# Wednesday 11 June 2014 – Morning

## A2 GCE ELECTRONICS

**F615/01** Communication Systems

Candidates answer on the Question Paper.

**OCR supplied materials:**
None

**Other materials required:**
- Scientific calculator

**Duration:** 1 hour 40 minutes

| Candidate forename | | Candidate surname | |
|---|---|---|---|

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

## INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

## INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **110**.
- You will be awarded marks for your Quality of Written Communication.
- You are advised to show all the steps in any calculations.
- This document consists of **20** pages. Any blank pages are indicated.

**A calculator may be used for this paper**

## Data Sheet

Unless otherwise indicated, you can assume that:

- op-amps are run off supply rails at +15 V and –15 V
- logic circuits are run off supply rails at +5 V and 0 V.

| | |
|---|---|
| resistance | $R = \frac{V}{I}$ |
| power | $P = VI$ |
| series resistors | $R = R_1 + R_2$ |
| time constant | $\tau = RC$ |
| monostable pulse time | $T = 0.7\,RC$ |
| relaxation oscillator period | $T = 0.5\,RC$ |
| frequency | $f = \frac{1}{T}$ |
| voltage gain | $G = \frac{V_{out}}{V_{in}}$ |
| open-loop op-amp | $V_{out} = A(V_+ - V_-)$ |
| non-inverting amplifier gain | $G = 1 + \frac{R_f}{R_d}$ |
| inverting amplifier gain | $G = -\frac{R_f}{R_{in}}$ |
| summing amplifier | $-\frac{V_{out}}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} \ldots$ |
| break frequency | $f_0 = \frac{1}{2\pi RC}$ |

| | |
|---|---|
| Boolean Algebra | $A.\overline{A} = 0$ |
| | $A + \overline{A} = 1$ |
| | $A.(B + C) = A.B + A.C$ |
| | $\overline{A.B} = \overline{A} + \overline{B}$ |
| | $\overline{A + B} = \overline{A}.\overline{B}$ |
| | $A + A.B = A$ |
| | $A.B + \overline{A}.C = A.B + \overline{A}.C + B.C$ |
| amplifier gain | $G = -g_m R_d$ |
| ramp generator | $\Delta V_{out} = -V_{in}\frac{\Delta t}{RC}$ |
| inductor reactance | $X_L = 2\pi f L$ |
| capacitor reactance | $X_C = \frac{1}{2\pi f C}$ |
| resonant frequency | $f_0 = \frac{1}{2\pi\sqrt{LC}}$ |

Answer **all** questions.

1 Fig. 1.1 shows the five connections which carry digital information from a computer to a colour monitor.

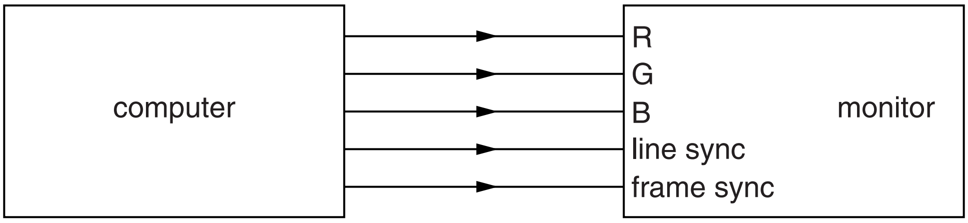


**Fig. 1.1**

**(a)** Explain how the **five** signals control the raster scan which displays a colour picture on the monitor screen.

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...................................................................................................................................... **[5]**

**(b)** Each of the three video signals are packets of 7-bit words.
Explain why this suggests about 30 different levels of intensity for each pixel.

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...................................................................................................................................... **[3]**

**(c)** Each video signal has its own cable.
The bandwidth of each video signal is 170 MHz.

Calculate the rate at which each packet passes through each video cable.

packet rate = ................................................ MHz **[2]**

Fig. 1.2 is an oscilloscope trace of the frame sync signal.

