ES180 – Circuits & Devices - Additional Example Problems

(Actual Exercise numbers from course text – Crofts, Godfrey & Staunton – are used)

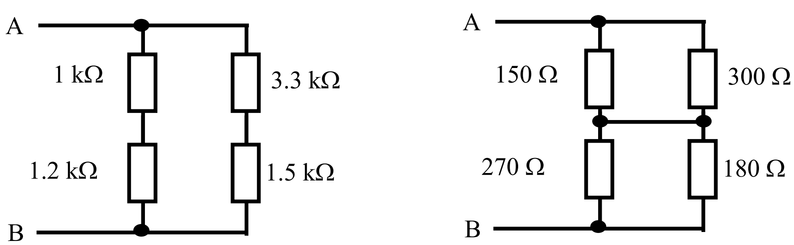
1.5 List five basic functions, or processes, that appear in electrical and electronic systems.

1.13 Describe what is meant by ‘partitioning’ with respect to the design of an electronic system.

1.14 Explain how a module in an electrical system may be described in terms of ‘sources’ and ‘loads’.

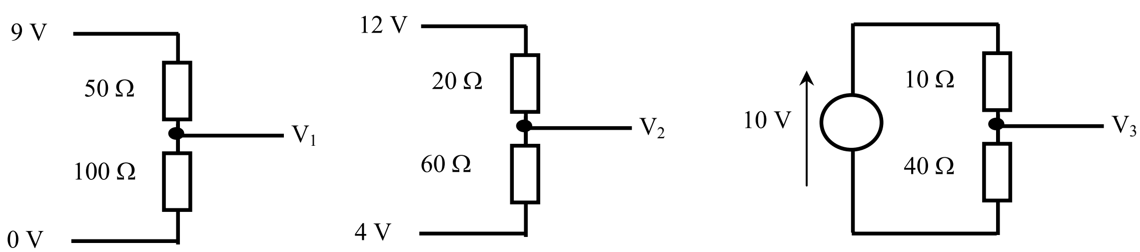
2.7 If a 400 Ω resistor has a current of 5 μA flowing through it, what power is being dissipated by the resistor?

2.13 Calculate the effective resistance between the terminals A and B in the following arrangements.



(a) (b)

2.14 Calculate the voltages V_1, V_2, and V_3 in the following arrangements.



(a) (b) (c)

3.2 What is meant by the resolution of a sensor?

3.4 Define the terms ‘accuracy’ and ‘precision’.

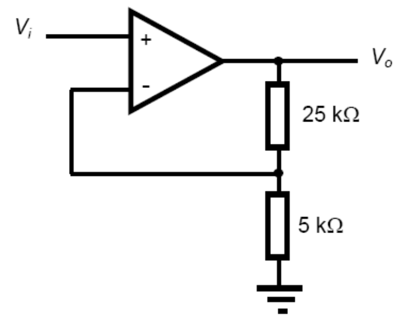
4.13 What form of optical fibre would be preferred for communication over a distance of several kilometres? What form of light source would normally be used in such an arrangement?

4.15 Describe the operation of a simple solenoid.

7.8 Sketch a block diagram of a generalised feedback system and derive an expression for the output in terms of the input and the gains of the forward path (A) and feedback path (B).

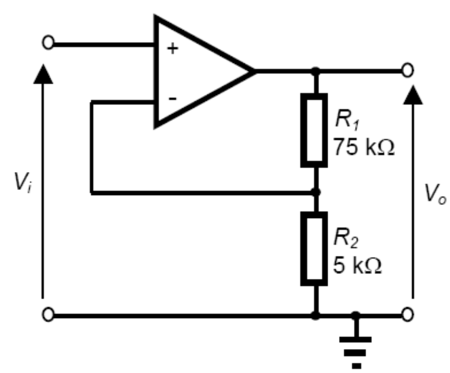
7.13 Design an arrangement with a stable voltage gain of 10 using a high-gain active amplifier. Determine the effect on the overall gain of the circuit if the voltage gain of the active amplifier varies from 100,000 to 200,000.

