SENIOR CERTIFICATE EXAMINATION
SENIORSERTIFIKAAT-EKSAMEN

FEBRUARY / MARCH
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2007

TECHNIKA (ELECTRONICS)
TECHNIKA (ELEKTRONIES)

HG

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TECHNIKA ELECTRONICS/ELEKTRONIES HG

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14 pages / *bladsye*

X05

GAUTENGSE DEPARTEMENT VAN ONDERWYS
SENIORSERTIFIKAAT-EKSAMEN

TECHNIKA (ELEKTRONIES) HG

TYD: 3 uur

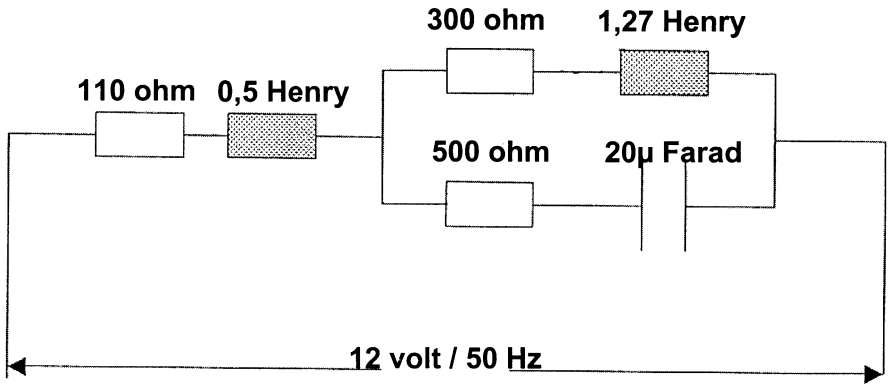
PUNTE: 300

INSTRUKSIES:

- Beantwoord ALLE vrae.
- Sketse en diagramme moet groot en netjies wees en van byskrifte voorsien word.
- Alle berekeninge moet getoon word.
- Antwoorde moet duidelik genommer word.
- 'n Formuleblad (bladsye 12 – 14) is aangeheg aan die einde van die vraestel.

VRAAG 1
ELEKTRIESE STROOMTEORIE

1.1 Verwys na **Figuur 1.1** en bereken die totale stroomvloei van die kring. (25)



Figuur 1.1: Serieparallel-RLC-kring

GAUTENG DEPARTMENT OF EDUCATION
SENIOR CERTIFICATE EXAMINATION

TECHNIKA (ELECTRONICS) HG

TIME: 3 hours

MARKS: 300

INSTRUCTIONS:

- Answer ALL the questions.
- Sketches and diagrams must be large, neat and labelled.
- All calculations must be shown.
- Answers must be clearly numbered.
- A formula sheet (pages 12 – 14) is provided at the end of the paper.

QUESTION 1
ELECTRIC CURRENT THEORY

1.1 Refer to **Figure 1.1** and calculate the total current flow of the circuit. (25)

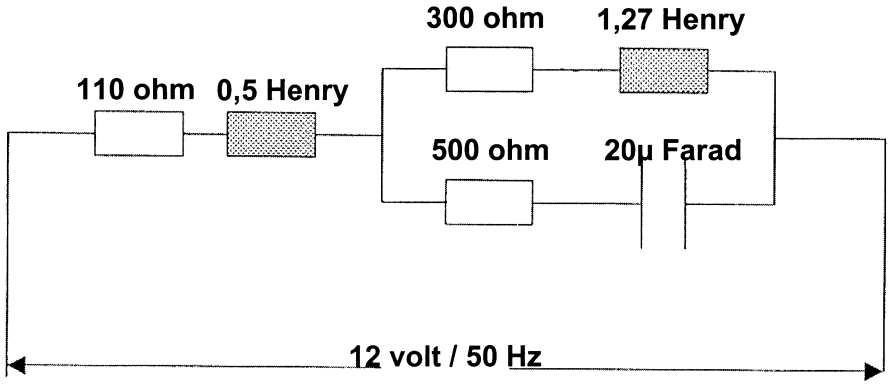
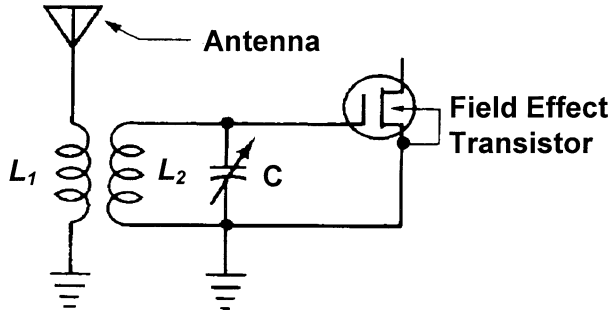


Figure 1.1: Series-Parallel RLC Circuit

1.2 Verwys na **Figuur 1.2** en bereken die resonante frekwensie van die ingestemde kring, indien die ingestemde kapasitor op 348 pikoFarad gestel is, en die induktansie van L2 gelyk aan 232 mikroHenry is.



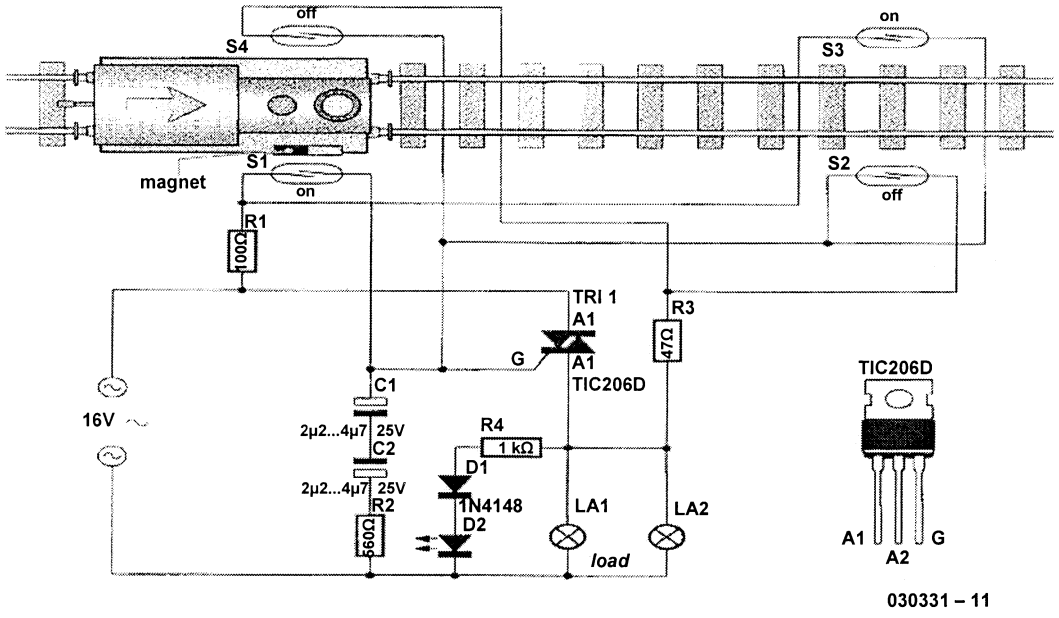
(4)
[29]

Figuur 1.2: Ingestemde Serie-RF-kring

VRAAG 2
HALFGELEIER-TOESTELLE

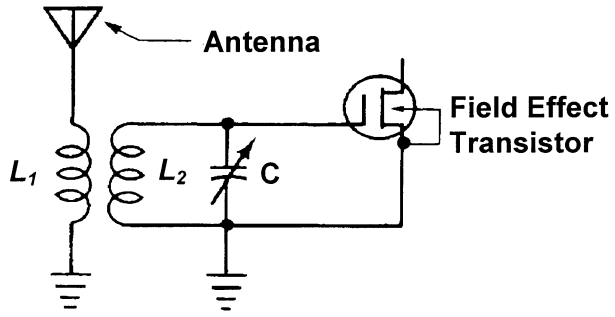
2.1 Identifiseer die volgende elektroniese komponente met verwysing na die elektroniese kringdiagram in **Figuur 2.1**. Voorbeeld: R4 is 'n 1 kΩ-weerstand.

2.1.1 D1 (1)
2.1.2 D2 (2)
2.1.3 LA1 & LA2 (1)
2.1.4 C1 (4)
2.1.5 TIC 206 D (2)



Figuur 2.1: Krag-wipkringbron vir 'n modeltrein

1.2 Refer to **Figure 1.2** and calculate the resonant frequency of the tuned circuit if the tuning capacitor is set at 348 picoFarad, and the inductance of L2 is 232 microHenry.



