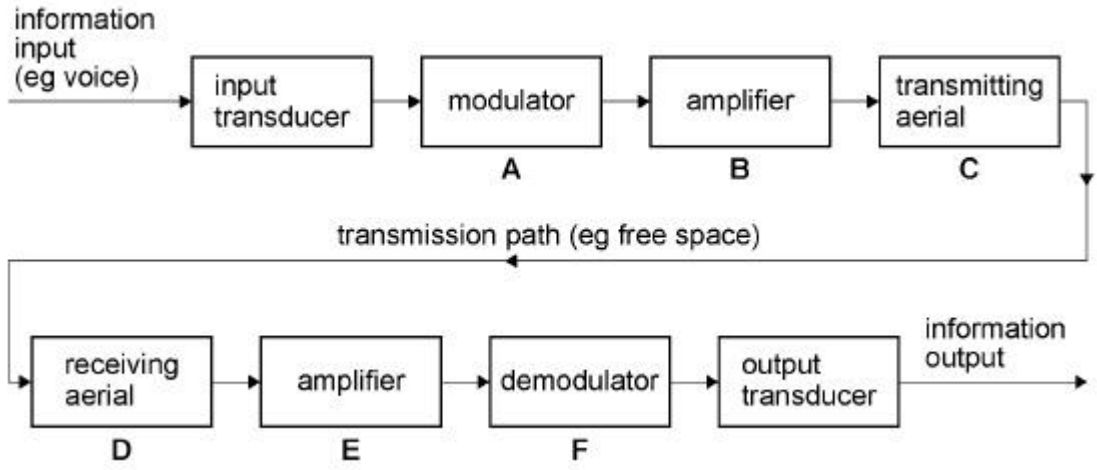
Communications

Q1.

Figure 1 shows a block (subsystem) diagram for a radio communication system.

Figure 1



(a) State the letter representing the subsystem in which you might find an induced emf being generated.

(1)

(b) State the letter representing the subsystem where the audio and radio waves are combined.

(1)

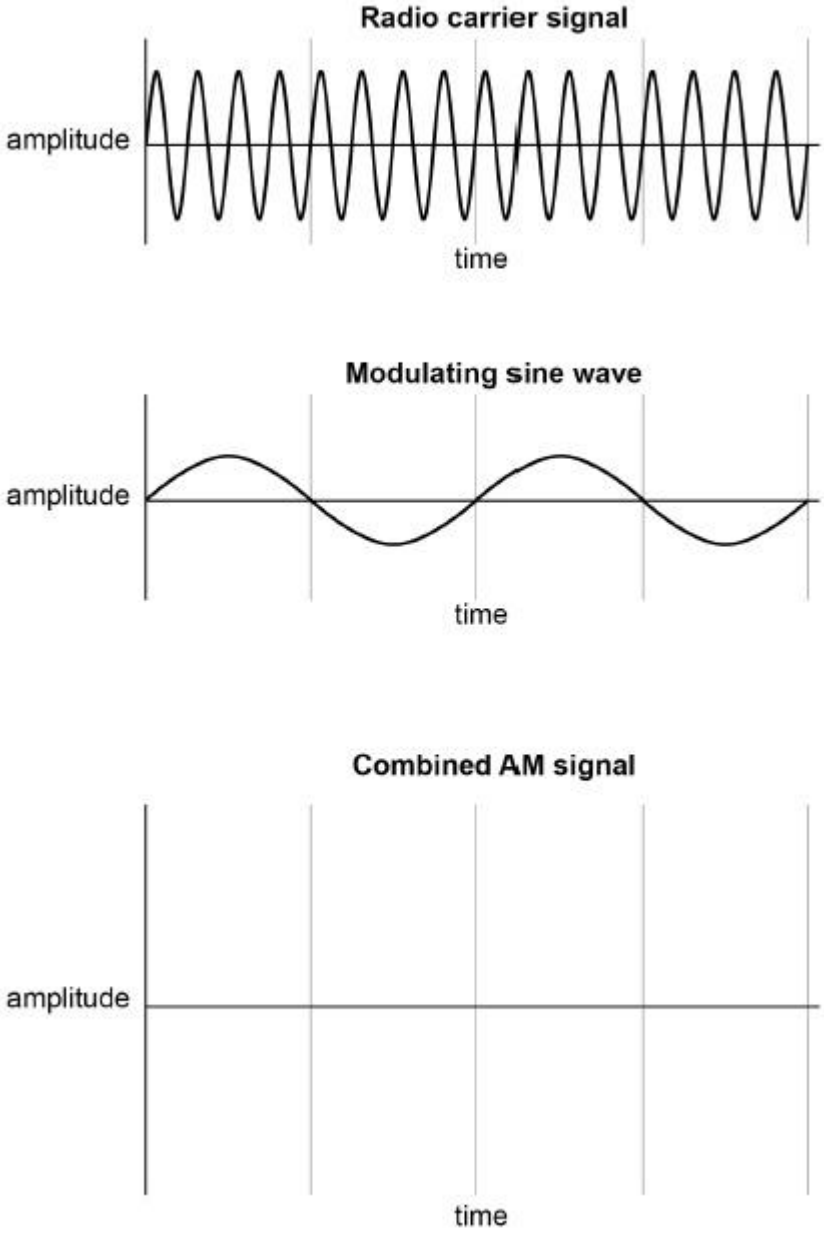
(c) The signal strength at stage **D** must be amplified.

