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Examiners' report

ENGINEERING

05822–05825, 05873

Unit 4 January 2022 series

Version 1

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Contents

Introduction

Our examiners’ reports are produced to offer constructive feedback on candidates’ performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates’ performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Unit 4 series overview

As with previous series, candidates taking the Principles of Electrical and Electronic Engineering exam seemed particularly confident with the electronic content and particularly digital. Most challenging was DC theory and the application of Ohm's Law, Kirchoff's Laws, and the resistor equivalency formula. Candidates who had revised and committed to memory circuit diagrams performed well as did those able to handle the algebra required to use the formula booklet successfully.

Candidates who did well on this paper generally did the following:	***Candidates who did less well on this paper generally did the following:***
• Recalled circuit symbols for electrical components. • Had the knowledge of algebra required to use the formula in the formula booklet to solve an equation for an unknown. • Could confidently apply Kirchoff's first and second laws. • Could confidently recall circuit diagrams for op amps and motors. • Wrote clearly with any changes/corrections to responses being clearly understood, e.g. when changing responses in the truth table there was no ambiguity.	• Did not carefully draw circuit diagrams, and missed some labelling where required, or symbols were drawn inaccurately. • Did not successfully handle prefixes to give the correct response to the correct power of ten. • Did not always include correct units. • Did not attempt or gave incorrect/weak responses to questions looking for an explanation. • Did not give a response to all of the numerical questions and were therefore unable to access later parts of the question (candidates should be attempting all parts, as error carried forward marking for subsequent questions is given).

Question 1 (a) (i)

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

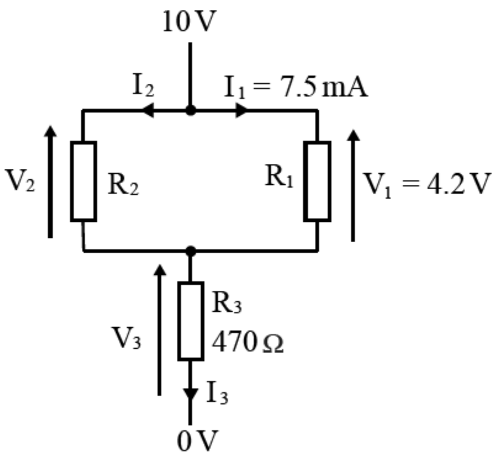

Fig. 1

(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]**

The majority of candidates answered this question successfully showing the voltmeter connected in parallel across resistor R_1. However, there were many responses where the voltmeter symbol did not appear to be familiar to the candidate with alternative symbolling used, which was accepted within the context of this question but in future series may not be, so candidates should be familiar with the symbols for meters.

	AfL	Candidates should be familiar with the symbols for the main electrical meters i.e. voltmeter, ammeter, and ohmmeter and how they are connected in a circuit.

Question 1 (a) (ii)

(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.