(4)
[29]

Figure 1.2: Tuned Series RF Circuit

QUESTION 2
SEMICONDUCTOR DEVICES

2.1 Identify the following electronic components with reference to the electronic circuit diagram in **Figure 2.1**. For example: R4 is a 1 kΩ resistor.

2.1.1 D1 (1)
2.1.2 D2 (2)
2.1.3 LA1 & LA2 (1)
2.1.4 C1 (4)
2.1.5 TIC 206 D (2)

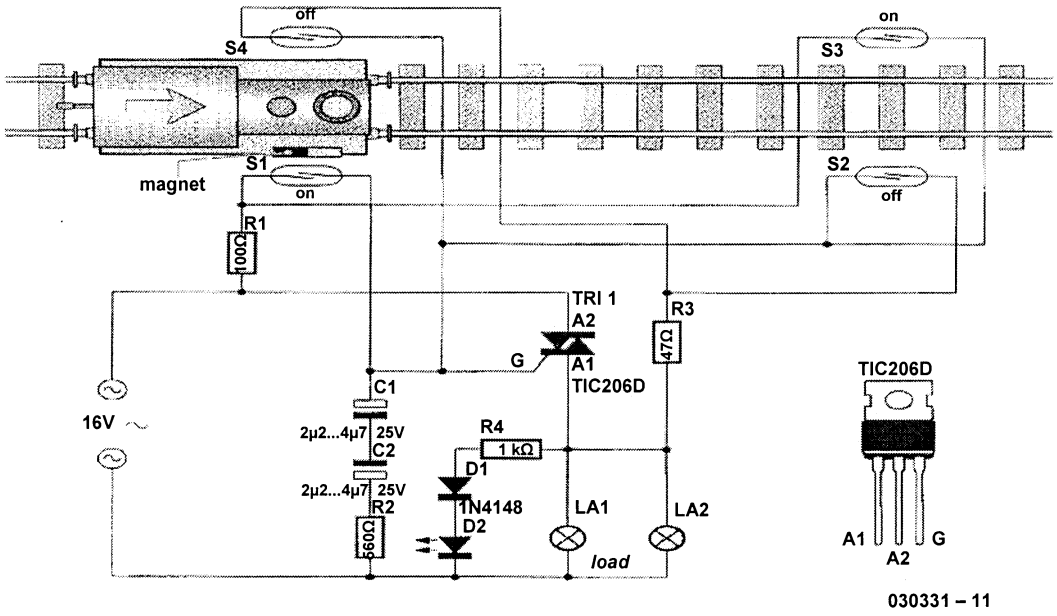
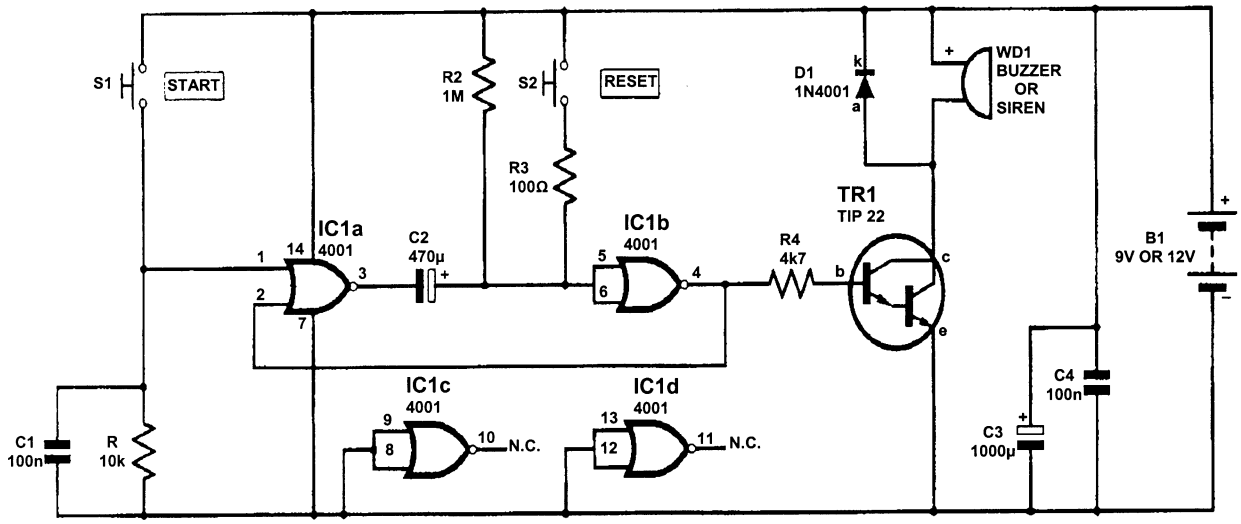


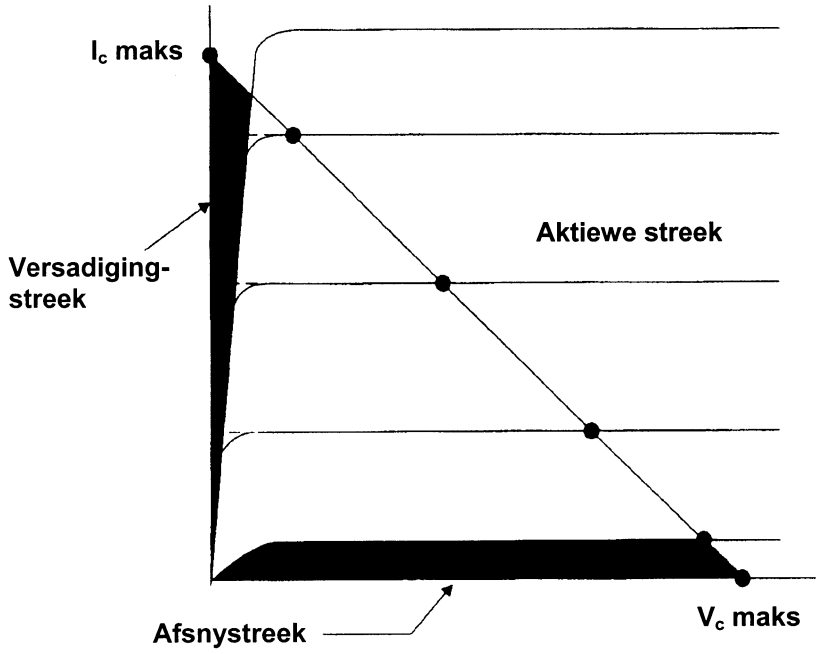
Figure 2.1: Power Flip-Flop circuit for a model railway system

2.2 Verwys na die alarmkring in **Figuur 2.2**. Identifiseer TR1 en verduidelik aan die hand van 'n netjiese, benoemde skets en 'n kort beskrywing die basiese werksbeginsel en kenmerke van slegs TR1. (11)



Figuur 2.2: Alarmkring

2.3 Interpreteer die kenkromme in **Figuur 2.3** en noem die halfgeleier toestel wat hier voorgestel word. (10)



Figuur 2.3: Kenkromme

2.4 Noem DRIE voorsorgmaatreëls wat toegepas moet word wanneer daar met CMOS-toestelle gewerk word. (3)
[34]

2.2 Refer to the alarm circuit in **Figure 2.2**. Identify TR1 and explain by means of a neat, labelled sketch and a brief description, the basic operating principle and characteristics of TR1 only. (11)