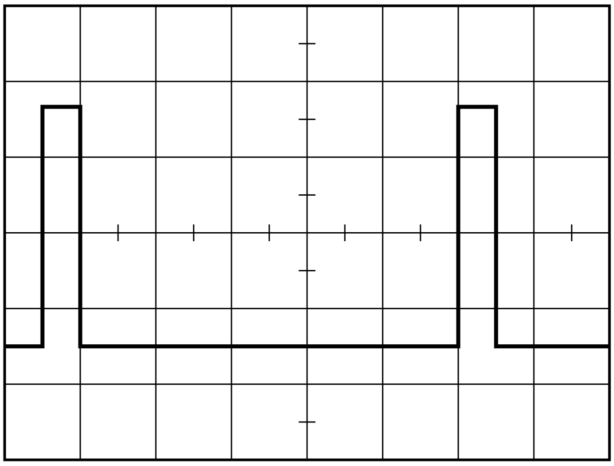

**Fig. 1.2**

**(d)** The oscilloscope settings are as follows:

- timebase setting 2 ms/div
- vertical scale 500 mV/div

Show that the refresh rate is about 100 Hz.

**[2]**

**[Total: 12]**

**2** Fig. 2.1 shows a voltage-controlled amplifier and its transfer characteristic.

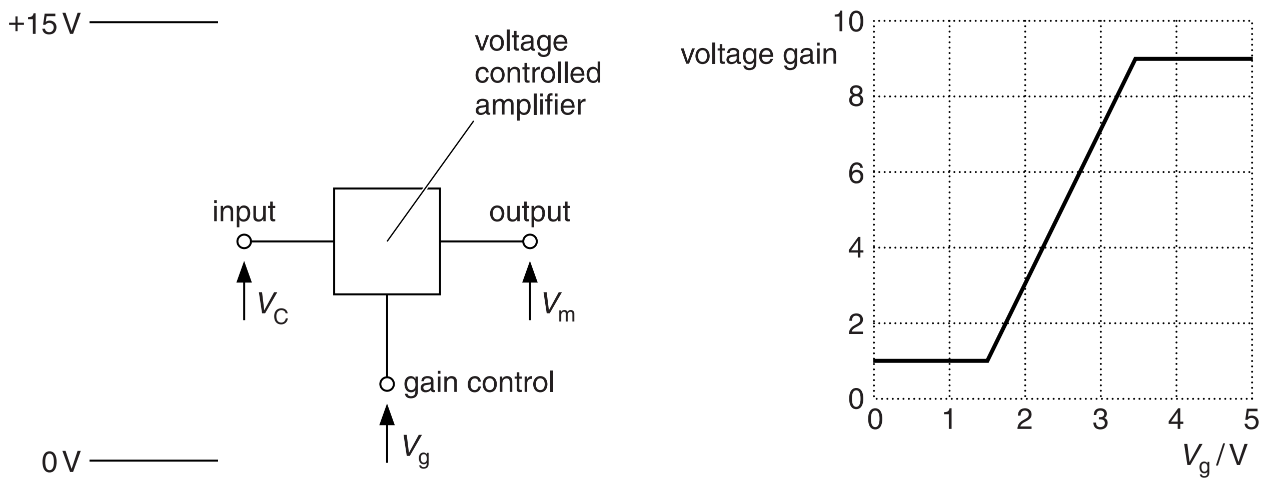


**Fig. 2.1**

**(a)** The amplifier is part of an amplitude modulator. The amplifier alters the amplitude of the carrier signal $V_C$ by an amount which depends on the value of the signal $V_g$.

**(i)** In the absence of a modulating signal, the amplifier gain needs to be 5.
Draw on Fig. 2.1 to show how a pair of resistors can be used to bias the amplifier. Show component values and justify them with calculations.