Explain why the signal strength at stage **D** is weak.

(1)

(d) **Figure 2** shows graphs of a radio carrier signal and a modulating sine wave.

Figure 2



Complete the graph in **Figure 2** to represent the combined amplitude modulated (AM) signal.

(1)

(e) Approximately 20 radio stations use amplitude modulation (AM) to broadcast to people living in the London area. Another 35 AM stations broadcast to people outside the London area. However, these broadcasts can still be received in London.

The allocated frequency spectrum for all these broadcasts is in the range 540 kHz to 1600 kHz

Suggest whether all these stations can broadcast hi-fi music using the full audio frequency of 20 kHz

(3)

(Total 7 marks)

Q2.

In a recording studio the output from a microphone is an analogue signal.
The equipment in the studio converts this analogue signal into a digital signal before storing it.

Discuss aspects of the analogue-to-digital conversion in this context.

In your answer you should include:

- what is meant by quantisation
- factors that affect the quality of the digital version of the analogue signal
- the advantages and disadvantages of digitising the analogue signal.

You may use diagrams to help make clear aspects of your answer.

(Total 6 marks)

Q3.

Discuss how longwave (LW), shortwave (SW) and microwave links can be used to communicate beyond the visible horizon.

For each link, you should give:

- a typical carrier frequency that is used
- an explanation of how the signals travel from the transmitter to the receiver
- a typical use.

You may use a diagram to help make clear aspects of your answer.

(Total 6 marks)

Q4.

A student needs to monitor the temperature of a pond using a remote link. To provide the link the student decides to use radio transmitter and receiver modules.

The radio modules available to the student are available with either amplitude modulation (AM) or with frequency modulation (FM).

(a) Describe what is meant by amplitude-modulated and by frequency-modulated radio waves.

In your answer you should:

- indicate the principal features of each of these two types of modulation
- explain the differences between them
- refer to the advantages and disadvantages of using each type of modulation.

(6)

(b) The radio modules chosen by the student transmit a signal that is amplitude modulated having a carrier frequency of 434 MHz. The data sheet for the modules specifies quarter-wave aerials for both the transmitter and receiver.

Calculate the length of a quarter-wave aerial.

length of aerial = _____ m

(2)

(c) The output from the temperature sensor in the pond is connected to an astable oscillator. The frequency f (in Hz) of the astable varies with temperature θ (in °C) according to the equation

$$f = 7.3(6\theta + 273)$$

During the course of the year the temperature of the pond varies between 4°C and 22°C. The highest frequency produced by the astable is 3.0 kHz.

Calculate the lowest frequency in kHz produced by the astable.

lowest frequency = _____ kHz

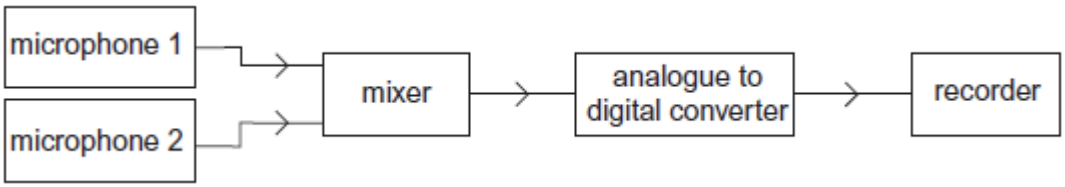
(1)

(d) Deduce the maximum bandwidth required by the AM carrier wave produced by the radio transmitter as the signal from the astable is transmitted.