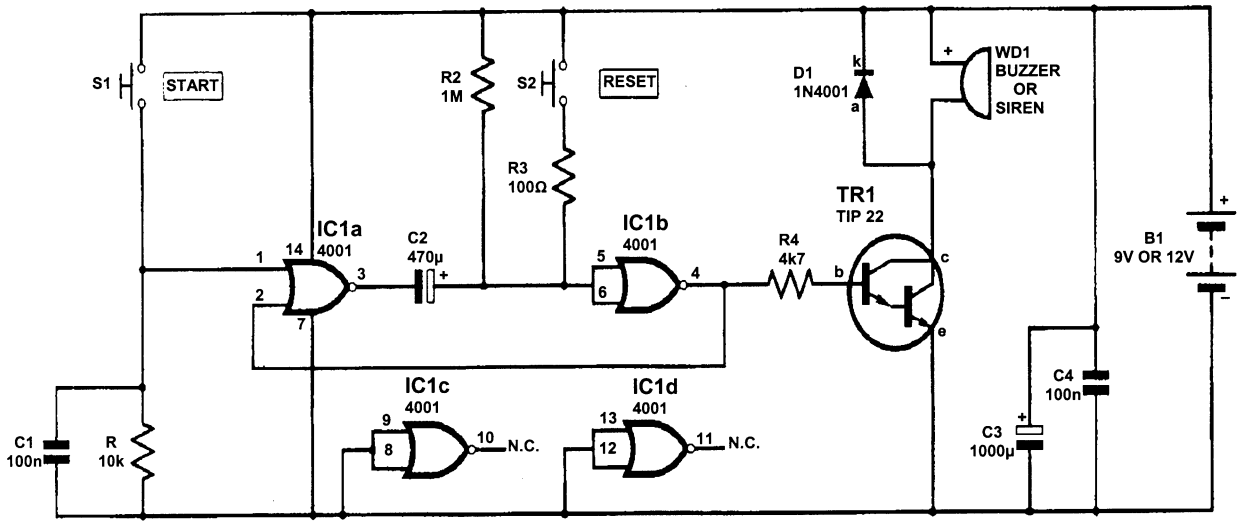


Figure 2.2: Alarm Circuit

2.3 Interpret the characteristic curve in **Figure 2.3** and name the semiconductor device that is represented here. (10)

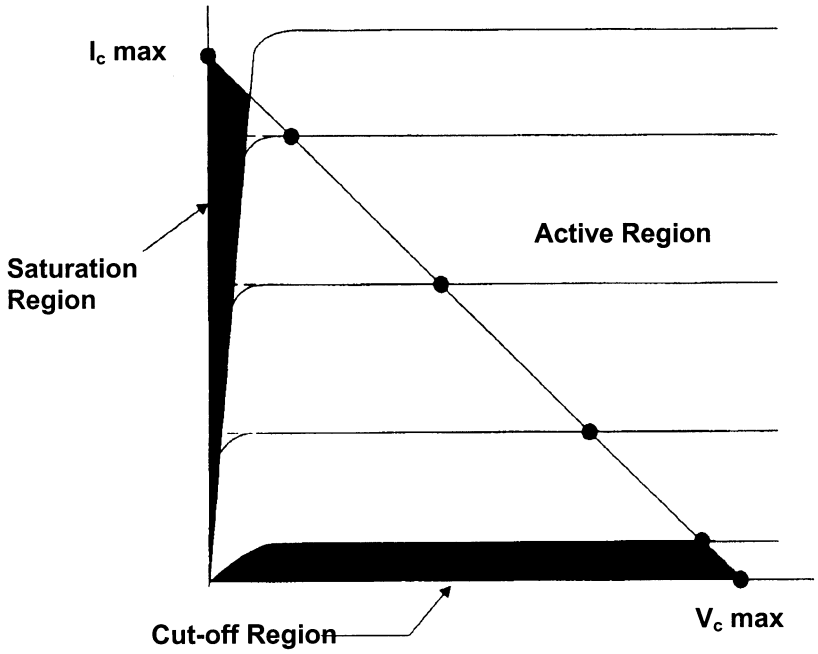


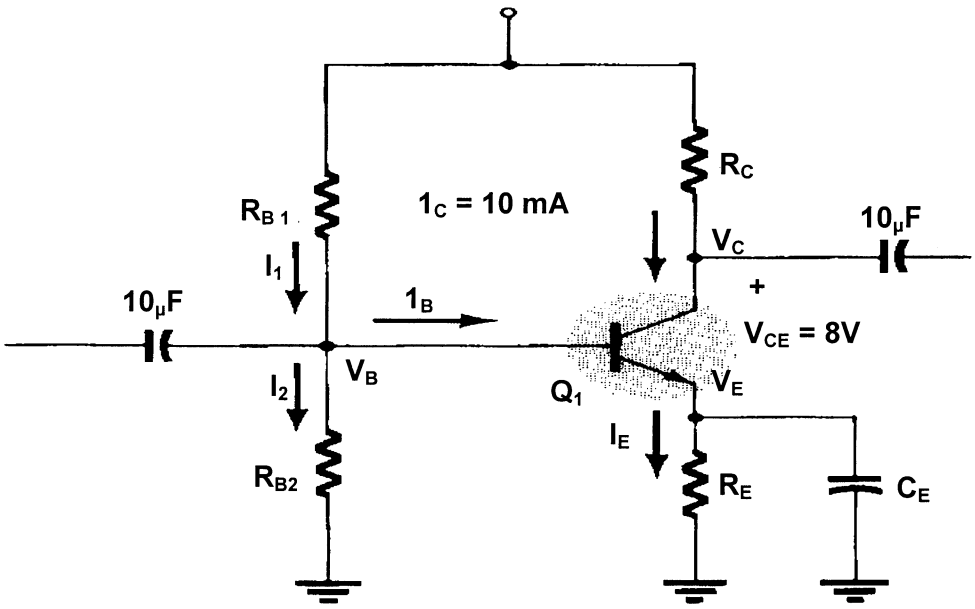
Figure 2.3: Characteristic Curve

2.4 Name THREE precautions that must be taken into account when handling CMOS devices. (3)

[34]

VRAAG 3
VERSTERKERS

3.1 Ontwerp 'n GS-voorspanningkring vir die versterker in **Figuur 3.1**. Die spesifikasies van die vervaardiger dui aan dat die transistor 'n stroomwins van 80 het, teen 'n kollektorstroom van 10 mA, en 'n toevoerspanning van 20 Volt. (20)



Figuur 3.1: Gemeenskaplike emitter versterker

3.1.1 Verwys na **Figuur 3.1** en identifiseer die komponente wat daarvoor verantwoordelik is om die volgende funksies te verrig:

A. Spanningsverdeling (2)
B. Die las (2)
C. Termiese wegholbeskerming (2)

3.2 Teken 'n netjiese, benoemde diagram van 'n operasionele sommeer-versterker wat in die omkeermodus gekoppel word met die volgende stelle insetspannings en weerstande, en bereken die uitsetspanning.

Rf = 60 kΩ

V1 = + 10 Volt, V2 = -12 Volt, V3 = - 6 Volt

R1 = 10 kΩ, R2 = 5 kΩ, R3 = 30 kΩ (12)

3.3 Bereken die dB-verhoging in drywing, indien die insetfrekwensie na 'n sekere filterkring van 5 kHz na 10 kHz verhoog en die uitsetdrywing van 25 mW na 50 mW verhoog. (4)

[42]

QUESTION 3
AMPLIFIERS

3.1 Design a DC bias circuit for the amplifier in **Figure 3.1**. The manufacturer's specifications state that the transistor has a current gain of 80, at a collector current of 10 mA, and a supply voltage of 20 Volts. (20)

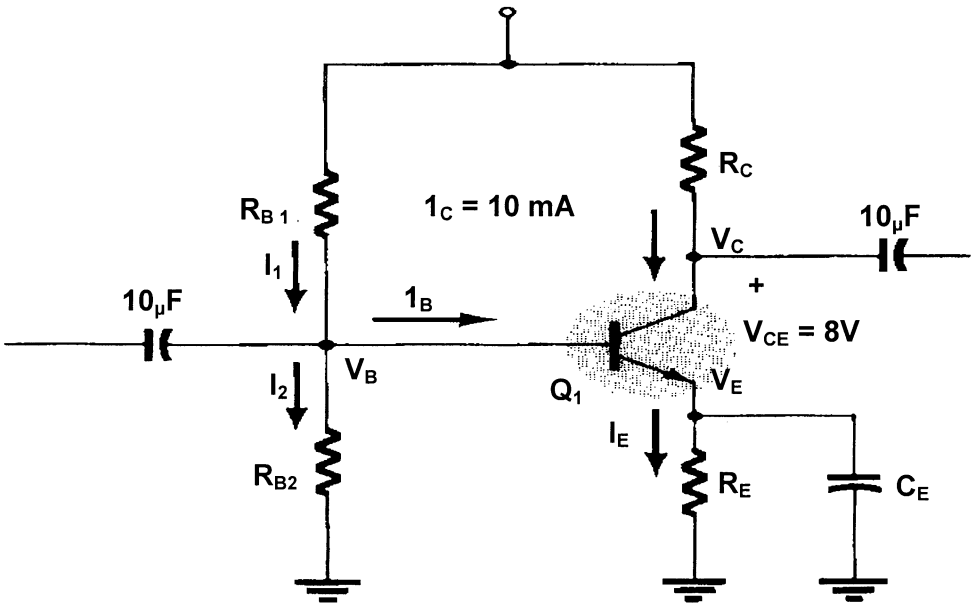


Figure 3.1: Common-emitter amplifier

3.1.1 Refer to **Figure 3.1** and identify the components responsible for performing the following functions:

A. Voltage division (2)
B. The load (2)
C. Thermal runaway protection (2)

3.2 Draw a neat, labelled diagram of an op-amp summing amplifier connected in the inverting mode with the following sets of input voltages and resistors, and calculate the output voltage.

