melted __________________________ current is supplied to the electrical device and it stops operating.

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5 (a) The table below compares the characteristics of an ideal operational amplifier (op-amp) with a real op-amp.

Complete the table using the most appropriate word in each gap.

Choose words from the following list.

Each word may be used once, more than once or not at all. [4]

differential

high

infinite

low

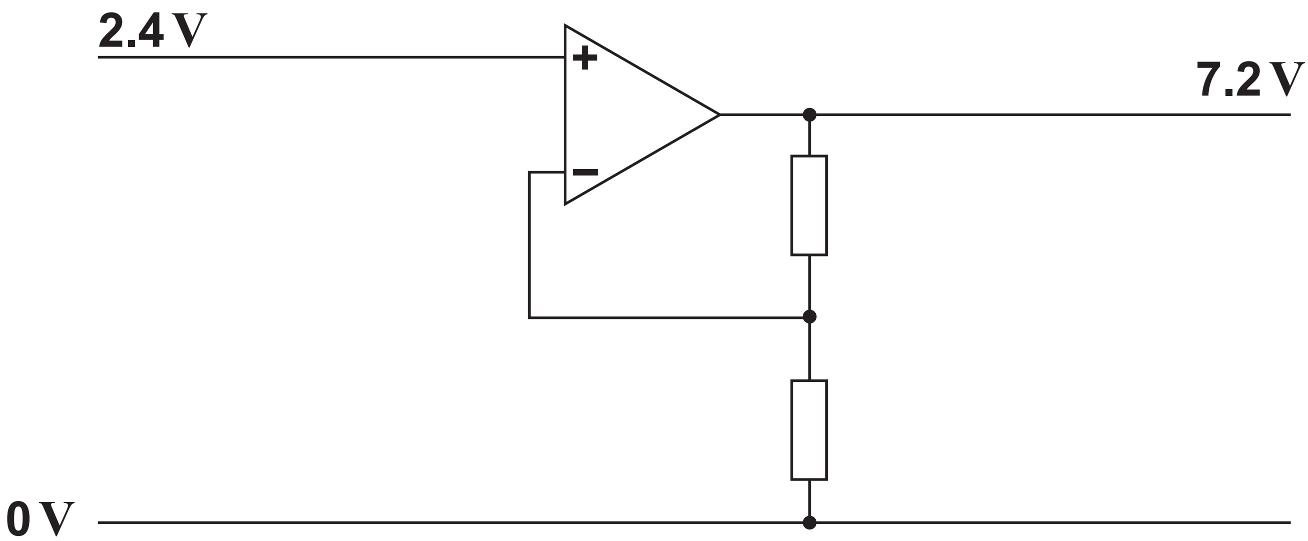
zero

Characteristic	Ideal op-amp	Real op-amp
open-loop gain		very high
input impedance		
output impedance	zero	

(b) The circuit diagram of an op-amp amplifier is shown in Fig. 5.

(i) Label the INPUT and OUTPUT of the amplifier. [1]

Fig. 5



(ii) Put a ring around the name of the amplifier circuit in Fig. 5. [1]

class C amplifier

inverting amplifier

non-inverting amplifier

RF amplifier

(iii) Calculate the voltage gain of the circuit in Fig. 5.

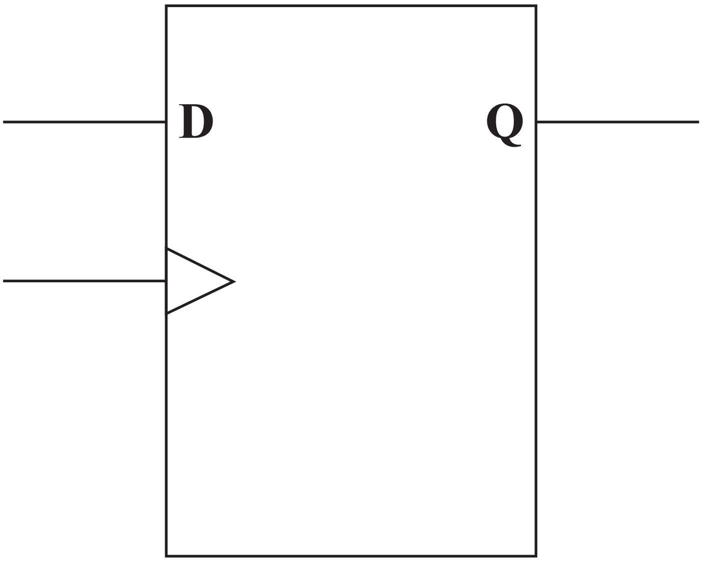
Use the equation Voltage Gain = $\frac{V_{out}}{V_{in}} = 1 + \frac{R_F}{R_2}$

voltage gain = ______________________________ [1]