**[3]**

**(ii)** Draw on Fig. 2.1 to show how a capacitor should be connected to allow an audio frequency signal $V_S$ to amplitude modulate the carrier signal $V_C$. **[1]**

**(iii)** Suggest the maximum amplitude of audio frequency signal $V_S$ which should be used. Explain your choice.

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

..............................................................................................................................................

.............................................................................................................................................. **[3]**

**(b)** Fig. 2.2 shows an amplitude demodulator for use with the modulator of Fig. 2.1.

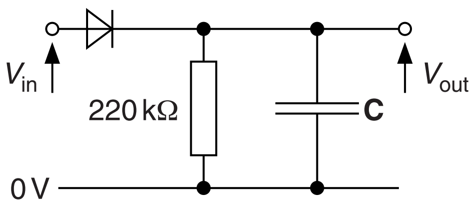


**Fig. 2.2**

**(i)** The carrier signal $V_C$ has a frequency of 450 kHz.
Calculate a suitable value for the capacitor **C** if the audio frequency signal ranges from 50 Hz to 5 kHz.

**C** = ................................................... pF **[2]**

**(ii)** The diode in Fig. 2.2 has a voltage drop of 100 mV in forward bias.
On Fig. 2.3 draw a voltage-time graph for $V_{out}$ when $V_{in}$ has the following properties.

| | |
|---|---|
| carrier frequency | 450 kHz |
| signal frequency | 5 kHz |
| maximum carrier amplitude | 600 mV |
| minimum carrier amplitude | 200 mV |

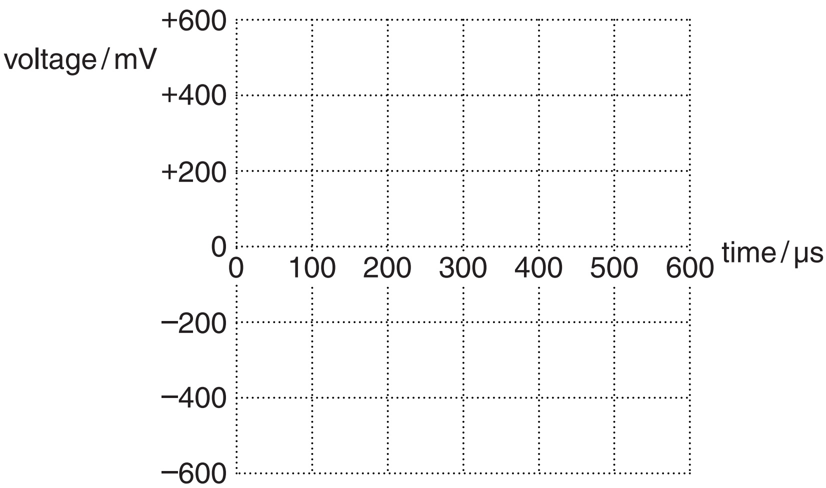


**Fig. 2.3**

**[3]**

**[Total: 12]**

**3** Fig. 3.1 shows the block diagram of a demodulator of frequency modulated signals.


**Fig. 3.1**

**(a)** Explain the function of the Schmitt trigger.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** The monostable produces a pulse of duration 2 μs each time a falling edge arrives from the Schmitt trigger. The pulse goes from 0 V to 5 V and back.
In the space below, draw a circuit diagram for the monostable.
Include all component values and justify them.