Rf = 60 kΩ

V1 = + 10 Volt, V2 = -12 Volt, V3 = - 6 Volt

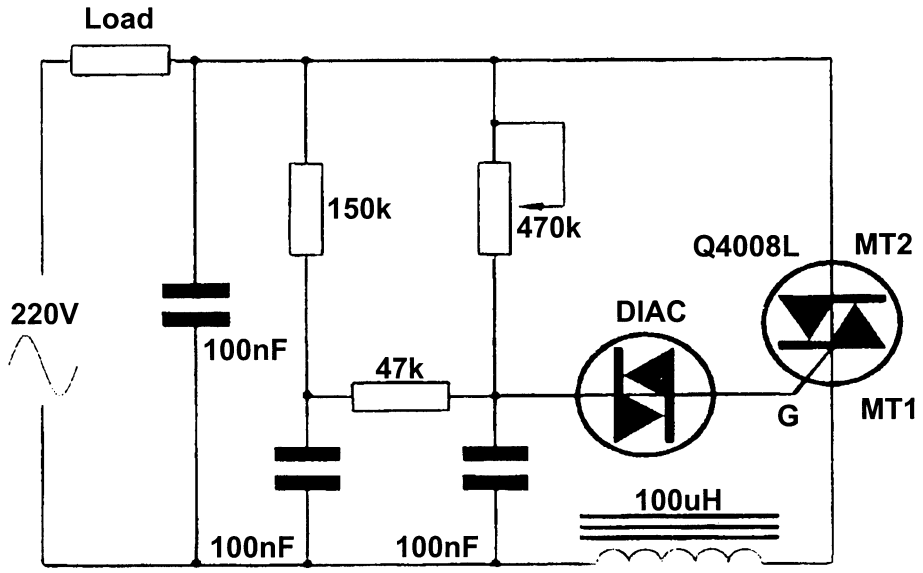
R1 = 10 kΩ, R2 = 5 kΩ, R3 = 30 kΩ (12)

3.3 Calculate the dB increase in power if the input frequency to a certain filter increases from 5 kHz to 10 kHz and the output power rises from 25 mW to 50 mW. (4)

[42]

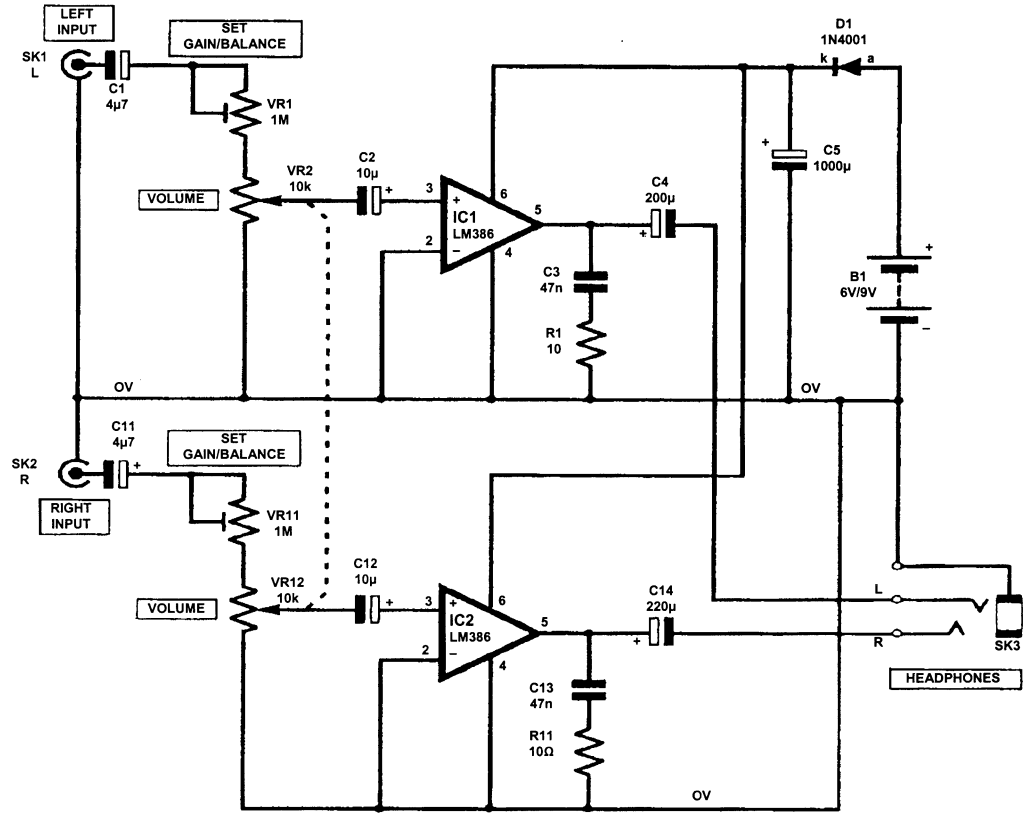
VRAAG 4
SKAKEL- EN BEHEERKRINGE

4.1 **Figuur 4.1** illustreer 'n ligverdowwerbeheerkring. Verduidelik die werksbeginsel van dié kring. (10)



Figuur 4.1: Ligverdowwer-beheerkring

4.2 Die elektroniese kring in **Figuur 4.2** illustreer 'n stereo oorfoonmonitor wat voldoende uitset genereer om 'n stel standaardoorfone te laat werk. Verduidelik die werksbeginsel van dié kring. (10)



Figuur 4.2: Stereo-oorfoonmonitor

QUESTION 4
SWITCHING AND CONTROL CIRCUITS

4.1 **Figure 4.1** illustrates a light dimmer control circuit. Explain the working principle of this circuit. (10)

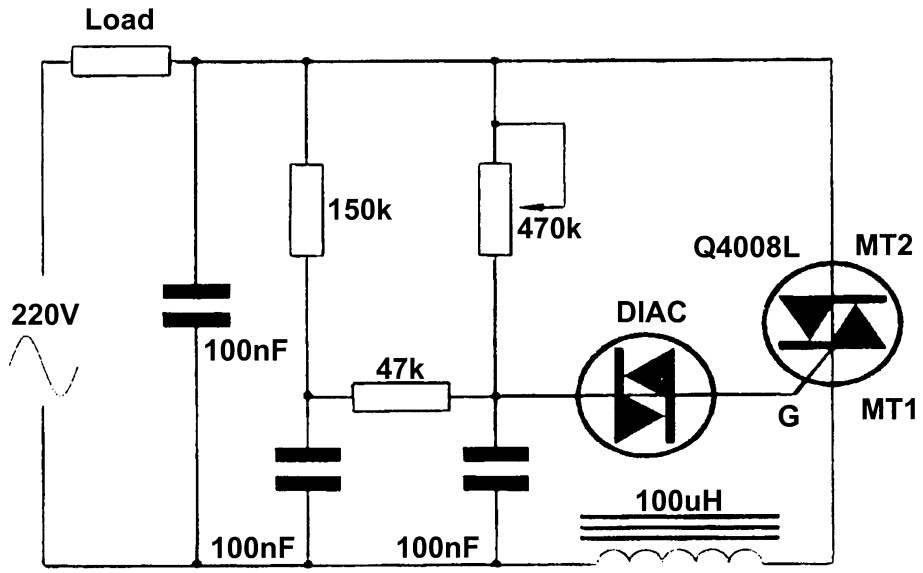


Figure 4.1: Light Dimmer Control Circuit

4.2 The electronic circuit in **Figure 4.2** illustrates a stereo headphone monitor that provides sufficient output to operate a pair of standard headphones. Explain the working principle of this circuit. (10)