7.16 Determine the voltage gain of the following amplifier.

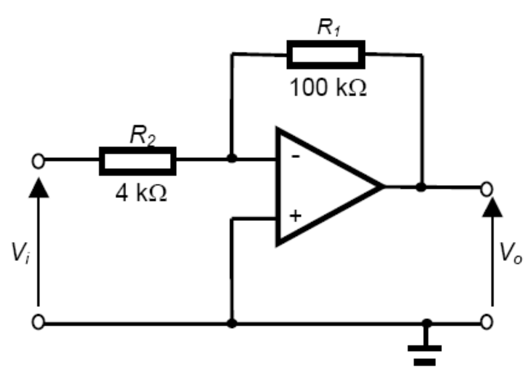


8.4 Outline the characteristics of an 'ideal' op-amp.

8.6 Determine the gain of the following circuit.



8.9 Determine the gain of the following circuit.



8.23 If an amplifier with a gain of 25 is constructed using a 741, what would be a typical value for the bandwidth of this circuit?

8.24 What is meant by the slew rate of an op-amp? What would be a typical value for this parameter.

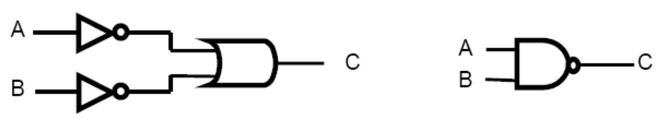
9.1 Show how a power source, a lamp and a number of switches can be used to represent the following logical functions.

$$L = A \bullet B \bullet C$$

$$L = A + B + C$$

$$L = (A \bullet B) + (C \bullet D)$$

9.6 Show that the two circuits (a) and (b) below are equivalent, by drawing truth tables for each element.



(a) (b)

9.12 Write the function of a three-input NOR gate as a Boolean expression.

9.16 Implement the following expressions using standard logic gates.

$$X = \overline{(A + B)} \bullet C$$

$$Y = A\overline{B}C + \overline{A}D + C\overline{D}$$

$$Z = \overline{(A \bullet B) + \overline{(C + D)}}$$

12.2 What quantity of charge is transferred if a current of 5 A flows for 10 seconds?

12.12 Derive Thévenin equivalent circuits for the following arrangements (next page).
(Note, Norton equivalent – as per textbook version of 12.12 is not required)

15.1 A signal v is described by the expression $v = 15 \sin 100t$. What is the angular frequency of this signal, and what is its peak magnitude?

15.4 Give an expression for a sinusoidal signal with an r.m.s. voltage of 14.14 V and a frequency of 50 Hz.

15.5 Give an expression relating the voltage across an inductor to the current through it.

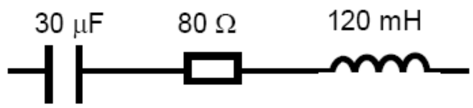
15.6 Give an expression relating the voltage across a capacitor to the current through it.

15.14 Calculate the reactance of an inductor of 20 mH at a frequency of 100 Hz, being sure to include the units in your answer.

15.21 A voltage is formed by summing two sinusoidal waveforms of the same frequency. The first has a magnitude of 20 V and is taken as the reference phase (that is, its phase angle is taken as 0^o). The second has a magnitude of 10 V and leads the first waveform by 45^o. Draw a phasor diagram of this arrangement and hence estimate the magnitude and phase of the resultant signal.