(2)
(Total 11 marks)

Q7.

The diagram shows a block diagram of an audio recording system.



(a) Explain the purpose of the mixer in this system.

_____

_____

(1)

(b) Suggest a type of recorder that may be used in this system.
Give **one** reason for your answer.

_____

_____

_____

_____

(2)

(c) Explain **one** advantage of including the analogue to digital converter in the system.

_____

_____

_____

_____

(2)
(Total 5 marks)

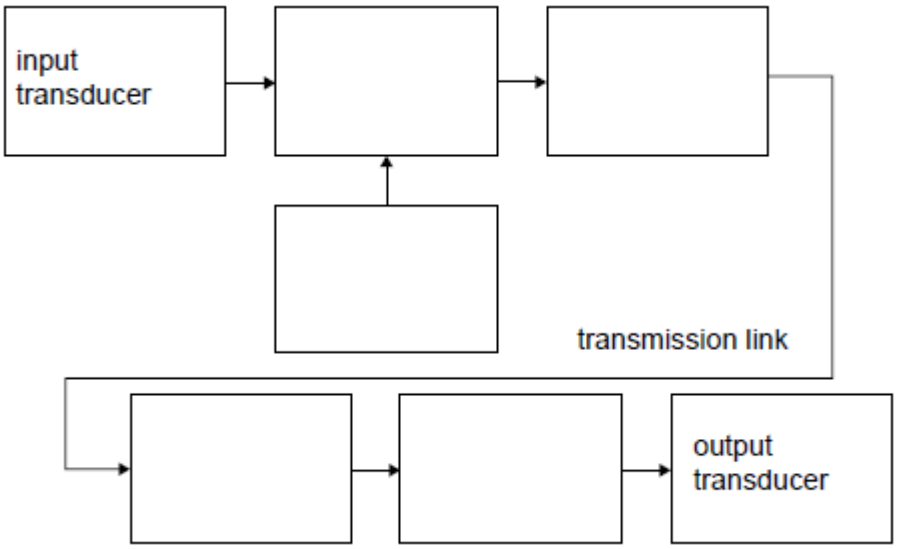
Q9.

Figure 1 shows a block diagram of a generalised communications system.

(a) Complete the labelling of the block diagram, using the following terms:

carrier wave generator **demodulator** **modulator** **receiver** **transmitter**

Figure 1



(2)

(b) Name **three** different media suitable for the transmission link.

1. _____

2. _____

3. _____

(3)

(c) (i) State the function of the modulator.