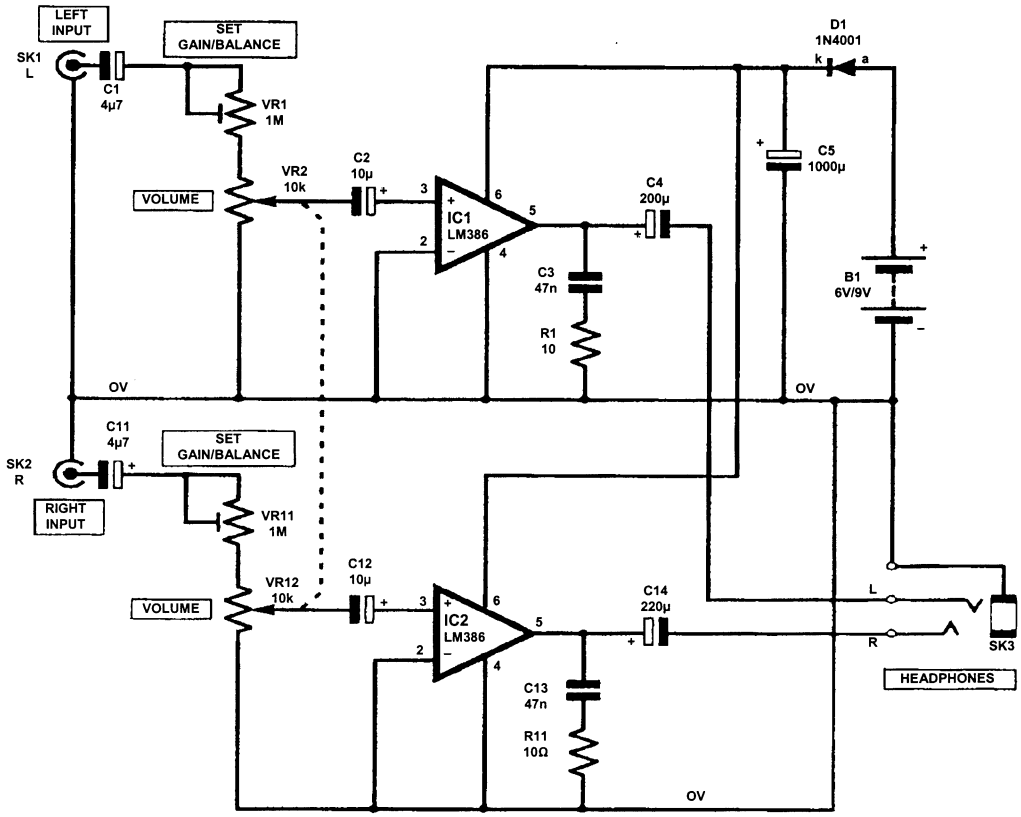
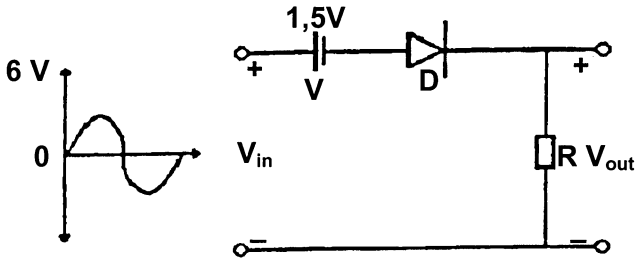


Figure 4.2: Stereo Headphone Monitor

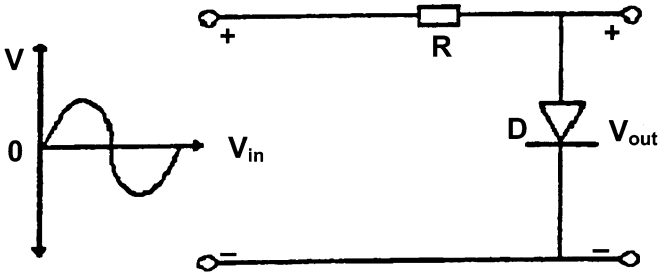
4.3 Vasklem- en afkapstroombane is golfvormingskringe wat sekere gedeeltes van golwe deurlaat en ander dele weer beperk tot sekere waardes. Vind die uitsetspanninggolfvorm vir die insetgolwe in die kringe in **Figuur 4.3**. (Skets slegs die uitsetgolfvorm in jou antwoordboek.)

4.3.1



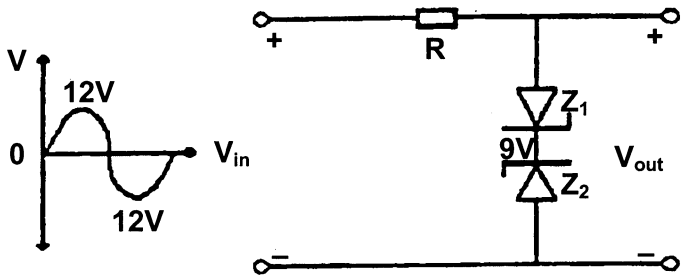
(4)

4.3.2



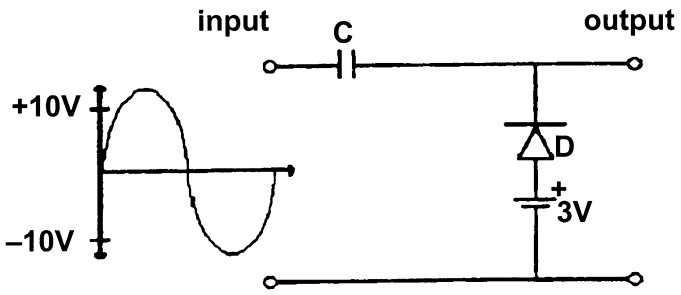
(3)

4.3.3



(4)

4.3.4

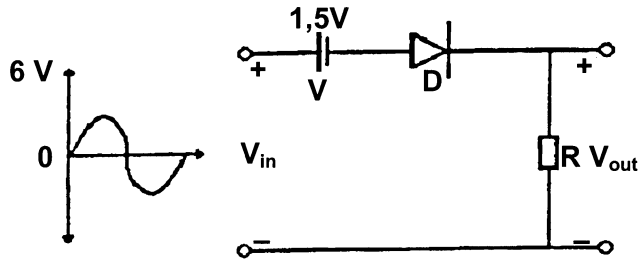


(4)

Figure 4.3: Golfvormingskringe

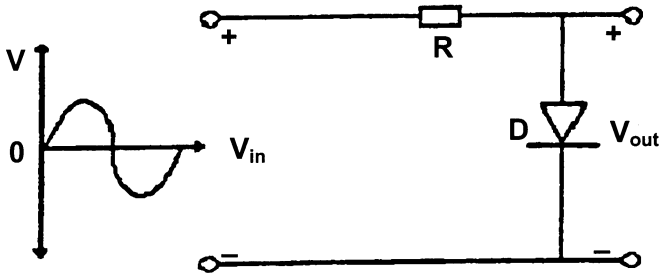
4.3 Clippers and clampers are diode waveshaping circuits transmitting parts of waveforms and suppressing others to a predetermined value. Find the output voltage wave shape for the input waves in the circuits shown in **Figure 4.3**. (Only sketch the output voltage wave shape in your answer book.)