15.31 Determine the complex impedance of the following arrangement at a frequency of 200 Hz. [i.e. part (a) of original question only]

(a)

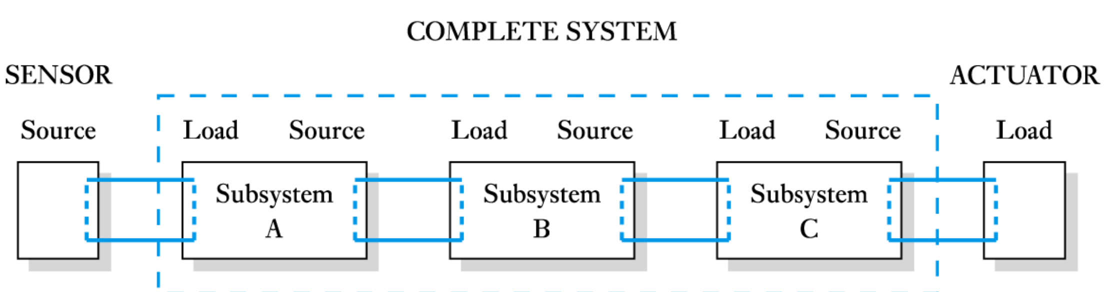


ES180 – Circuits & Devices – SOLUTIONS to Additional Example Problems

1.5 Five basic functions are: generation; transmission or communication; control or processing; utilization and storage.

1.13 Partitioning is the process of dividing a complex system into a series of modules or sub-systems to aid its design and implementation.

1.14 In a system consisting of a series of sub-systems, the output of each sub-system represents the input of the next. Thus the output of each module represents a *source*, while the input of each module represents a *load*. This process is illustrated in Figure 1.7 of the text. The modules within the system can then be defined in terms of the characteristics of the sources and loads that they represent, and the relationship between their input and output signals.



2.7 $P = I^2R = (5 \times 10^{-6})^2 \times 400 = 10$ nW.

2.13 (a) This is (1kΩ + 1.2 kΩ)//(3.3 kΩ + 1.5 kΩ) = 2.2 kΩ//4.8 kΩ = 1.51 kΩ.

(b) This is (150Ω//300Ω) + (270Ω//180Ω) = 100 Ω + 108 Ω = 208 Ω.

2.14 (a) $V1$ = 9 × 100 Ω/(50 Ω + 100 Ω) = 6 V.

(b) $V2$ = 4 + (12 – 4) × 60 Ω/(20 Ω + 60 Ω) = 10 V.

(c) $V3$ = 10 × 40 Ω/(10 Ω + 40 Ω) = 8 V.

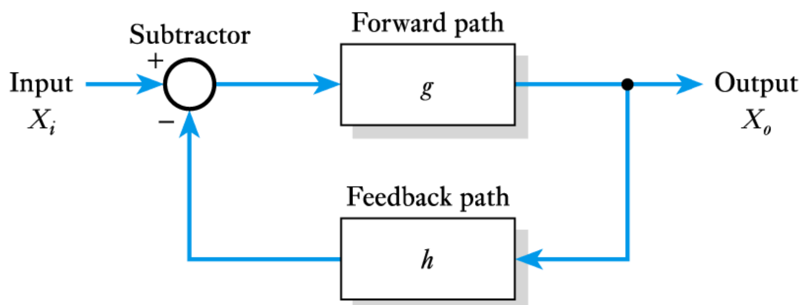
3.2 The resolution of a sensor is the smallest discernible change in the measured quantity that the sensor is able to detect.

3.4 The term **accuracy** describes the maximum expected error associated with a measurement (or a sensor) and may be expressed as an absolute value or as a percentage of the range of the system. **Precision** is a measure of the lack of random errors (scatter) produced by a sensor or instrument.

4.13 Long distance communication normally uses fibres made of glass since these have a lower attenuation than polymer fibres. In such applications laser diodes are normally used as the light source.

4.15 A solenoid consists of an electrical coil and a ferromagnetic slug which can move into, or out of, the coil. When a current is passed through the solenoid the slug is attracted towards the centre of the coil with a force determined by the current in the coil.