**[4]**

**(c)** Fig. 3.2 contains the circuit diagram for the filter.

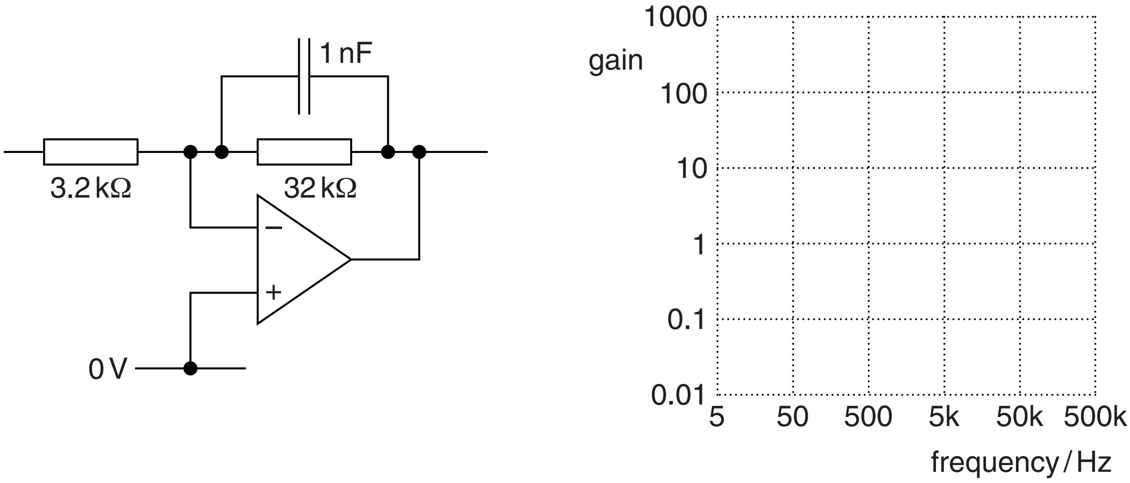


**Fig. 3.2**

**(i)** Draw a gain-frequency graph for the filter on the axes of Fig. 3.2.
Show your calculations in the space below.

**[4]**

**(ii)** Calculate a value for the bandwidth required by the f.m. carrier.

bandwidth = ................................................ kHz **[2]**

**[Total: 12]**

4 Fig. 4.1 is the circuit diagram of a pulse-width modulator (PWM).

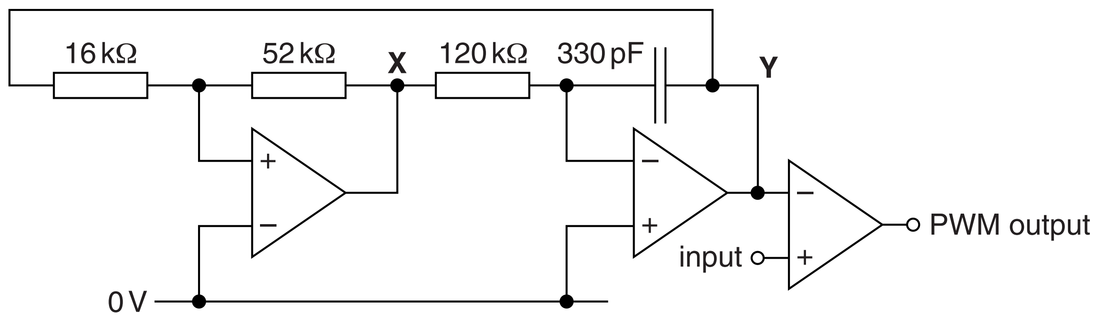


**Fig. 4.1**

**(a)** **X** is the output of the Schmitt trigger. It is either positive or negative.
Explain, with calculations, why the signal at **Y** has to be raised above +4.0V to change **X** from negative to positive.

**[3]**

**(b)** Calculate how long it takes for the signal at **Y** to rise from –4.0V to +4.0V.

time = ...................................................... μs **[2]**

**(c)** Calculate the highest frequency signal at the modulator input which will be correctly encoded.

frequency = ................................................ kHz **[3]**

**(d)** Fig. 4.2 is an incomplete block diagram for a demodulator of a PWM signal.

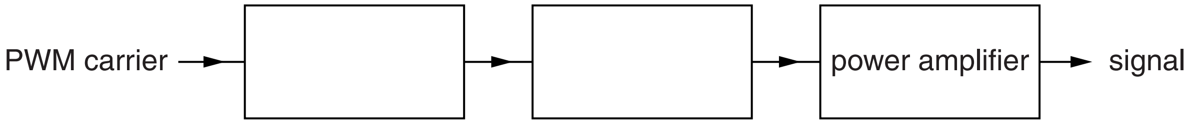


**Fig. 4.2**

**(i)** Complete the block diagram. Choose from the list below.

**ramp generator** **Schmitt trigger** **tone control** **treble cut filter** **voltage amplifier**

**[2]**

**(ii)** Suggest a reason why the system contains a power amplifier.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