4.3.1



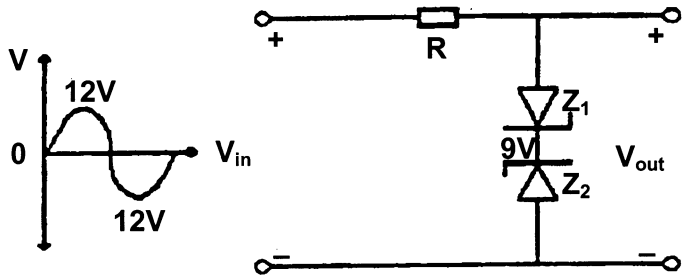
(4)

4.3.2



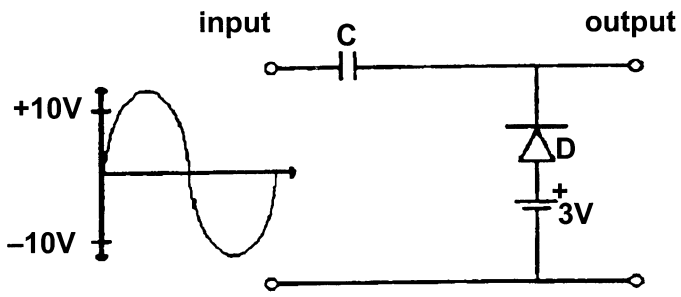
(3)

4.3.3



(4)

4.3.4



(4)

Figure 4.3: Waveshaping circuits

4.4 Verduidelik die werksbeginsel van **ENIGE** elektroniese eksperiment **OF** model wat jy hierdie jaar gebou/ontwerp het. Neem kennis dat jou verduideliking 'n netjiese, benoemde kringdiagram of blokdiagram met 'n kort beskrywing moet insluit. Alle relevante golfvorms moet getoon word. Neem verder kennis dat die beskrywing direk verband moet hou met die kringdiagram. Jy mag nie vrae wat in hierdie vraestel voorkom, herhaal nie. (15)
[50]

VRAAG 5
OSSILLATORS

5.1 Verduidelik die werksbeginsel van 'n ossillator aan die hand van 'n netjiese, benoemde kringdiagram en 'n kort beskrywing. (14)

5.2 Beskryf kortliks, met verwysing na kristalle, wat met die piëso-elektriese effek bedoel word. (4)
[18]

VRAAG 6
REKENAARBEGINSELS

6.1 Ontwerp 'n NEN-heknetwerk vir die volgende Boole-uitdrukking (A, B en C is direkte hekinsette.):

$F = ABC + AB + AC$ (6)

6.2 Bewys met Boole-algebra dat

$\overline{A \oplus B} = A\,B + \overline{A}\ \overline{B}$ (5)

6.3 Jy word deur 'n leidende elektroniese maatskappy gekontrakteer om 'n logikastelsel te ontwerp wat aan die volgende vereistes sal voldoen.

Drie waterreservoirs voorsien die verkoelingstelsel by 'n kernkragaanleg van water. Op enige gegewe tydstip moet ten minste twee van die reservoirs vol wees. Indien minder as twee vol is, moet 'n alarm geaktiveer word. Indien al die reservoirs leeg is, moet die stelsel afskakel. Ontwerp 'n logikakring wat hierdie twee situasies sal kan beheer.

6.3.1 Stel 'n waarheidstabel vir hierdie toestand op. (8)

6.3.2 Druk die verkoelingstelselfunksie uit in terme van A, B en C. (7)

6.3.3 Vereenvoudig die funksie en ontwerp 'n praktiese logikakring. (6)

4.4 Explain the working principle of **ANY** electronic experiment **OR** model that you have built/designed this year. Take note that your explanation should include a neat, labelled circuit diagram or block diagram with a brief description. All relevant wave forms should be included. Please note that the description should directly relate to your circuit diagram. You are not allowed to replicate a question already covered in this question paper. (15)

[50]

QUESTION 5
OSCILLATORS

5.1 Explain with the aid of a neat, labelled circuit diagram and brief description, the operating principle of an oscillator. (14)

5.2 Briefly explain the piezo-electric effect with reference to crystals. (4)

[18]

QUESTION 6
COMPUTER PRINCIPLES

6.1 Design a NAND gate network for the following Boolean expression (A, B and C are direct gate inputs.):

$F = ABC + AB + AC$ (6)

6.2 Prove by means of Boolean algebra that

$\overline{A \oplus B} = A\,B + \overline{A}\ \overline{B}$ (5)

6.3 You have been contracted by a leading electronics company to design a logic system that will satisfy the following needs.

Three water reservoirs supply the cooling system at a nuclear power plant. At any given time at least two reservoirs must be full. If fewer than two are full, an alarm should sound. The system must switch off if all the reservoirs are empty. Design a logic circuit that will control these two situations.

6.3.1 Draw up a truth table for this situation. (8)

6.3.2 Represent the cooling system function in terms of A, B and C. (7)

6.3.3 Simplify the function and design a practical logic circuit. (6)

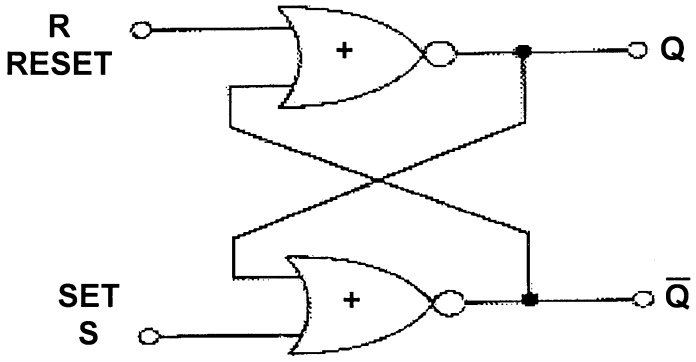
6.4 Bereken die som van die onderstaande twee desimale getalle in binêr:

25,375

\+ 7,00

(4)

6.5 **Figuur 6.1** illustreer 'n basiese geheue-element wat uit 'n NOF-heknetwerk bestaan. Verduidelik kortliks die werksbeginsel van die kring aan die hand van 'n waarheidstabel. (16)



Figuur 6.1: Basiese geheue-element

6.6 Noem TWEE toepassings van die kring in **Figuur 6.1**. (2)
[54]

VRAAG 7
INLIGTINGOORDRAG

7.1 Verduidelik die werksbeginsel van 'n FM-ontvanger aan die hand van 'n netjiese, benoemde blokdiagram. Alle golfvorme moet aangedui word. (15)

7.2 Noem DRIE hoofoorsake van seinverliese in optiese-veselstelsels. (6)

7.3 Noem TWEE voordele van optiese-veselstelsels. (2)

7.4 Verduidelik aan die hand van 'n netjiese, benoemde blokdiagram die basiese werksbeginsel van 'n tipiese mikrogolfkommunikasiestelsel. (12)
[35]

6.4 Add the following two numbers in binary:

25,375

\+ 7,00

(4)

6.5 **Figure 6.1** illustrates a basic memory element consisting of a NOR gate network. Briefly explain the working principle of this circuit with the aid of a truth table. (16)

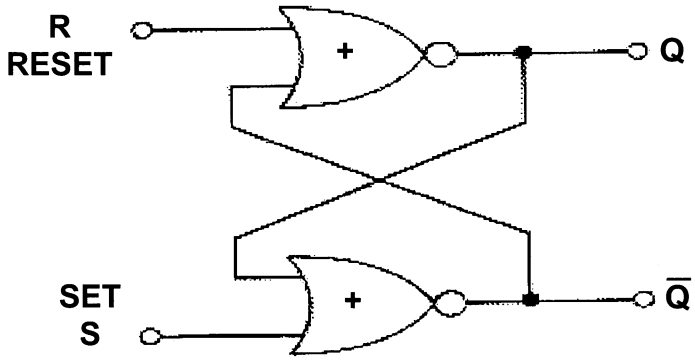


Figure 6.1: Basic memory element

6.6 Name TWO applications of the circuit in **Figure 6.1**. (2)

[54]

QUESTION 7
INFORMATION TRANSFER

7.1 Explain by means of a neat, labelled block diagram the working principle of an FM receiver. All waveforms have to be indicated. (15)

7.2 Name THREE major causes of signal losses in fibre-optic cables. (6)

7.3 Name TWO advantages of fibre-optic systems. (2)

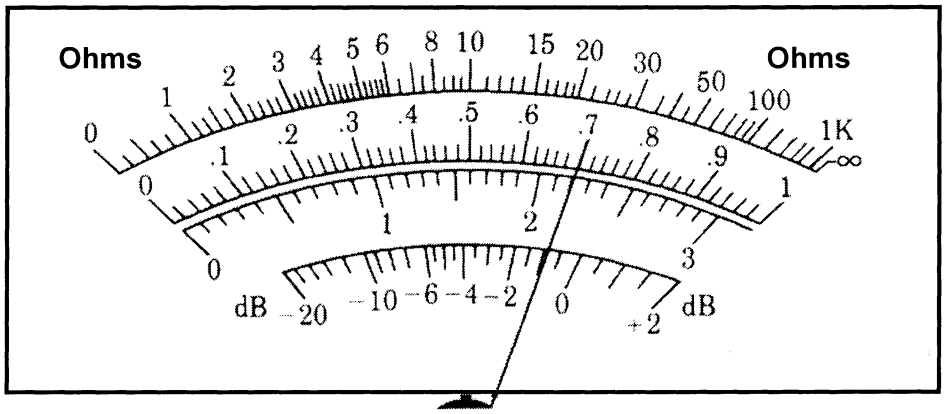
7.4 Explain, by means of a neat, labelled block diagram, the basic working principle of a typical microwave communication system. (12)