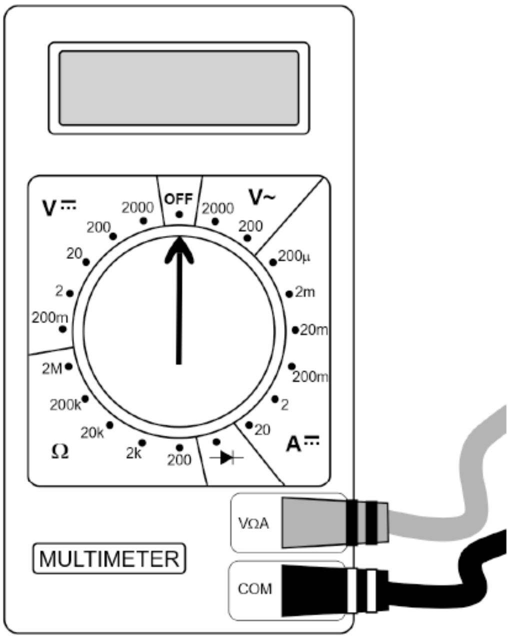

Fig. 2a

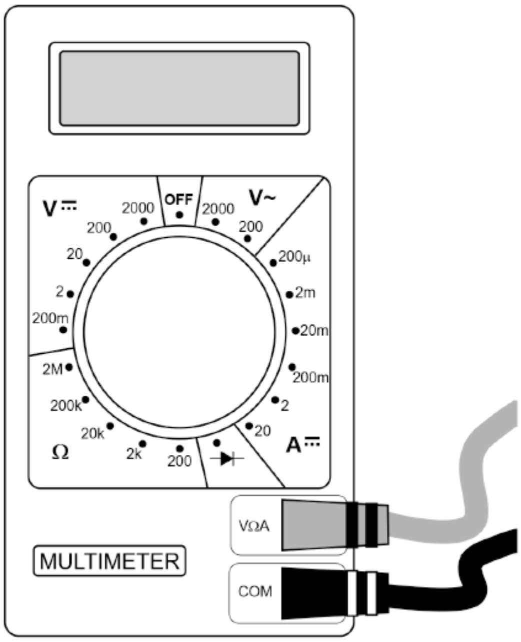

Fig. 2b

[1]

Although the majority of candidates responded correctly with the 20V DC setting, a significant minority opted for either the 2V or attempted to choose a value between the 2V and 20V, with very few choosing an alternative response.

Question 1 (b)

(b) Calculate the value of the resistor R_1.

R_1 = ... Ω **[1]**

This question was handled well with the majority of candidates comfortable using Ohm's Law. The most common error was ignoring the milli prefix on the current.

Question 1 (c)

(c) Calculate the voltage V_3.

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

This question was much less successfully handled with candidates struggling to apply Kirchoff's second law. Frequently seen incorrect responses were 10V and 4.2V. Candidates should be familiar with the use of this law in a range of contexts both with full circuit diagrams and resistor networks, as in this question.

Question 1 (d)

(d) Calculate the current I_3.

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

Again candidates coped well with this application of Ohm's Law, with the vast majority being able to divide their response to 1c by 470 ohms.

Question 1 (e)

(e) Calculate the value of the resistor R_2.

$R_2 =$ .... Ω **[2]**

This question was only answered successfully by the most able candidates. The majority were unable to access the first mark which required use of Kirchoff's second law to determine voltage and Kirchoff's first law to determine current, with a significant minority incorrectly adding I_3 to I_1 to get I_2.

	AfL	Candidates should be given opportunity to apply Kirchoff's first and second laws to a range of simple circuits and resistor networks.

Question 1 (f)

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

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

Candidates that were able to identify that R_1 and R_2 were connected in parallel in general applied the parallel formula successfully. The majority of candidates were able to access the second mark for adding 470 Ohms (for a resistor in series) onto their calculated value of R_1 and R_2.

Question 2 (a) (i)

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]

Although the majority of candidates appeared familiar with the symbols for a resistor, capacitor, inductor, and AC supply, a significant minority were unable to draw all accurately and many did not follow the instructions to label all components. On a significant minority of papers, one of the symbols was omitted entirely.

Question 2 (a) (ii)

(ii) The value of inductor $L = 240\ \mu H$.

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

$X_L =$ .... Ω **[3]**

The vast majority of candidates were able to select and use the correct formula with marks predominantly being lost due to incorrect handling of prefixes.

	AfL	Candidates should be familiar with the use of prefixes.

Question 2 (a) (iii)

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

Calculate the value of the capacitor (C).

Give the units for your answer.

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

Candidates seemed far less familiar with using this equation to find C rather than X_C with many failing to substitute correctly. Of those that did substitute correctly only a minority were able to successfully rearrange the equation. The units of capacitance were not well known as Farad (F) with many candidates selecting Henry, Ohm or just using C.

	AfL	Candidates should have the level of algebra required to use all equations in the formula booklet, rearranging as appropriate. Standard units for all variables should be learned.

Question 2 (a) (iv)

(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]**

Although many candidates were able to select the correct formula from the formula booklet (with the most common error being using the RL or RC formula instead of RLC) a significant number of candidates substituted the value for C into the equation rather than X_C.