**[Total: 11]**

 

**5** This question is about the transmission of signals as pulses of waves.

**(a)** Name the type of wave which carries pulses down an optical fibre.

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

**(b)** State and explain what happens to these pulses as they move along the fibre.

........................................................................................................................

........................................................................................................................

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

**(c)** Explain why optical fibre transmission systems usually have large values for their signal-to-noise ratio.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................ **[3]**

**(d)** Optical fibre systems do **not** have problems with interference. This is partly because of the opaque cladding around the fibres.

**(i)** Explain why interference is a problem for systems which use radio waves.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................ **[3]**

**(ii)** Explain how this can be overcome by systems which use radio waves.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................ **[3]**

**[Total: 12]**

**6** This question is about the use of frequency division multiplexing (FDM) for mobile phone systems. A mobile phone uses radio waves for two-way communication with the nearest phone mast.

**(a)** Suggest why mobile phone systems use FDM.

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

........................................................................................................................................ **[3]**

**(b)** A particular mast uses the frequencies between 909.375 MHz and 915.625 MHz. How many phones can simultaneously communicate with the mast if each phone signal has a bandwidth of 64 kHz?

number of phones = ........................................................ **[2]**

**(c)** The phones communicate by amplitude modulating a digital signal onto a carrier. Calculate the number of phones which could simultaneously communicate with the mast if frequency modulation was used instead. Explain your answer.

**[3]**

**(d)** Show in the space below how a bandpass filter for a phone can be assembled from a resistor, inductor and capacitor. Label the input and output. No component values are required.

**[2]**

**[Total: 10]**

7 Fig. 7.1 is an incomplete block diagram for part of a superhet radio receiver.

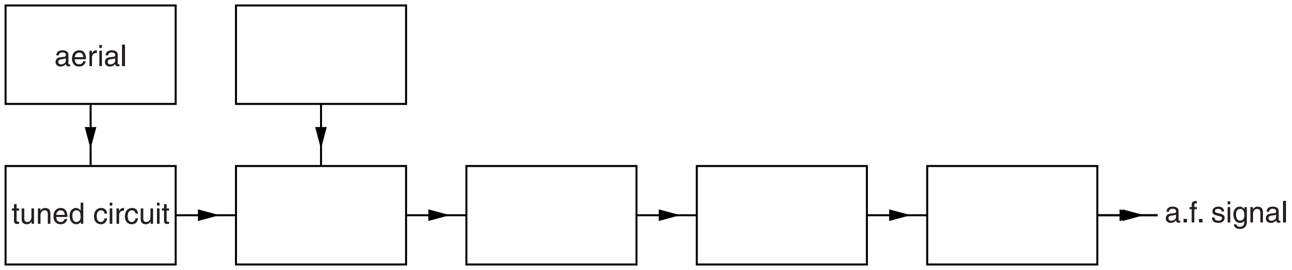


**Fig. 7.1**

**(a)** Complete the block diagram. Choose from the list below.

**amplifier** **demodulator** **filter** **mixer** **oscillator** **ramp generator** **Schmitt trigger**

**[5]**

**(b)** The tuned circuit contains a 4.7 nH inductor and a variable capacitor.
The circuit is to select a signal at 902.50 MHz from the aerial.
Calculate the required setting of the variable capacitor.

capacitor = ................................................... pF **[2]**

**(c)** Explain why a superhet receiver has better selectivity than a simple radio receiver.

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

............................................................................................................................. **[4]**

**(d)** Fig. 7.2 shows the rest of the block diagram for the superhet receiver.


**Fig. 7.2**

The voltage amplifier has these properties:

- input impedance 100 kΩ
- voltage gain +50

Complete Fig. 7.3 to show how the amplifier can be assembled.
Show all component values.