[35]

VRAAG 8
MEETINSTRUMENTE

8.1 Verduidelik die werksbeginsel van 'n digitale multimeter aan die hand van 'n netjiese, benoemde blokdiagram. (10)

8.2 Bestudeer **Figuur 8.1** en bepaal die lesing wat op die multimeter aangedui word, indien die strekskakelaar op X 10K gestel is. (2)

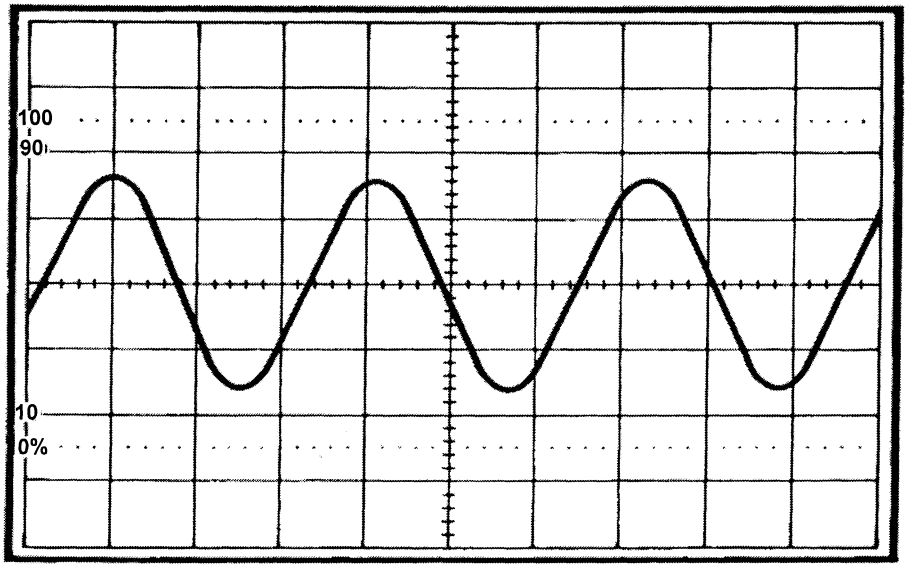


Figuur 8.1: Multimeterlesing

8.3 Bestudeer die sinusgolfvorm in **Figuur 8.2** en

8.3.1 bepaal die piek-tot-piek-waarde van die golf, indien die Volts/Divisie-skakelaar op 100 mV/Divisie gestel is. (3)

8.3.2 bepaal die frekwensie indien die Tyd/Divisie-skakelaar van die ossilloskoop op 10 µsek/Div. gestel is. (6)



Figuur 8.2: Golfvorm **[21]**

QUESTION 8
MEASURING INSTRUMENTS

8.1 Explain the working principle of a digital multimeter by means of a neat, labelled block diagram. (10)

8.2 Examine **Figure 8.1** and determine the reading of the multimeter if the range switch is on X 10K. (2)

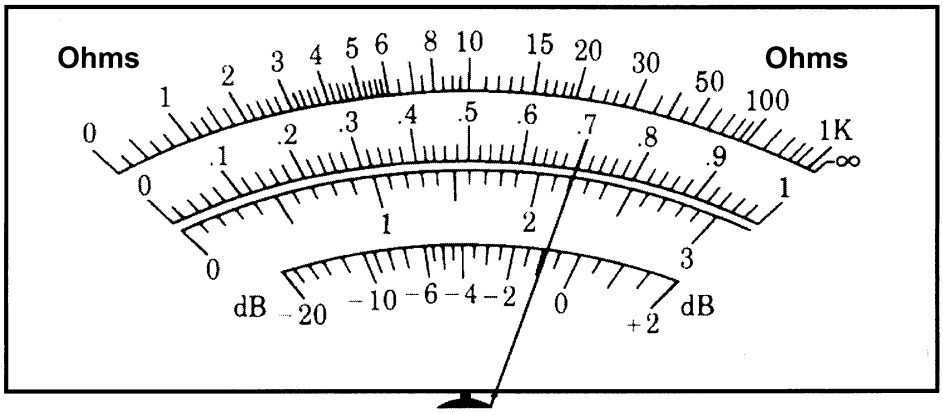


Figure 8.1: Multimeter reading

8.3 Examine the sinus waveform in **Figure 8.2** and

8.3.1 determine the peak-to-peak voltage of the wave if the Volts/Division switch is on 100 mV/Division. (3)

8.3.2 determine the frequency if the Time/Division switch of the oscilloscope is set at 10µsec/Div. (6)

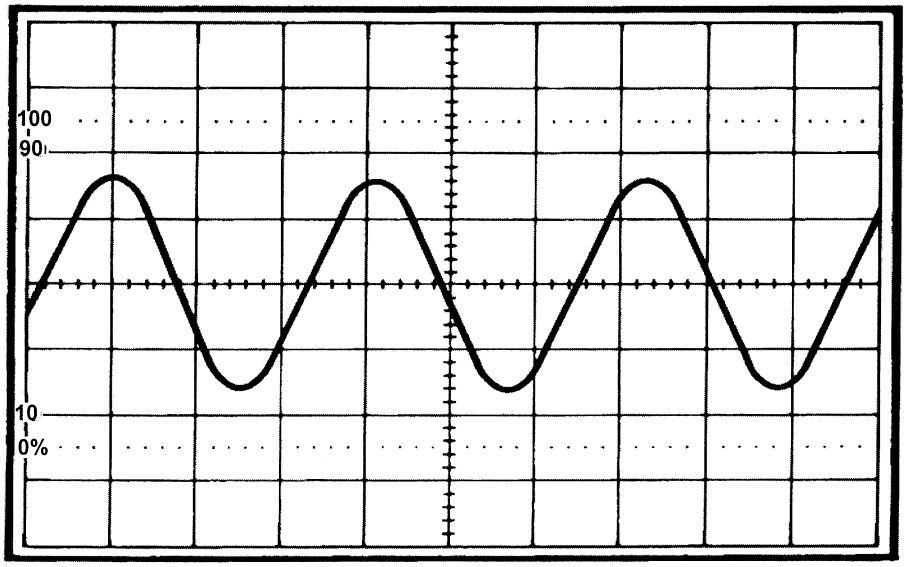


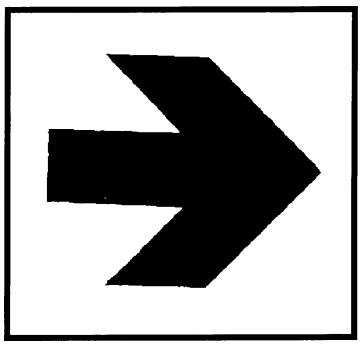
Figure 8.2: Waveform **[21]**

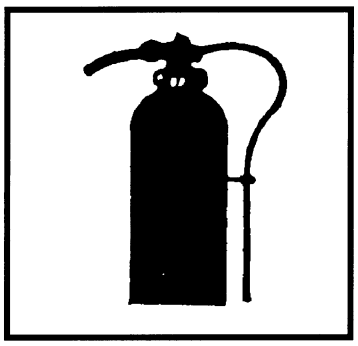
VRAAG 9
VEILIGHEID

9.1 Noem VYF huishoudelike reëls wat jy hierdie jaar in julle werkswinkel toegepas het. (5)

9.2 Identifiseer die volgende veiligheidsinligtingstekens:

9.2.1  (1)

9.2.2  (1)

9.2.3  (1)

9.3 Noem TWEE hoofoorsake van brand. (2)

9.4 Beantwoord die volgende vrae. Skryf slegs WAAR of ONWAAR in jou antwoordboek teenoor die toepaslike vraagnommer neer.