Question 2 (a) (v)

(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]**

This question was handled well with almost all candidates able to divide 15 by their answer to Question 2 (a) (iv) to secure the mark. The majority of incorrect responses were from candidates who did not attempt the question.

Question 3 (a)

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.

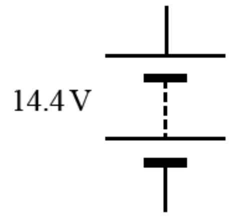

Fig. 3

[2]

The symbol for field winding appeared far more familiar than that for an armature with many candidates appearing to need practice with drawing this. However, the question was well handled in general with a small minority drawing the symbols in series rather than parallel.

Question 3 (b)

(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]

This question was not well handled with only a minority of candidates able to show an understanding of electrical theory in a shunt wound motor.

Question 3 (c) (i)

(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]**

The application of Ohm's Law was attempted by most but some candidates attempted to include the armature resistance in their calculation.

Question 3 (c) (ii)

(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]**

Although the correct equation was given, a minority were able to handle the algebra required to rearrange the equation successfully to come to the correct answer.

Question 3 (c) (iii)

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

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

The majority of candidates were able to apply the correct formula and add their Question 3 (c)(i) to their Question 3 (c)(ii) to find the total current.

Question 4 (a)

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

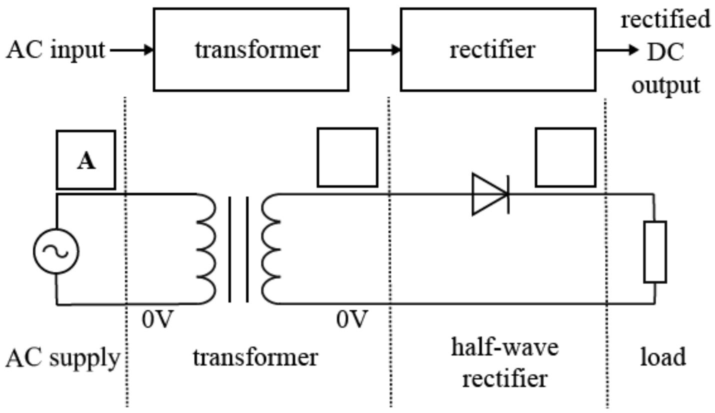

Fig. 4

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]

