A-Level Physics

Data Communication Systems

Mark Scheme

Time available: 77 minutes
Marks available: 48 marks

1. (a) ($f = 1 / T$; $f = 1 / 5\ \mu s$)

200 ✓ (kHz)

1

(b) Measurement from the graph of the half wavelength of signal

$T = 2 \times 42\ \mu s$ ✓

First mark for factor 2 in calculation

Allow range 2 × (40 – 44) μs

Calculation of frequency ($f = 1 / T$) using their T

11.9 kHz (± 0.6 kHz) ✓

Second mark – allow ecf only if their T is clearly derived form analysis of the graph

2

(c) Any one from: ✓

- Immune to any noise in amplitude. (since information stored in the frequency variation)
- Quality of an FM signal remains high even when the transmitter power is low.
- (since most of power is in sidebands / information).
- Carries more information
- (since the FM bandwidth is much wider than that of AM)

Max 1 mark

1

(d)

= 100 stations ✓

$$\frac{(108\ \text{MHz} - 88\ \text{MHz})}{200\ \text{kHz}}$$

1

(e) Bandwidth = $2(\Delta f + f_m)$ = 2 × (75 kHz + 15 kHz) = 180 kHz ✓

This fits in allocated 200 kHz band ✓

Second mark – allow ecf if conclusion is consistent with their calc.

2

[7]

2. **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
L3 **6 marks**	Candidate matches the **three** areas of the communications spectrum with the correct pathway. They provide a coherent and comprehensive explanation of the properties of each pathway. The answer has structure and detail.
L3 **5 marks**	Candidate matches the **three** areas of the communications spectrum with the correct pathway. They provide a comprehensive explanation of the properties of each pathway, but the answer may lack structure / detail.
L2 **4 marks**	Candidate matches **two** areas of the communications spectrum with the correct pathway. They provide a coherent and comprehensive explanation of the properties of each pathway. The answer has structure and detail.
L2 **3 marks**	Candidate matches the **two** areas of the communications spectrum with the correct pathway. They provide a comprehensive explanation of the properties of each pathway, but the answer may lack structure / detail.
L1 **2 marks**	Candidate matches **one** area of the communications spectrum with the correct pathway. They provide a coherent and comprehensive explanation of the properties of that pathway. The answer has some structure and detail.
L1 **1 mark**	Candidate matches **one** area of the communications spectrum with the correct pathway. They provide some explanation of the properties of the pathway. The answer may lack structure / detail.
L1 **0 marks**	The work contains no significant analysis of the question asked.

Longwave

Typical frequency range

Broadcasts between 150 kHz – 300 kHz which fits into the LF band.

Also accept extended (3 kHz – 500 kHz) range to allow for special applications.

Pathway – Ground (surface waves)

i. Generally, line of sight.

ii. Beyond the horizon communication by following earth's curvature.

iii. Diffraction in the atmosphere due to different refractive index.

iv. Diffraction due to interaction of the wave with conductive surface (earth).
v. Diffraction due to interaction with geographical topography – hills / buildings.
vi. Long distance propagation due to low attenuation of low frequency waves.
vii. Transmission severely attenuated by ionosphere so little reflection

Shortwave

Typical frequency range

Normally taken as 3 MHz – 30 MHz which includes the full HF band. (Accept lower limit of 1.7 MHz)

Pathway – Sky waves

i. Ionosphere acts to refract and hence reflect waves back to the earth.
ii. This allows beyond the horizon reception due to single/multiple reflections (skips).
iii. Below this frequency, ionosphere will absorb waves.
iv. Above this frequency, the wave will pass through the ionosphere.
v. Can suffer disruption due to the state of the ionosphere day/night effects or sunspot cycle.

Microwaves

Typical frequency range

Normally taken as 2 GHz – 100 GHz Accept 1.7 GHz – 300 GHz

Pathway – Space wave

i. Due to high frequency, microwaves do not diffract around terrestrial objects, so line of sight required.
ii. Microwaves travel straight through atmosphere and ionosphere.
iii. Significant attenuation of transmission by atmosphere and ionosphere.
iv. Different frequencies used for up-link and down-link so that satellite receiver is not desensitized.
v. Up-link normally at higher frequency (17 – 18 GHz) than down-link (10 – 13 GHz) since higher frequency gives narrower beam and can be given more power to overcome attenuation. (Converse argument for down-link based on wider target area and low power available from satellite).
vi. Microwave communication allows for greater bandwidth to carry complex information.

[6]

3. **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 in marking this question.**

Level	Criteria
L3 **6 marks**	The candidate shows a good understanding of the way **both** systems operate. They propose a valid and reasoned solution for both Island **B** and Oil rig **C**. They use technical terms correctly, the answer has structure and clearly conveys the information required.
L3 **5 marks**	The candidate shows a good understanding of the way **both** systems operate. They propose a valid and reasoned solution for both Island **B** and Oil rig **C**. However, there may be minor gaps in knowledge OR the style / structure may lead to a lack of clarity in some of the information being presented.
L2 **4 marks**	The candidate shows a general understanding of the material but one of the systems or supported solutions will be treated superficially. Structure and technical language used is generally good.
L2 **3 marks**	The candidate shows a general understanding of the material but one of the systems or supported solutions will be treated superficially. There may be some lack of clarity either through the structure or in use of technical terms.
L1 **2 marks**	The candidate shows a basic understanding of the way **one** system operates. They propose a supported valid solution for either Island **B** or Oil rig **C**. There may be some lack of clarity in structure, there is good use of technical terms.
L1 **1 marks**	The candidate shows a basic understanding of the way **one** system operates. They propose an unsupported but valid solution for either Island **B** or Oil rig **C**. There may be some lack of clarity either through the structure or in use of technical terms.
L1 **0 marks**	The work contains no significant analysis of the question asked.

