Answers to Coursebook questions – Chapter F1

1 **a** We look at the coefficient of time *t*, which is the angular frequency $\omega = 2\pi f$: $3.0\sin(2000\pi t + 0.1)$. Hence $2\pi f = 2000\pi \Rightarrow f = 1000$ Hz.

b $2\pi f = 6600 \Rightarrow f = 1050$ Hz

c $2\pi f = \dfrac{\pi}{10^{-4}} \Rightarrow f = 5000$ Hz

2 **a** Modulation is the modification of a carrier wave in such a way that it can carry information.

b AM transmissions are more susceptible to noise; in AM the amplitude of the carrier is modified by the information signal and also by noise that gets added to the amplitude.

3 In amplitude modulation the instantaneous displacement of the information signal gets added to the amplitude of the carrier wave.

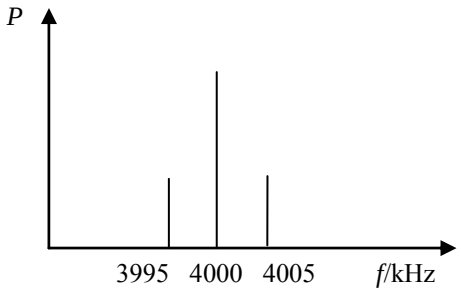
4 **a** The amplitude modulated wave will have three components of frequency:

i 4.0 MHz or 4000 kHz,

ii $4000 + 5.0 = 4005$ kHz and

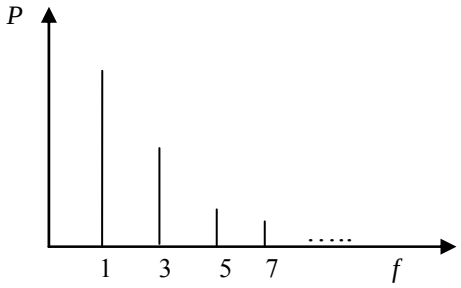
iii $4000 - 5.0 = 3995$ kHz.

b



5 The modulated wave contains components of frequency other than that of the carrier. These frequencies are called sideband frequencies.

6



7 It is twice the highest frequency in the information signal, i.e. $2 \times 4.5 = 9.0$ kHz.

8 **a** The bandwidth is $2 \times 3 = 6$ kHz.

b The upper sideband will contain frequencies from $1500 + 0.20 = 1500.2$ kHz to $1500 + 20 = 1520$ kHz.
The lower sideband will contain frequencies from $1500 - 20 = 1480$ kHz to $1500 - 0.20 = 1499.8$ kHz.
The bandwidth is $1520 - 1480 = 40$ kHz.

c The range is $1200 - 800 = 400$ kHz, and so $\frac{400}{40} = 10$ radio stations can broadcast.

9 The frequency range is very small and completely unsuitable for an FM bandwidth. You would be forced to use AM.

10 **a** There are 6 full waves in a time of 0.05 ms and so the period of the carrier is $\frac{0.05}{6} = 0.00833$ ms and so the carrier frequency is $\frac{1}{0.00833 \times 10^{-3}} = 120$ kHz.

b The time from peak of envelope to next peak is about 0.1 ms and so the frequency of the information signal is $\frac{1}{0.1 \times 10^{-3}} = 10$ kHz.

c $A = \frac{\max - \min}{2} = \frac{1.6 - 0.4}{2} = 0.6$ mV.

11 In frequency modulation the frequency of the carrier wave gets modified according to the instantaneous displacement of the information signal. The frequency is largest when the information signal is large and positive; the frequency is least when the information signal is large and negative.

12 FM:

i has a larger bandwidth,

ii is less susceptible to noise and

iii more information can be transmitted with less power.

13 Bandwidth determines the range of frequencies that can be transmitted and therefore is intimately related to the quality of the transmission. Reducing the bandwidth reduces the quality of the transmission.

14 **a** $\dfrac{108-88}{1}=20$

b The range of FM is small, so different parts of a country can use the same frequency without interference.

15 **a** There are 10 full waves in 1 ms, so the period is 0.1 ms and so the frequency is 10 kHz.

b The period from the second graph is 1 ms and so the frequency of the information signal is 1 kHz.

c From the enlarged graph the period is 0.20 ms and so the frequency is $\dfrac{1}{0.2\times10^{-3}}=5.0\text{ kHz}$. The carrier frequency is 10 kHz so the deviation is 5.0 kHz.

The required ratio is then $\beta=\dfrac{\Delta f}{f_{\text{I}}}=\dfrac{5.0}{1.0}=5.0$.

d The bandwidth is $2(\Delta f+f_{\text{I}})=2\times(5.0+1.0)=12\text{ kHz}$.

e There are 20 full waves in the 2.0 ms interval, from which we can deduce that the carrier wave has a frequency of $\dfrac{20}{2.0\times10^{-3}}=10\text{ kHz}$.

Concentrating on the part of the modulated graph from $t=0.9\text{ ms}$ to $t=1.1\text{ ms}$ we see that we have about 3 full waves there so the highest frequency in the modulated wave is $\dfrac{3}{0.2\times10^{-3}}=15\text{ kHz}$ and hence $\Delta f=5.0\text{ kHz}$.

The time from when the frequency of the modulated wave is least to the next time it is least is 1 ms, and this is the period of the information signal, i.e. its frequency is 1.0 kHz. The modulation index is then 5.0.

16 **a** $\beta=\dfrac{\Delta f}{f_{\text{I}}}=\dfrac{75}{12}=6.2$

b The bandwidth is $2(\Delta f+f_{\text{I}})=2\times(75+12)=174\text{ kHz}$.

17 See the block diagram on page 550 in *Physics for the IB Diploma*. The tuning circuit will select the appropriate carrier frequency of the many that are picked up by the aerial of the receiver. A radio frequency amplifier will amplify the voltage in the tuning circuit and a demodulator circuit will extract the information signal from the carrier wave. The signal extracted by the demodulator is then sent to an audio amplifier that amplifies the audio signal so that it can drive a loudspeaker.

18 The tuning circuit has its own natural frequency of oscillation (determined by the electrical components of the circuit). The current/voltage in the circuit will be large only when the incoming carrier wave through the antenna has the same frequency as the natural frequency of the circuit. Thus the circuit will respond to only a particular carrier wave.