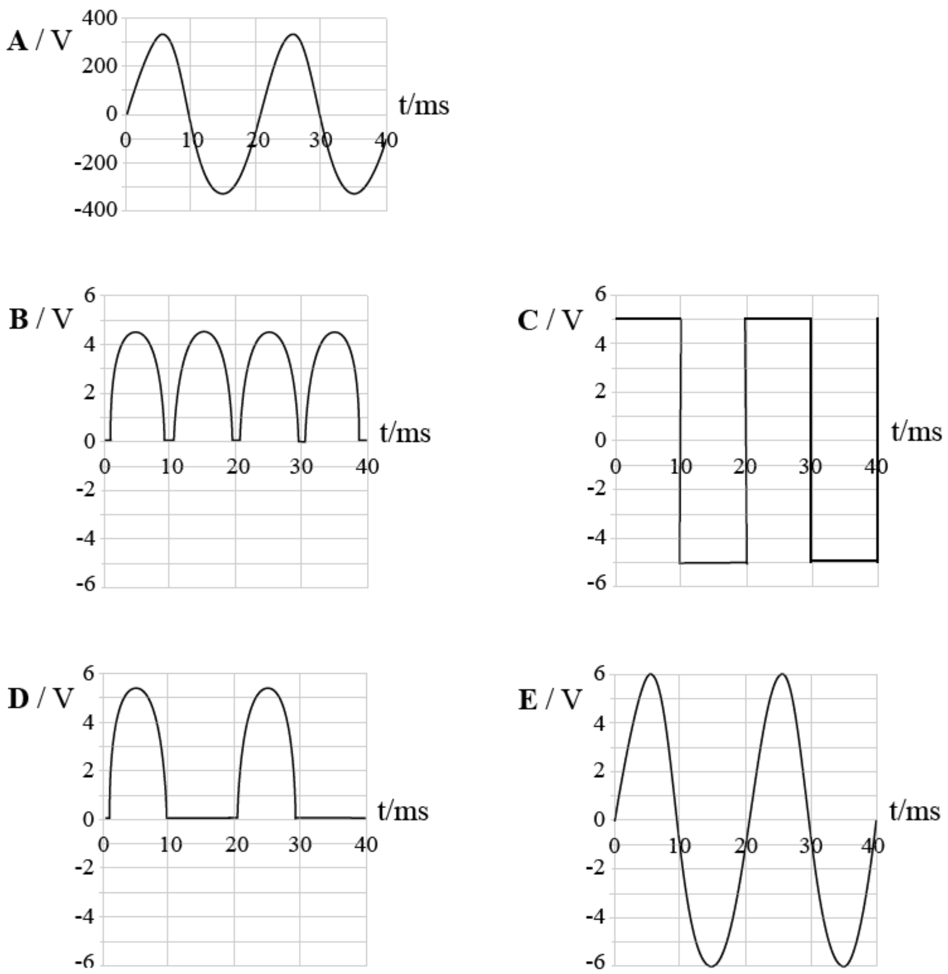

Fig. 5

Most candidates were able to score at least 1 mark for this question with the trace after the transformer being attempted the most successfully. Many candidates chose the full rectification pattern although a single diode would give half wave rectification.

Question 4 (b) (i)

(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.

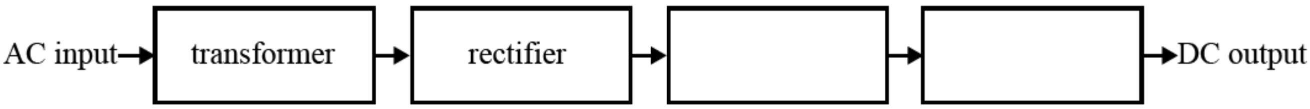

Fig. 6

[2]

The majority of candidates responded with smoothing and stabilising although a significant minority listed them in the wrong order. The question was occasionally left blank and the most common alternative was to give 'capacitor' for 'smoothing'.

Question 4 (b) (ii)

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

Explain what is meant by good load regulation.

....

....

....

.... **[2]**

This question should be familiar to candidates with the response being straight from the specification. However, many candidates appeared unfamiliar with load regulation mentioning that the load value (rather than the voltage or current) remained constant or did not change much. Candidates who started with the fact that the voltage or current remained constant often went on to give confused explanations attempting to relate energy or power. A minority of candidates were able to identify that the voltage or current remained the same with varying load.

Question 4 (c) (i)

(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]

Although the majority of candidates drew two symbols in series, the LED symbol was not well known, often being drawn as a lamp or a combination of a triangle and arrow shape, and many candidates incorrectly assumed the current limiting resistor to be a variable resistor.

Question 4 (c) (ii)

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

....

....

....

.... **[2]**

Many candidates incorrectly stated that the purpose of a current limiting resistor was either to allow the LED to be dimmed or to act as a fuse, melting when current was too high.

?	**Misconception**	Candidates should be confident of the role of a current limiting resistor in protection of other components (particularly LEDs) from the heating effect of high current as opposed to a general protection of the 'circuit'.

Question 5 (a)

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]

The majority of candidates were given marks for this question with the voltage gain being the most successful calculation. The rearrangement to find V_{in} was the most challenging, with many candidates giving the reciprocal due to difficulty with the algebra involved. The handling of the negative numbers could be improved, with some candidates giving all answers as positive numbers.

Question 5 (b)

(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]

The vast majority of candidates were given marks for this question being able to use the formula given to realise that the ratio of resistors was required to be 1:2.

Question 5 (c)

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

Label the input, output, R_F and R_2.