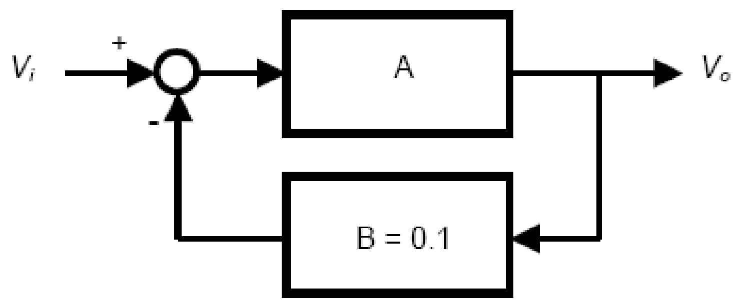
7.8 Such a block diagram is given as Figure 7.3 in the text (repeated below) and the derivation is given in Section 7.4.



The resultant expression is

$$X_O = X_i \frac{A}{1 + AB} \quad \text{or} \quad \frac{X_O}{X_i} = \frac{A}{1 + AB}$$

7.13 The answer to this question could use an op-amp or an unspecified black-box amplifier as shown below. Since the gain with feedback is 1/*B*, to achieve a gain of 10 we require *B* = 0.1 as shown.



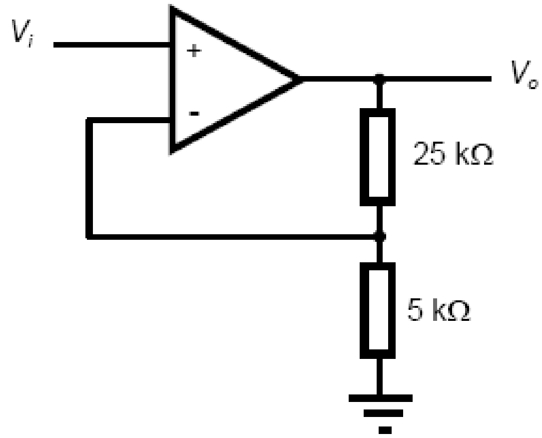
When the gain of the amplifier (*A*) is 100 000, the overall gain will be

$$
\begin{aligned}
G = \frac{A}{1+AB} &= \frac{100\,000}{1+(100\,000\times 0.1)} \\
&= \frac{100\,000}{1+10\,000} \\
&= 9.999 \\
&\approx \frac{1}{B}
\end{aligned}
$$

When the gain of the amplifier (*A*) is 200 000, the overall gain will be

$$
\begin{aligned}
G = \frac{A}{1+AB} &= \frac{200\,000}{1+(200\,000\times 0.1)} \\
&= \frac{200\,000}{1+20\,000} \\
&= 9.9995 \\
&\approx \frac{1}{B}
\end{aligned}
$$

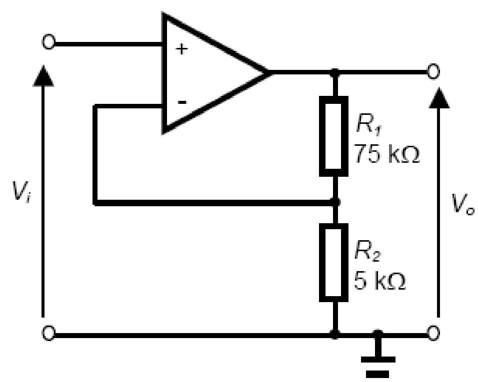
7.16



Gain = (25 kΩ + 5 kΩ)/5 kΩ = 6.

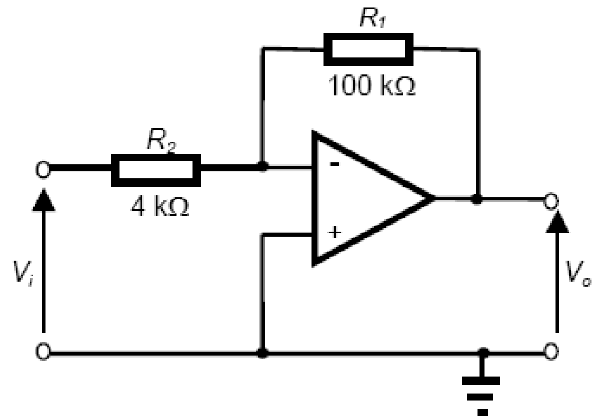
8.4 An 'ideal' op-amp would have an infinite voltage gain, an infinite input resistance and a zero output resistance.

