A carrier wave is frequency modulated.

(a) Describe what is meant by *frequency modulation*.

frequency of the carrier wave varies in synchrony with a displacement of the signal with the unchanged amplitude. [2]

(b) The sinusoidal carrier wave has a frequency of 750 kHz and an amplitude of 5.0 V.
The carrier wave is frequency modulated by a sinusoidal signal of frequency 7.5 kHz and amplitude 1.5 V.
The frequency deviation of the carrier wave is 20 kHz V^{-1}.

Determine, for the frequency-modulated carrier wave,

(i) the amplitude,

amplitude = 5 V [1]

(ii) the minimum frequency,

minimum frequency = 720 kHz [1]

(iii) the maximum frequency,

maximum frequency = 780 kHz [1]

(iv) the number of times per second that the frequency changes from its minimum value to its maximum value and then back to the minimum value.

number = 7500 s^{-1} [1]

(b) The variation with time of part of the signal at the input P to the analogue-to-digital converter (ADC) is shown in Fig. 12.2.

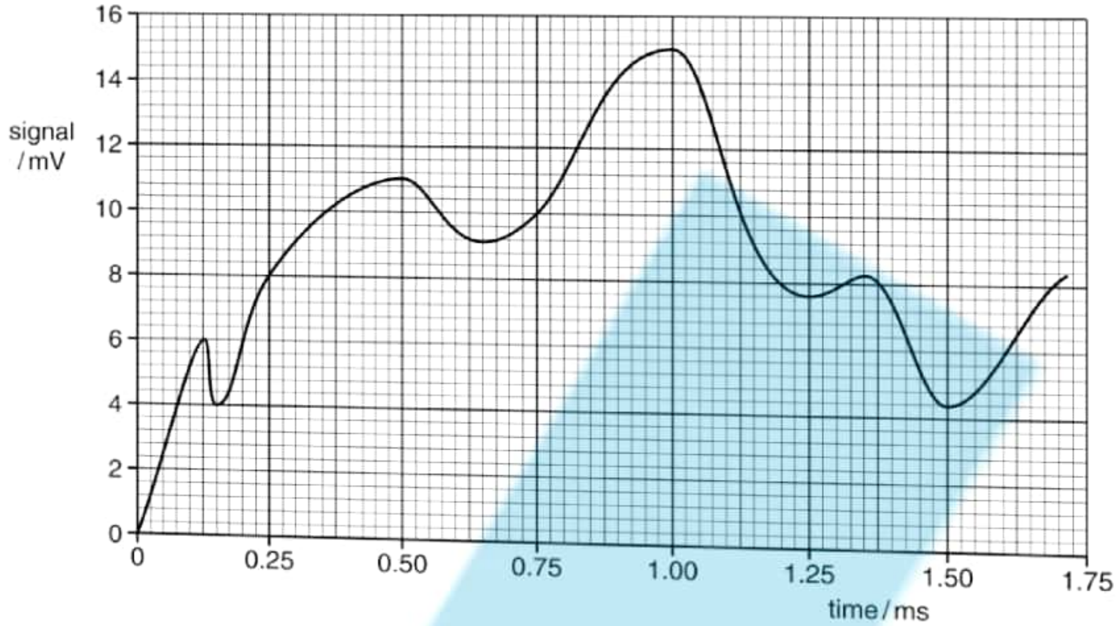

Fig. 12.2

Each number of the output from the ADC is a digital number where the smallest bit represents 1 mV.

State

(i) the minimum number of bits in each digital number so that the signal in Fig. 12.2 can be sampled fully,

number = ...4........ [1]

(ii) the digital number produced by the ADC at time 0.50 ms.

number = ...1011........ [1]

(c) The ADC samples the signal in Fig. 12.2 at a frequency of 4.0 kHz. The first sample is taken at time zero.

$2.5 \times 10^{-4} \times 1000 = 0.25\,ms$

Using data from Fig. 12.2, draw, on the axes of Fig. 12.3, the variation with time of the output at point Q for time zero to time 1.5 ms.