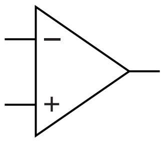


**Fig. 7.3**

**[4]**

**[Total: 15]**

**8** Fig. 8.1 shows the circuit diagram of a 6-bit analogue-to-digital converter (ADC).

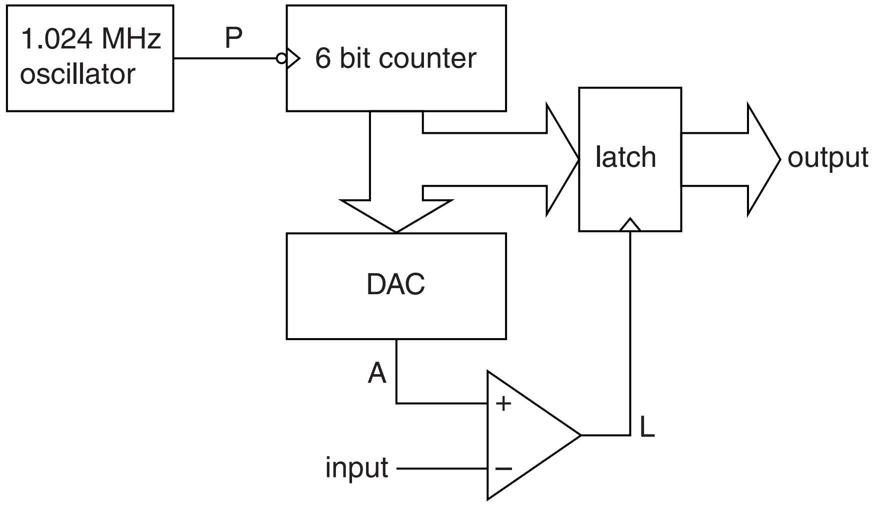


**Fig. 8.1**

**(a)** The block labelled DAC is a 6-bit digital-to-analogue converter.

**(i)** Describe the behaviour of a digital-to-analogue converter.

..........................................................................................................................................

..........................................................................................................................................

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

**(ii)** The DAC in Fig. 8.1 has a resolution of 100 mV.
Show that the range of the DAC is 6.3 V.

**[2]**

**(b)** Describe the behaviour of the block labelled **latch**.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.................................................................................................................................... **[3]**

**(c)** Explain why the sample rate of the ADC of Fig. 8.1 is 16 kHz.

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

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

**(d)** Explain how the ADC of Fig. 8.1 converts the voltage at **input** into a 6-bit word at **output**.

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

............................................................................................................................. **[5]**

**[Total: 13]**

9 Fig. 9.1 shows how a number of computers (labelled A to Z) can exchange packets of data along a single cable.


**Fig. 9.1**

**(a)** Each packet is a 1024-bit word.
It starts with a 0 (the start bit) and ends with a 1 (the stop bit).
Name the other parts of the packet and explain their function.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.................................................................................................................................... **[4]**

**(b)** For correct transmission, each packet must be the only one on the line at that instant.

Explain how this is achieved by the computers.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.................................................................................................................................... **[3]**

**(c)** Each computer has a serial transmitter and serial receiver connected to the cable.
Explain why only one of them is connected to the cable through an analogue switch.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.................................................................................................................................... **[3]**

**[Total: 10]**

Quality of Written Communication **[3]**

**END OF QUESTION PAPER**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

**PLEASE DO NOT WRITE ON THIS PAGE**