8.6



From the discussion in Section 8.3.1 the gain of the circuit is $(R_1 + R_2)/R_2 = 16$.

8.9



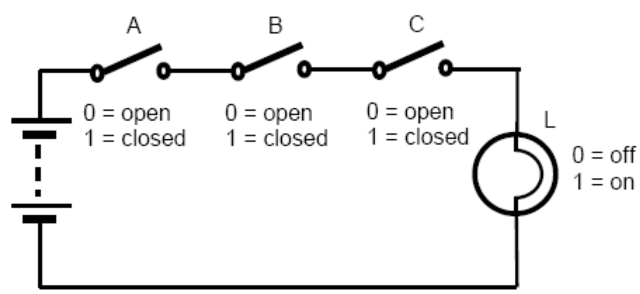
From the discussion in Section 8.3.2 the gain of the circuit is $-R_1/R_2 = -25$.

8.23 Since for a 741 Gain × Bandwidth ≈ 10^6, if the gain is 25, the bandwidth will be about $10^6/25 \approx 40$ kHz.

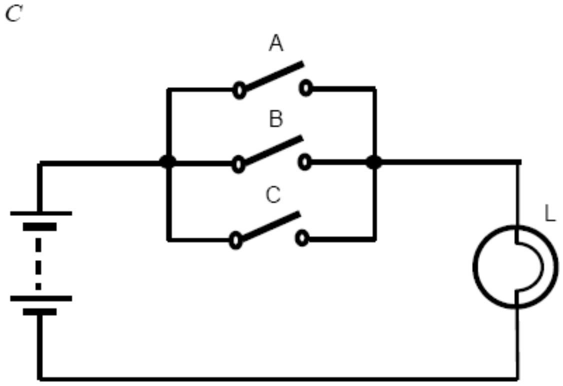
8.24 This is the maximum rate at which the output voltage can change and is typically a few volts per microsecond.

9.1

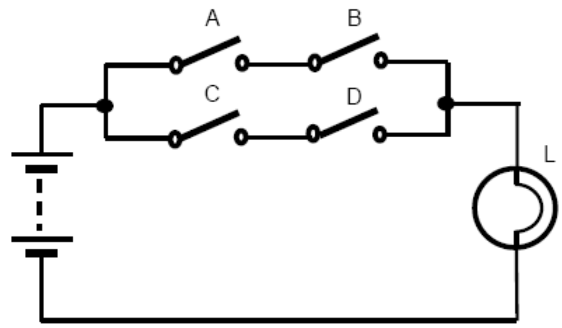
$L = A \cdot B \cdot C$



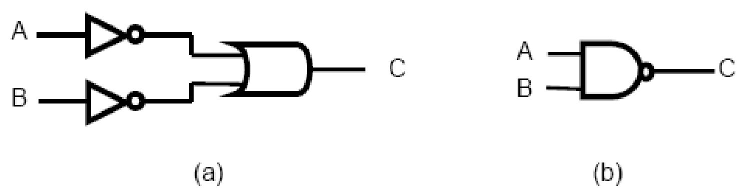
$L = A + B + C$



$L = (A \cdot B) + (C \cdot D)$



9.6

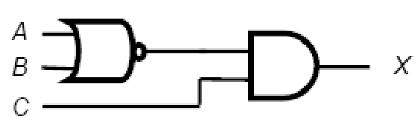


Truth table for each is:

A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

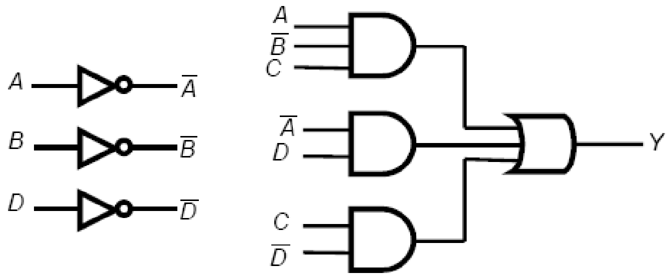
9.12 $X = \overline{(A + B + C)}$

9.16 $X = \overline{(A + B)} \bullet C$

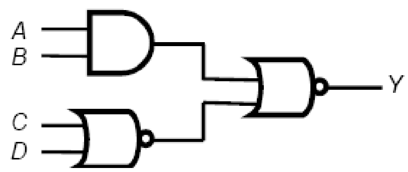


Continued overleaf

$Y = A\overline{B}C + \overline{A}D + C\overline{D}$

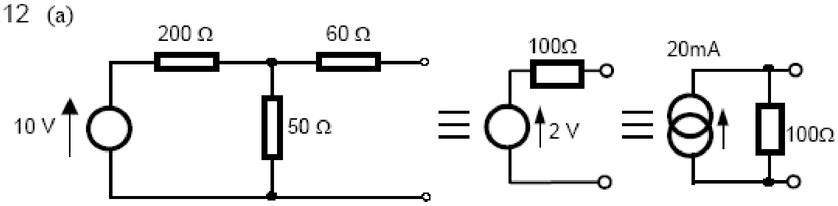


$Z = \overline{(A \bullet B) + \overline{(C + D)}}$

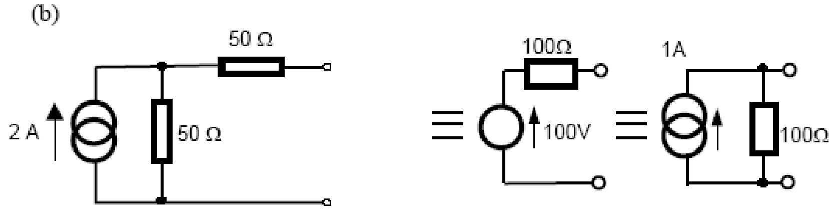


12.2 I is constant so $Q = I \times t = 5 \times 10 = 50$ coulombs.

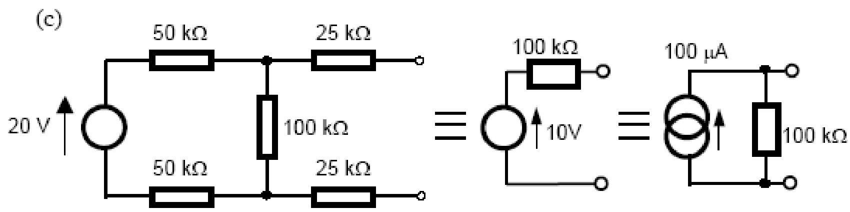
12.12 (a)



(b)



(c)



Norton equivalent not required from question, but included for interest if student has attempted it.

15.1 The general expression for a sinusoidal voltage signal is $\boldsymbol{v} = \boldsymbol{P}\sin\omega t$, where $\boldsymbol{P}$ is the peak maximum and ω is the angular frequency (rad s^{-1}).
Hence, the angular frequency ω = 100 rad s^{-1} and the peak magnitude = 15V