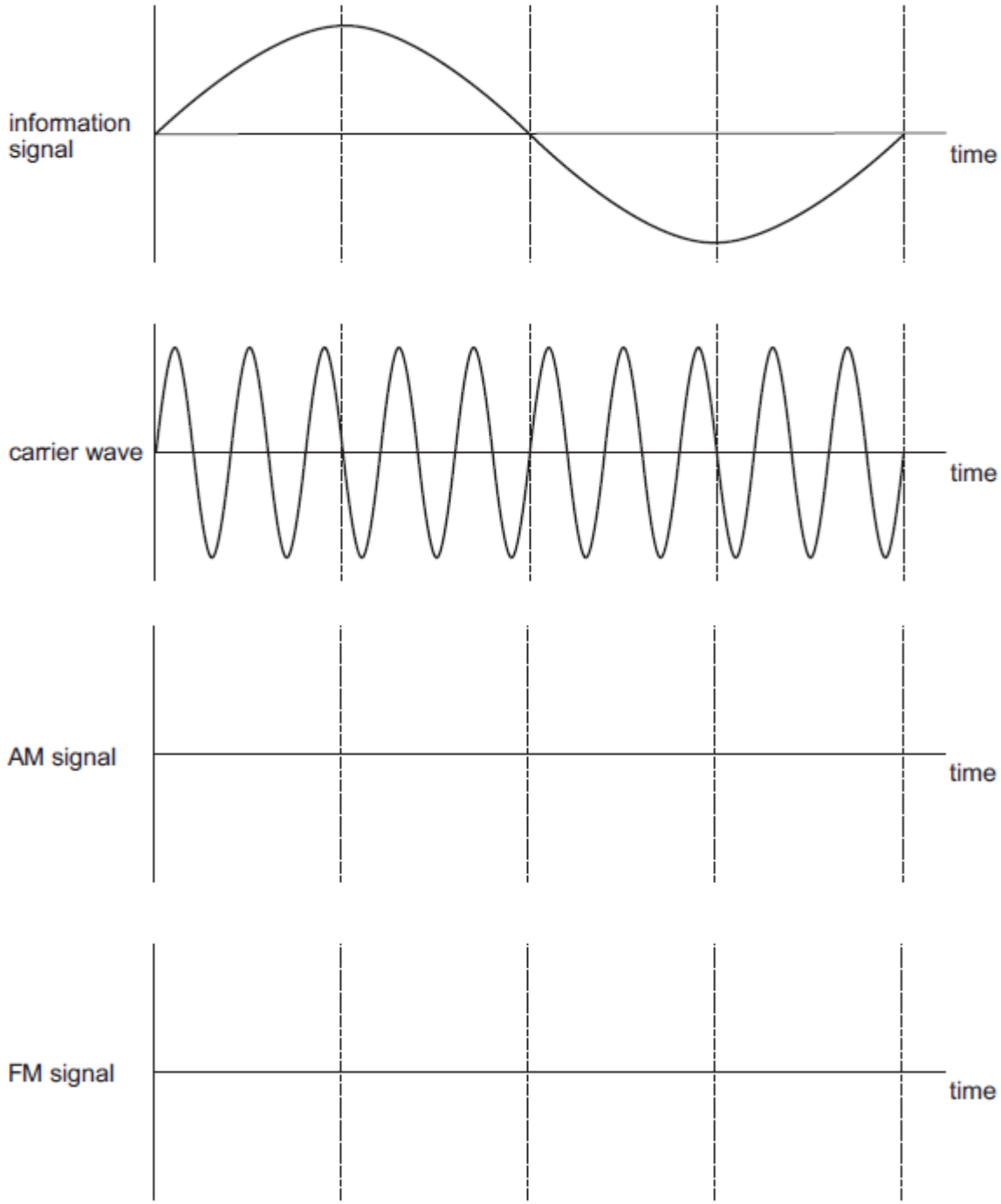
_____

(1)

(ii) AM and FM are two types of modulation.
An information signal and a carrier wave are shown on the upper axes of **Figure 2**.

Draw on the lower axes the AM signal and the FM signal that these would produce.

Figure 2



(4)

(Total 10 marks)

Q10.

The audio signals on an audio CD are digitally encoded. Part of the audio CD specification describes the encoding as:

'PCM with 16-bit values sampled at 44.1 kHz'.

(a) Explain why 44.1 kHz is a suitable sampling frequency for high quality audio recording.

_____

_____

_____

_____

(3)

(b) Calculate the number of different voltage levels which can be detected in each sample.

_____

(1)

(c) The **quantisation error** is the voltage step difference between each level.
The peak-to-peak signal voltage is 5 V.

Calculate the quantisation error for an audio CD.

_____

_____

(2)

(d) A call centre uses an audio CD to play music to callers while they are waiting for their calls to be answered. The telephone system operates in the frequency range 300 Hz to 3 kHz.

Describe **two** different effects this will have on the quality of the music the callers hear.

_____

_____

_____

_____

(2)

(Total 8 marks)

Q1.

(a) **D ✓**

1

(b) **A ✓**

1

(c) One of: ✓

Attenuation of e-m wave across transmission path

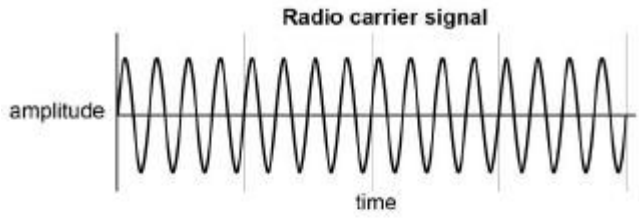
Small fraction of radiated energy in direction of receiver

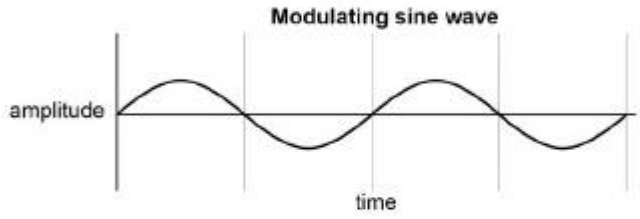
Energy loss due to reflection from ground / natural topography / absorption in atmosphere