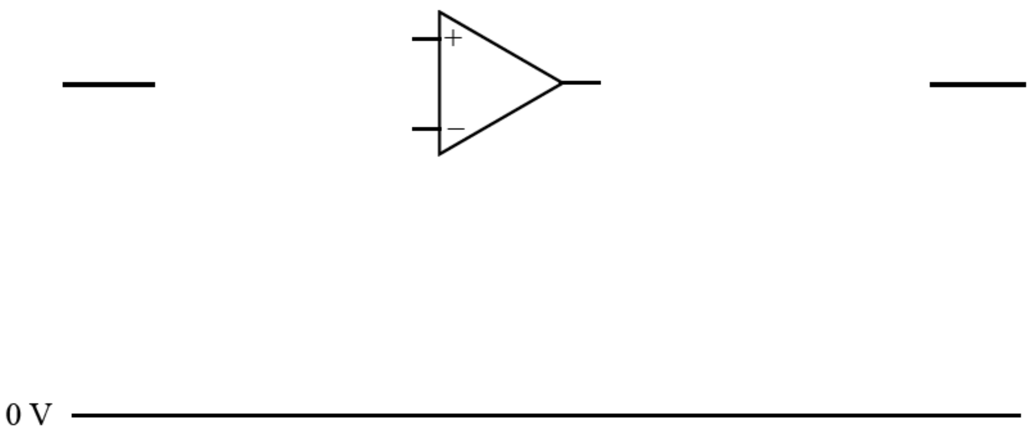

Fig. 8

[5]

This question led to a mixed response from candidates, some of whom were fully prepared to recall the diagram and others who made little or no attempt. Many candidates had not read the question carefully and so neglected to label the input, output, R_F and R_2 as required. The most common error was to draw the feedback loop giving positive feedback.

Question 6 (a)

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

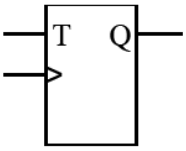

Fig. 9

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]

The majority of candidates gained at least 1 mark however, incorrect responses were wide-ranging from the alternatives given.

Question 6 (b) (i)

(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]

As the three remaining options did not have to be given in any particular order, the vast majority of candidates answered this question successfully.

Question 6 (b) (ii)

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

.... **[1]**

Candidates appeared to find difficulty with identifying the name of the logic gate from the truth table.

	AfL	When given either a logic gate name, circuit symbol, truth table or Boolean expression, candidates should be able to provide the rest of the information listed. It was apparent that candidates were not as used to identifying a gate from its truth table as they were recalling a truth table when given the logic circuit symbol/name.

Question 6 (b) (iii)

(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]

The majority of candidates that had answered Question 6 (b) (ii) correctly were able to gain this mark. Common errors were to draw the incorrect gate named in Question 6 (b) (ii), although the question did refer the candidate back to the truth table, or to omit the labelling of the inputs A and B and the output Q on the circuit symbol.

Question 6 (b) (iv)

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

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

[1]

Candidates seemed familiar with the Boolean expressions and a small majority were able to match the correct expression to the truth table.

Question 6 (c)

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

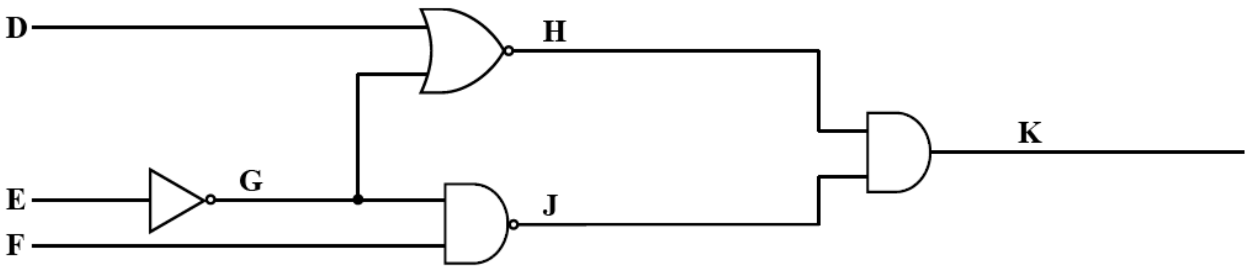

Fig. 10

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]

The vast majority of candidates were confident completing the truth table for the NOT gate with slightly fewer being comfortable with the AND gate. However the NOR and NAND gates seemed to pose more of a challenge with many candidates obtaining incorrect responses for columns H and J.

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