9.4.1 Verwagtende vroue kan die MI-virus aan hul ongebore kind oordra. (1)

9.4.2 Jy mag nie 'n skool bywoon indien jy MIV-positief is nie. (1)

9.4.3 Jou werkgewer het die reg om jou te ontslaan indien jy MIV-positief is. (1)

9.4.4 Jy mag nie vir die MI-virus getoets word sonder jou toestemming nie. (1)

9.5 Verduidelik die term **vensterperiode** met verwysing na MIV/Vigs-toetsing. (3)
[17]

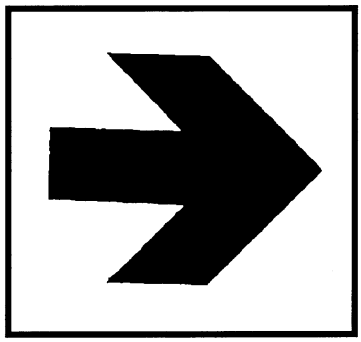
TOTAAL: 300

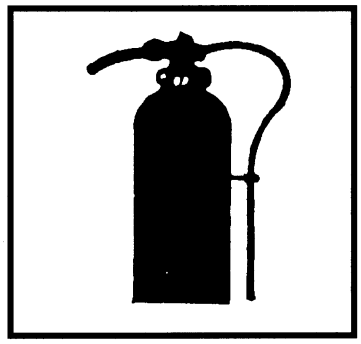
QUESTION 9
SAFETY PRECAUTIONS

9.1 Name FIVE housekeeping rules that you have applied in your workshop this year. (5)

9.2 Identify the following safety information signs:

9.2.1  (1)

9.2.2  (1)

9.2.3  (1)

9.3 List TWO main causes of fire. (2)

9.4 Answer the following questions. Only write TRUE of FALSE next to the appropriate question number in your answer book.

9.4.1 A pregnant woman with HIV/Aids may pass the virus onto her unborn. (1)

9.4.2 You will not be allowed in a school if you are HIV positive. (1)

9.4.3 Your employer has the right to dismiss you if you are HIV positive. (1)

9.4.4 You cannot be tested for HIV without your consent. (1)

9.5 Explain the term **window period** with reference to HIV/Aids testing. (3)
[17]

TOTAL: 300

INFORMATION SHEET / *INLIGTINGSBLAD*

ELECTRIC CURRENT THEORY / *ELEKTRIESE STROOMTEORIE*

$$I = \frac{V}{R} \text{ AMPS}$$

$$P = V \times I \text{ WATT}$$

$$t = \frac{1}{f} \text{ seconds / } \textit{sekondes}$$

$$V_{ave./\ gem.} = V_m \times 0{,}637$$

$$V_{rms./\ wgk.} = V_m \times 0{,}707$$

$$X_C = \frac{1}{2 \times \pi \times f \times C}$$

$$X_L = 2 \times \pi \times f \times L$$

$$V_T = \sqrt{V_R^{\,2} + V_C^{\,2}}$$

$$V_T = \sqrt{V_r^{\,2} + V_L^{\,2}}$$

$$V_T = \sqrt{V_R^{\,2} + V_X^{\,2}}$$

$$V_X = V_L - V_C$$

$$f_r = \frac{1}{2 \times \pi \times \sqrt{LC}}$$

$$f_r = \frac{1}{2 \times \pi} \times \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$Q = \frac{X_L}{R}$$

$$Q = \frac{X_C}{R}$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

INFORMATION SHEET / *INLIGTINGSBLAD*

ELECTRIC CURRENT THEORY / *ELEKTRIESE STROOMTEORIE*

$$I = \frac{V}{R} \text{ AMPS}$$

$$P = V \times I \text{ WATT}$$

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$$V_T = \sqrt{V_r^{\,2} + V_L^{\,2}}$$

$$V_T = \sqrt{V_R^{\,2} + V_X^{\,2}}$$

$$V_X = V_L - V_C$$

$$f_r = \frac{1}{2 \times \pi \times \sqrt{LC}}$$

$$f_r = \frac{1}{2 \times \pi} \times \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$Q = \frac{X_L}{R}$$

$$Q = \frac{X_C}{R}$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$V_C = I_T \times X_C$

$V_L = I_T \times X_L$

$V_R = I_T \times R$

$V_T = \sqrt{V_R^2 + V_X^2}$

$V_X = V_C - V_L$

$I_T = \sqrt{I_R^2 + I_X^2}$

$I_X = I_C - I_L$

$\frac{N_1}{N_2} = \sqrt{\frac{Z_1}{Z_2}}$

$Z = \sqrt{R^2 + X_C^2}$

$Z = \sqrt{R^2 + X_L^2}$

$Z = \sqrt{R^2 + X_X^2}$

$X_X = X_L - X_C$

AMPLIFIERS / *VERSTERKERS*

$I_e = I_c + I_b$

$V_{cc} = V_{Rc} + V_{ce}$

$I_c = \frac{V_{cc}}{Rc}$

$V_e \cong \frac{1}{10} V_{cc}$

DECIBEL RATIOS / *DESIBELVERHOUDINGS*

$$G_I = 20 \text{ LOG} \frac{I_2}{I_1}$$

$$G_V = 20 \text{ LOG} \frac{V_2}{V_1}$$

$$G_P = 10 \text{ LOG} \frac{P_2}{P_1}$$

$V_C = I_T \times X_C$

$V_L = I_T \times X_L$

$V_R = I_T \times R$

$V_T = \sqrt{V_R^2 + V_X^2}$

$V_X = V_C - V_L$

$I_T = \sqrt{I_R^2 + I_X^2}$

$I_X = I_C - I_L$

$\frac{N_1}{N_2} = \sqrt{\frac{Z_1}{Z_2}}$

$Z = \sqrt{R^2 + X_C^2}$

$Z = \sqrt{R^2 + X_L^2}$

$Z = \sqrt{R^2 + X_X^2}$

$X_X = X_L - X_C$

AMPLIFIERS / *VERSTERKERS*

$I_e = I_c + I_b$

$V_{cc} = V_{Rc} + V_{ce}$

$I_c = \frac{V_{cc}}{Rc}$

$V_e \cong \frac{1}{10} V_{cc}$

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$$G_I = 20 \text{ LOG} \frac{I_2}{I_1}$$

$$G_V = 20 \text{ LOG} \frac{V_2}{V_1}$$

$$G_P = 10 \text{ LOG} \frac{P_2}{P_1}$$

OPERATIONAL AMPLIFIERS / *OPERASIONELE VERSTERKERS*

$$A_V = -\frac{R_F}{R_I}$$

$$V_{OUT} = A_V \times V_I$$

$$A_V = 1 + \frac{R_F}{R_I}$$

$$V_{OUT} = A_V \times V_I$$

$$V_{OUT} = \frac{1}{RC} \int V_I \, dt$$

$$V_{OUT} = - RC \frac{dv}{dt}$$

$$V_{OUT} = - (V_1 \frac{R_F}{R_1} + V_2 \frac{R_F}{R_2} + V_3 \frac{R_F}{R_3})$$

COMPUTER PRINCIPLES / *REKENAARBEGINSELS*

$A.B = B.A$
$A + B = B + A$

$A. (B . C) = (A . B) .C$
$A + (B + C) = (A + B) + C$

$A. (B + C) = AB + AC$
$A + (B.C) = (A + B) . (A + C)$

$A(A + B) = A$
$A + (AB) = A$

$A + 0 = A$
$A + 1 = 1$
$A.0 = 0$
$A.1 = A$
$A + \underline{A} = A$
$A + A = 1$
$A.\underline{A} = A$
$A.A = 0$

END / *EINDE*

OPERATIONAL AMPLIFIERS / *OPERASIONELE VERSTERKERS*

$$A_V = -\frac{R_F}{R_1}$$

$$V_{OUT} = A_V \times V_I$$

$$A_V = 1 + \frac{R_F}{R_1}$$

$$V_{OUT} = A_V \times V_I$$

$$V_{OUT} = \frac{1}{RC} \int V_1 \, dt$$

$$V_{OUT} = - RC \frac{dv}{dt}$$

$$V_{OUT} = - (V_1 \frac{R_F}{R_1} + V_2 \frac{R_F}{R_2} + V_3 \frac{R_F}{R_3})$$

COMPUTER PRINCIPLES / *REKENAARBEGINSELS*

$A.B = B.A$
$A + B = B + A$

$A.(B . C) = (A . B) .C$
$A + (B + C) = (A + B) + C$

$A.(B + C) = AB + AC$
$A + (B.C) = (A + B) . (A + C)$

$A(A + B) = A$
$A + (AB) = A$

$A + 0 = A$
$A + 1 = 1$
$A.0 = 0$
$A.1 = A$
$A + \underline{A} = A$
$A + A = 1$
$A.\underline{A} = A$
$A.A = 0$

END / *EINDE*