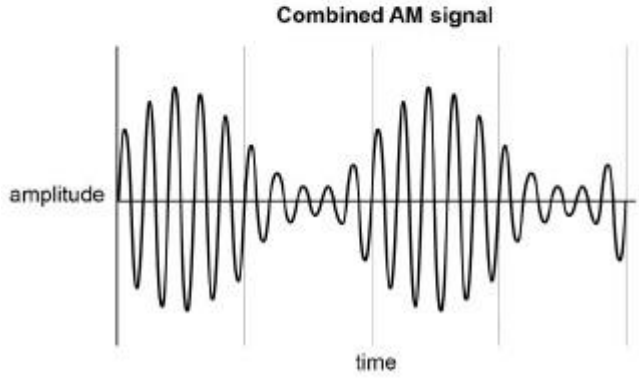
Accept any other reasonable response

1

(d)







Correct relative positions of envelope max – min on AM and an attempt made to keep carrier frequency constant ✓

Modulating signal forms envelope around carrier

1

(e) About 55 stations can be picked up in London

- A full audio frequency of 20 kHz would require a bandwidth of 40 kHz for each station ✓
- 55 × 40 kHz = 2200 kHz. This is twice as much as waveband available ✓ so stations would have to overlap leading to crosstalk / interference ✓

Accept equivalent arguments / calculations

3

[7]

Q2.

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.

Level	Criteria	QoWC
L3 5–6 marks	All bullet points in the question are covered in detail. The candidate shows good knowledge and uses the technical terms correctly. The answer has structure and clearly conveys the information required by the question. The candidate may show a depth of understanding that goes beyond basic recall and will appreciate the impact of the technology on society.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3–4 marks	All of the main processes are addressed and most of the detail is present. There may be an understanding of the impact of the technology on society. There will be some structure, but may be brief or unclear in parts.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1 1–2 marks	A limited answer with significant detail missing. The impact on society may be stated basically but not developed. Candidates may be able to recall some technical terms, but these may be used without expansion or understanding. The material may lack organisation.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0	The work contains no significant analysis of the question asked.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

Expected information:

***Quantisation** – the conversion of a continuously varying*

voltage level by sampling into one that contains discrete (stepped) voltage levels

Factors affecting quality of conversion

i) Sampling rate:

• The number of times/second that the analogue signal is assigned a digital code

*• Audio requires a sample rate = 2 × highest frequency component -------- **(Nyquist rate)***

*• Under sampling will cause a loss in quality. -------- **(Aliasing)***

• Over sampling results in superfluous data

ii) Size of digital code:

*• Number of bits per sample determines smallest change in analogue signal that can cause a change in digital code – ---------- **resolution***

*• **CD** – standard is 16 bits*

The combination of these two factors will determine the amount of data generated in the conversion process. The quantity of data will be very large and will probably require compression techniques to be applied

Advantages of a digital format:

• Good noise immunity

• Digital recordings don't degrade with frequent use in the same way as analogue recordings (Tape v CD)

• Digital files can be saved and manipulated by computer

• Can be coded for downloading across the Internet

Disadvantages of a digital format

• Can be conceived as being too clinical

• Data can become corrupt

• Format compatibility issues

Further points:

Why digital is dominant format in the recording industry

• V. good digital system is cheaper than v. good analogue system

• Scratch resistant format even on CDs

• Development of small personal music devices

• Development of downloads using personal computer

• Development of higher density storage devices (CD to SSD)

[6]

Q3.

Expected information:

Longwave
f ~ 150 kHz – 300 kHz
λ ~ 2 km – 1 km
Aerial Very long
Mode Ground (surface) wave – diffracted
Application Some national radio – large coverage

National time signal

Shortwave
f ~ 3 Mhz – 30 MHz
λ ~ 100 m – 10 m
Aerial medium
Mode Sky wave – reflected from ionosphere (above ~ 500 kHz)
Application Some national radio – large coverage
Long distance comms. for ships and planes
Amateur radio enthusiasts

Microwave
f ~ 100 GHz – 2 GHz
λ ~ 3 mm – 150 mm
Aerial Very short
Mode Direct (space) wave -terrestrial line of sight hops OR space satellite
Application 3G telephone network
Satellite TV
Data transfer to remote locations eg (Falkland Islands)