Proposed solution:

Island B

Initial phase – use of satellite link

- Quick and easy to set up mobile sat unit(s).
- Initial usage and platform range likely to be low, hence lower bandwidth / data rates not an issue.
- Some difficulties with two-way conversations due to signal delay.
- Higher maintenance costs and possible interference problems due to EM noise and security issues.

Later phase – install submarine cable

- More forward planning / expense needed to put this in – cable ship / terminations / internal network Heavier usage as development proceeds and wider platform support – hence more bandwidth / larger data rate required.
- More reliable link
- Low security issues and immune to EM interference.

Oil rig C

Satellite link

- Fibre optic cable not an option due to mobile nature of the rig.
- Satellite link is a low-cost short-term solution.
- Light use and limited platform requirement so reduced bandwidth / lower data rate not critical.
- Some difficulties with two-way conversations due to signal delay.
- Reliability issues.

[6]

4. 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 in marking this question.

Level	Criteria
L3 **6 marks**	The candidate shows a good knowledge of the **three** general properties of copper wire and optic fibre. They use technical terms correctly, the answer has structure and clearly conveys the information required. They reach a conclusion based on the supporting evidence.
L3 **5 marks**	The candidate shows a good knowledge of the **three** general properties of copper wire and optic fibre. However, there may be minor gaps in knowledge OR the style / structure may lead to a lack of clarity in some of the information being presented. There is a supported conclusion.
L2 **4 marks**	The candidate shows a good understanding of **two** general properties of copper wire and optic fibre. Technical terms will be used correctly and the information will generally be presented in a structured and coherent manner. A conclusion will be drawn from the information presented.
L2 **3 marks**	The candidate shows a good knowledge of **two** general properties of copper wire and optic fibre. There may be minor gaps in knowledge / detail which may lead to a lack of clarity. There will be a conclusion which draws some support from the information presented.
L1 **2 marks**	The candidate shows some knowledge of **two** general properties of copper wire and optic fibre. There may be significant gaps in knowledge / detail which may lead to a lack of clarity. There may be no supported conclusion.
L1 **1 marks**	The candidate shows some understanding of **one** of the general properties of copper wire and optic fibre. Overall, this will be a limited answer with significant detail missing. There may be a lack of structure and clarity.
L1 **0 marks**	The work contains no significant analysis of the question asked.

		Copper	Optic fibre
Physical	**Corrosion**	Will corrode unless well protected	Glass doesn't corrode
	Weight / connectivity	Heavier, easier to join	Lightweight, more difficult to join sections
External interference	**Security**	Can be tapped without breaking cable	Cannot be tapped unless broken into
	External access	Can pick up noise / cross talk	Immune from noise – can be used in noisy environments
Signal-carrying properties	**Signal degradation / attenuation**	High attenuation	Low attenuation / Possible pulse smearing
	Bandwidth / info carrying capacity	Relatively low bandwidth / fewer channels	Greater bandwidth / capacity / more channels / possibility of sending multiple types of signal eg data + talk

[6]

5. **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)

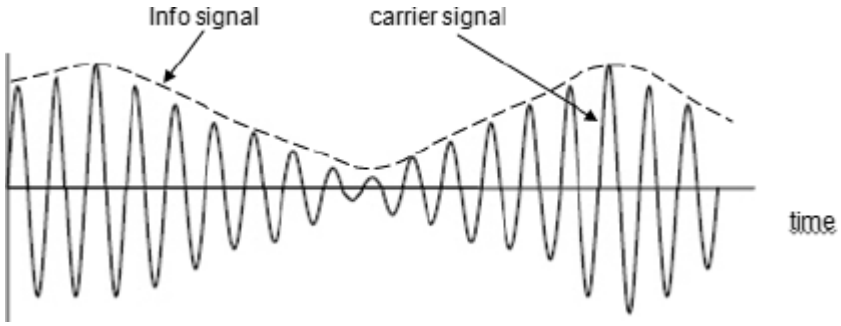
1–2 marks: *A limited answer with significant detail missing. Candidates may be able to recall terms such as 'sky waves' & 'ground waves', but there may be confusion as to the spectral frequencies or application. The material may lack organisation and technical terms may not be fully understood or used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

6. (a) amplitude of carrier varies in phase with information / audio signal ✓
accept labelled diagram in support



1

(b) 2 x 2.2 kHz = 4.4 kHz ✓

1

(c) requires a large bandwidth so would limit the number of channels / stations if low frequency carriers were used✓

1

(d) Noise distorts the amplitude of signals which is difficult to reduce in am✓
In fm the original signal can be recovered as long as the frequencies in the BW are detectable since no information in the amplitude. ✓
In AM receivers signals and noise are amplified equally.
ANY TWO

2

[5]

7. (a) input transducer to modulator✓
carrier generator to modulator✓
modulator to transmitter✓

3

(b) (i) no input, produces an oscillating signal✓
at desired frequency✓

2

(ii) takes a signal from the environment✓
and converts it to an electrical signal✓

2

(iii) uses the signal from the input transducer✓
to change some property of the signal produced by the carrier generator✓
to carry the information signal and feeds it to the transmitter✓

3

(iv) converts the modulated carrier signal✓
into a radio wave✓

2

[12]