(iv) Calculate suitable values for the resistors in the amplifier AND label them ON Fig. 5 with their values AND units. Use the space below for your calculations. [3]

6 (a) The circuit symbol for a rising-edge triggered D-type flip-flop is shown in Fig. 6.

Fig. 6



Draw a line to join the start of each sentence to the most appropriate end of sentence describing the behaviour of a rising-edge triggered D-type flip-flop.

There will be some end of sentences with no connecting line. [2]

Start of sentence	End of sentence
A rising-edge D-type flip-flop is triggered when the clock changes ...	from D to Q.
When a rising-edge D-type flip-flop is triggered, the information is copied ...	from 0 to 1.
	from 1 to 0.
	from Q to D.

(b) Draw the circuit symbol for an XOR gate.
Label the inputs A and B and label the output Q.
Use the space below. [1]

(c) Complete the truth table for an XOR gate. [2]

A	B	Q

(d) Put a ring around the correct Boolean expression for an XOR gate. [1]

$Q = A + B$

$Q = \overline{A + B}$

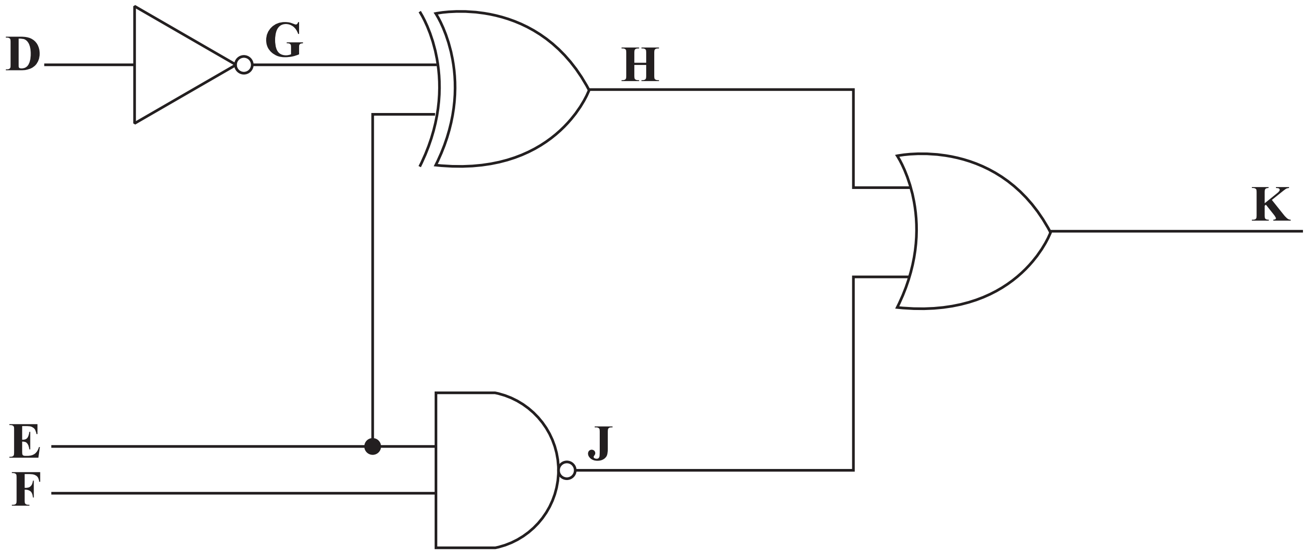
$Q = A \cdot B$

$Q = \overline{A \cdot B}$

$Q = A \oplus B$

(e) Fig. 7 shows a logic gate circuit.

Fig. 7



Complete the truth table for the logic gate circuit in Fig. 7. [4]

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				

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(b).

Version 4