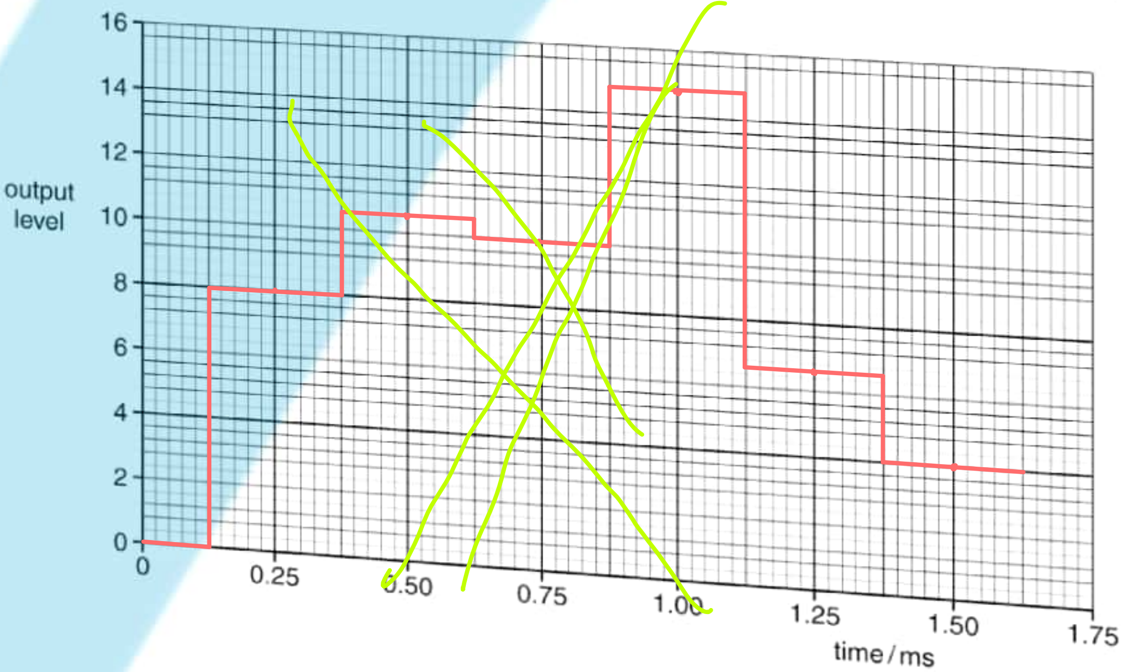

Fig. 12.3

[4]

(a) Signals may be transmitted in either analogue or digital form. One advantage of digital transmission is that the signal can be regenerated.

Explain

(i) what is meant by *regeneration*,

The noise is removed from the signal, and the original signal is reformed.

.... [2]

(ii) why an analogue signal cannot be regenerated.

noise will be amplified with the signal as analog signal is continuous so cannot be regenerated .... [2]

(b) Digital signals are transmitted along an optic fibre using infra-red radiation. The uninterrupted length of the optic fibre is 58 km.

The effective noise level in the receiver at the end of the optic fibre is 0.38 μW.
The minimum acceptable signal-to-noise ratio in the receiver is 32 dB.

(i) Calculate the minimum acceptable power P_{MIN} of the signal at the receiver.

$$32 = 10 \log\left(\frac{P_{min}}{0.38\times10^{-6}}\right)$$

$$P_{min} = \left(10^{3.2}\right)\left(0.38 \times 10^{-6}\right) = 6\times10^{-4}$$

P_{MIN} = ...6×10^{-4}.... W [2]

(ii) The input signal power to the optic fibre is 9.5 mW. The output power is P_{MIN}. Calculate the attenuation per unit length of the optic fibre.

$$-att = 10 \log\left(\frac{9.5\times10^{-3}}{6\times10^{-4}}\right)$$

$$att = -11.9$$

$$\frac{12}{58} = 0.2068$$

attenuation per unit length = ...0.21.... dB km^{-1} [2]

[Total: 8]

The signal from a radio station is amplitude modulated.

(a) State what is meant by *amplitude modulation* (AM).

Amplitude of the carrier wave varies in synchrony with a displacement of the signal with the unchanged frequency

.... [2]

(b) The variation with frequency of the intensity of the signal from the radio station is shown in Fig. 5.1.

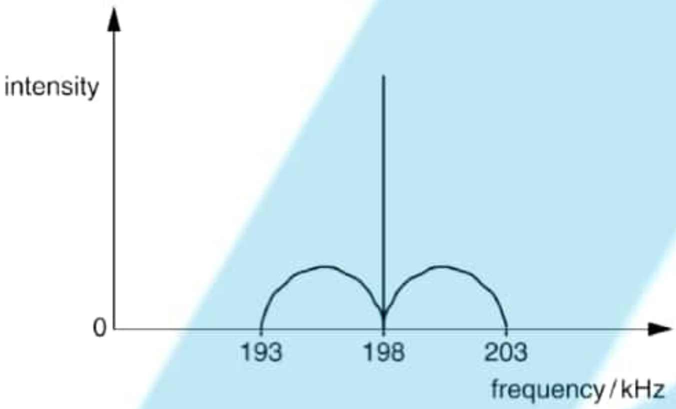

Fig. 5.1

State, for this signal,

(i) the bandwidth,

bandwidth = ...10.......... kHz [1]

(ii) the maximum audio frequency that is broadcast.

maximum frequency = ...203.......... kHz [1]

(c) A transmission line of length 45 km has an attenuation per unit length of 2.0 dB km^{-1}.