1–2 marks: *A limited answer with significant detail missing. Candidates may be able to recall terms such as 'sky waves' & 'ground waves', but there may be confusion as to the spectral frequencies or application. The material may lack organisation and technical terms may not be fully understood or used incorrectly.*

3–4 marks: *The roles of at least two links are covered and most of the detail is present. There will be some structure, but it may be either brief or unclear in parts.*

5–6 marks: *All three links are covered in detail. The candidate shows good knowledge and uses technical terms correctly. The answer has structure and clearly conveys the information required by the question. The candidate may show a depth of understanding that goes beyond basic recall.*

[6]

Q4.

(a) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the *'Mark Scheme Instructions'* document should be used to assist marking this question.**

L3 5-6 marks	All three bullet points of the question are addressed in good detail.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3-4 marks	The answer includes some discussion of two or three of the three	The student presents relevant information and in a way which assists the

	bullet points.	communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1 1-2 marks	The answer addresses one bullet point in some detail but the others may be neglected.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0 marks	Little or no discussion of relevant content.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

The following statements could be present:

- *description of variable amplitude of AM carrier wave*
- *description of variable wavelength of FM carrier wave.*

For AM :

- *amplitude of carrier wave varies at frequency of superimposed signal whilst frequency (or wavelength) of carrier wave is constant*
- *advantages of AM:*
  - *modulation is simpler to produce so equipment is less complex*
  - *fewer transmitters needed*
- *disadvantages of AM*
  - *more subject to interference and distortion*
  - *waveband has limited capacity.*

For FM:

- *frequency of carrier wave varies at frequency of superimposed signal whilst amplitude of carrier wave is constant*
- *advantages of FM:*
  - *less prone to interference*
  - *clearer reception*
  - *waveband has greater capacity*
- *disadvantages of FM:*
  - *signal less diffracted because of shorter wavelength so more difficult to receive*
  - *require more transmitters.*

6

(b) $\lambda \left(= \frac{c}{f}\right) = \frac{3.00 \times 10^8}{434 \times 10^6} = 0.691\,(\text{m})$ ✓

Length of aerial = 0.173 (m).✓

2

(c) At 4 °C $f = 7.3(6\theta + 273)$ gives $f = 7.3(6 \times 4 + 273) = 2170$ Hz = 2.2 (kHz).✓

1

(d) Bandwidth calculation based on higher frequency signal f_H i.e 3.0 kHz ✓ required bandwidth = 2 f_H = 6.0 kHz.✓

2

[11]

Q7.

(a) Balances the relative
strength / voltages / currents / intensity / signal / loudness / output from the two microphones / combines the signals to form one signal

Condone power

Not 'sorts the relative strengths'

Allow merges

B1

1

(b) CD or named digital recorder

Only allow magnetic media if clear mention of digital

B1

(A to D converter means) digital recorder is needed

Computer / mobile phone / ipad / MP3 because it processes digital data

B1

2

(c) Noise reduction
When recovering of original digital signal during playback
or
Less storage per file or shorter download time per file
due to compression of digital signal

Allow for 1 mark

- *concept of restoring the original signal more easily*
- *'faithful' multiple copies*
- *ease of manipulation of data*

<u>Not</u> easier to store

B1

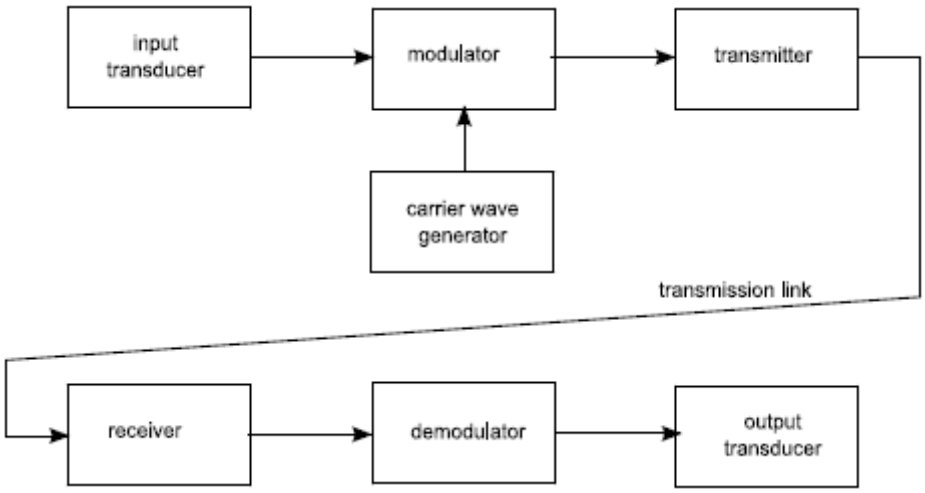
B1

2

[5]

Q9.