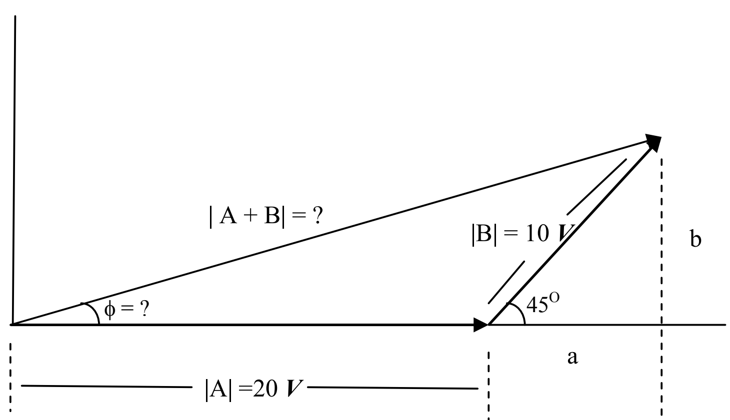
15.4 An r.m.s. value in a sinusoidal signal is $\frac{1}{\sqrt{2}}$ times the peak value, or approximately 0.7071***P***. Hence, the r.m.s. voltage of 14.14 V must be converted to the peak value before insertion into the expression for a sinusoidal signal.
$\therefore P \cong \frac{14.14}{0.7071} \cong 20V$
A cyclic frequency in cycles-per-second (***f*** *Hz*) is converted to an angular frequency (ω *rad s^{-1}*) by $= 2\pi f$, ∴ $\omega = 2\pi.50$ = 314.16 *rad s^{-1}* (2 dp).
Hence the required expression is $v = 20sin314.16t$

15.5 The voltage across an inductor is proportional to (a) the inductor value ***L*** *Henrys* (this being determined by the construction of the inductor) **and** (b) the rate of change of the current flowing through it.
Hence, $v_L = L\frac{di}{dt}$ (p89 Data book)

15.6 When current is flowing into – or out of – a capacitor, the voltage across the capacitor is (a) inversely proportional to the size of the capacitor (***C*** *Farads*), and (b) proportional to the integral of the current $\int i$ (i.e. rate of change of charge ***Q***).
Hence, $V_C = \frac{1}{C}\int i\,dt$ (p89 Data Book)

15.14 Inductive reactance $\boldsymbol{X_L = \omega L = 2\pi f L}$ Ω.
$\therefore X_L = 2\pi \times 100 \times 20 \times 10^{-3} = 12.57\,V$ (2 dp)

15.21



The diagram shows a phasor representing sinewave ***A*** drawn on the horizontal axis (0^O) with its length representing the modulus (magnitude) of the waveform, i.e. **|A| = 20 *V***. As the two sinusoidal waveforms are being added, the second sinewave ***B*** is drawn with its origin at the head (i.e. arrow head) of sinewave ***A***. Phasor ***B*** has a positive angle of 45^O to Phasor ***A*** because it is **leading** Phasor ***A***. We can use basic trigonometry to determine the modulus (|***A*** + ***B***|) and the phase (ϕ) of the resultant waveform as follows.
(*continued overleaf*)

Length $\boldsymbol{a}$ = 10 cos 45^{O} = 7.071, hence length **|*A*| + *a* = 27.071**
Length $\boldsymbol{b}$ = 10 sin 45^{O} = 7.071
$\therefore |A + B| = \sqrt{27.071^2 + 7.071^2} = 27.98\,V$
$\varphi = tan^{-1}\frac{7.071}{27.071} = 14.64°$ (the resultant waveform will **lead** waveform ***A***)

15.31 We use, $Z = Z_C + Z_R + Z_L$, where $Z_C = -jX_C$, $Z_R = R$, $Z_L = jX_L$
(see Data Book)
Note that $\omega = 2\pi f = 2\pi \times 200 = 1256.64$ rad s^{-1}
Hence, $Z = R + j(X_L - X_C)$

$$= R + j\left(\omega L - \frac{1}{\omega C}\right)$$
$$= 80 + j\left(1256.64 \times 120 \times 10^{-3} - \frac{1}{1256.64 \times 30 \times 10^{-6}}\right)$$
$$= 80 + j150.8 - j26.53$$
$$= 80 + j124.27\ \Omega$$