The input power to the transmission line is 500 mW.
The minimum acceptable signal-to-noise ratio is 24 dB for background noise of 5.0×10^{-13} W.

(i) Calculate the minimum acceptable power output from the transmission line.

$24 = 10 \log\left(\frac{P_{out}}{5 \times 10^{-13}}\right)$

$(10^{-2.4})(5 \times 10^{-13}) = 1.2559 \times 10^{-10} = 1.3 \times 10^{-10}$

power = ...1.3×10^{-10}.......... W [2]

(ii) Use your answer in **(i)** to determine whether it is possible to transmit the signal along the transmission line.

$-90 = 10 \log\left(\frac{P}{500 \times 10^{-3}}\right)$

$(10^{-9})(500 \times 10^{-3}) = 5 \times 10^{-10}$

[2]

[Total: 8]

(a) State two advantages of the transmission of data in digital form, compared with the transmission in analogue form.

1. can be encrypted

2. Noise can be eliminated and signal can be regenerated

[2]

(b) The digital numbers shown in Fig. 5.1 are transmitted at a sampling rate of 500 Hz.

	0111	1011	1001	0100	1110	0101	0010	
	7	11	9	4	14	5	2	
end of transmission	←			←				start of transmission

Fig. 5.1

The digital numbers are received, after transmission, by a digital-to-analogue converter (DAC).

On Fig. 5.2, complete the graph to show the variation with time t of the signal level from the DAC.

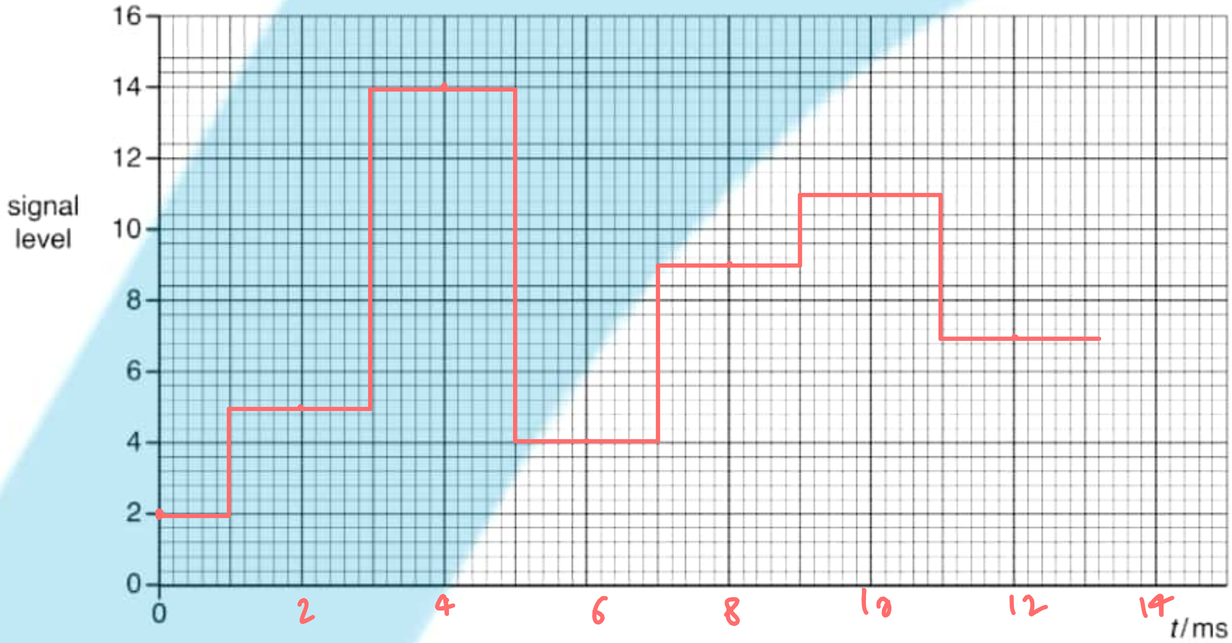

Fig. 5.2

[4]

(c) State the effect on the transmitted analogue signal when

(i) the sampling rate of the analogue-to-digital converter (ADC) and of the DAC is increased,

step width decreases

[1]

(ii) the number of bits in each sample is increased.

step hight decreases.

[1]

[Total: 8]