(a)



transmitter & receiver, carrier wave gen ✓
demodulator & modulator✓

2

(b) e.g. free space
optical fibre
twisted pair
coax cable (any 3 ✓✓✓)

3

(c) (i) superimpose the information signal onto the carrier wave ✓

1

(ii) AM − constant frequency sinusoidal wave matching carrier wave ✓
amplitude varies in phase with information signal ✓
FM − constant amplitude sinusoidal wave ✓
frequency varies in phase with information signal ✓

4

[10]

Q10.

(a) upper audio frequency maximum 15−20kHz ✓
sampling frequency must be higher ✓ than 2× ✓ highest audio frequency

3

(b) 65536 ✓

allow 65535

1

(c) 5 / 65535 ✓ = 76μV ✓

allow 65536
ecf from (b)

2

(d) high & low frequencies are lost *or* reduced bandwidth ✓
reference to perceived quality, e.g. lack of bass / treble in the music,'tinny', or similar ✓

2

[8]

Q1.

(a) Only about 52% of students were successful on this question, but given the success achieved on the next question there was obviously a good general understanding of the radio transmission system.

(b) A large proportion of students (82%) gained this mark.

(c) 'Attenuation across the transmission path' was accepted for the one mark, although it was good to see some students expand on this statement and give a reason for the attenuation.

(d) A significant number of students (61%) failed to get this mark. The problem appeared to be with not knowing the AM shape rather than succumbing to any technical difficulties in drawing the shape.

(e) Students found this question to be more difficult. Many forgot that this was an AM system and the broadcast frequency range had to accommodate the total bandwidth 2 x (f_m) for each station. Although a significant number of students still managed to argue (incorrectly) that not all stations could broadcast 20 kHz hi-fi, they failed to pick up the last marking point which was for stating what the consequences would be if the stations went ahead with hi-fi broadcasts across the full audio range. Only 19% of students scored all three marks.

Q2.

This question proved to be a good discriminator, with a good spread of marks. However, only a few students (18%) accessed the top mark band. There was considerable evidence of the answer evolving rather than being planned. Consequently, a number wrote a lot but said very little. In particular, only the very good students expanded on the second bullet point by considering the problems created by under- and over-sampling. 57% of students managed to score at least three marks.

Q3.

This question was designed to give students the chance to write about 'ground, sky and space waves' related to the two radio frequency bands, LW and SW, and also to the use of microwaves as communication links. Only a relatively small number of students gained scores in the upper mark band, mainly due to confused knowledge of this part of the specification as opposed to a lack of eloquence.

Q7.

(a) There were many acceptable responses but a significant proportion of the candidates were unclear as to its purpose. Balancing frequencies or combining two frequencies to give one frequency were examples of such responses.

(b) Most realised that a recording system that could store digital data was needed and a good proportion of the candidates named a suitable recorder.

(c) The storage concept was identified by many but relatively few explained how this was achieved by compressing the digital signal. Those who gave noise reduction were rarely able to expand on this.

Q9.

(a) Nearly all candidates scored both marks on this basic completion of a system diagram. A few swapped the modulator and demodulator.

(b) There was some confusion about the meaning of the term ‘transmission medium’, some naming light or electromagnetic waves.

(c) Candidates need to show their knowledge. Even when asked to simply ‘state the function’, they should not just use a form of the same word in the question, i.e. ‘a modulator modulates’!

In drawing modulated waves, the relationship to the carrier wave and the information signal should be clear and careful. Good candidates drew envelopes or guidelines, or labelled their diagrams. A common mistake was to amplitude modulate at twice the information signal frequency.

Q10.

(a) In explaining the sampling frequency, reference needs to be made to the upper frequency limit of human hearing.

(b) It is perhaps surprising that a third could not make this basic calculation.

(c) A common error was to calculate the inverse of the quantisation error.

(d) Just describing the quality of the music as ‘poor’, for example, was not considered enough.