Checkpoints Chapter 14

Transformers and transmission.

Solutions

Question 1

The electrical transformer uses the principals of electromagnetic induction to vary the voltage between the input and the output.

∴ **A (ANS)**

Question 2

To transform 210 V_{RMS} into 7 V_{RMS} you need a step down transformer. Therefore the number of turns on the primary must be 30 times greater than the number of turns on the secondary.

∴ **D (ANS)**

Question 3

If the voltage is stepped down by a factor of 30, the current must be stepped up by the same factor. (It is an ideal transformer).

∴ I = 600 mA × 30

∴ I_S = 18 A

∴ **C (ANS)**

Question 4

RMS is the average value, so a peak value must be $\sqrt{2}$ greater, and the peak to peak value must be $2\sqrt{2}$ greater.

∴ $210 \times \sqrt{2} = 297\ V_{PEAK}$

∴ $210 \times 2\sqrt{2} = 594\ V_{PEAK\ to\ PEAK}$

∴ **B (ANS)**

Question 5

The active and the neutral should always carry the same current, because all the current that flows into a device should flow out of it. If the currents are not equal, i.e. the current in the active is greater than the current in the neutral, then some of the current has found an alternative path to Earth. This should not happen.

If the current in the active wire is greater than the current in the neutral wire, there will be a net field in the transformer core. This field will vary sinusoidally, so there will be a changing flux through the transformer core.

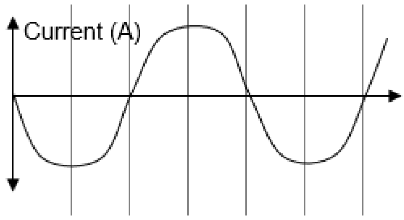
∴ **D (ANS)**

Question 6

I think that Syd meant for these questions to be about current, so the answers should use "current" instead of "voltage".

The supply is AC, (otherwise the transformers wouldn't work) So with an RMS current of 3.5 Amp, this means that the peak value of the current will be $3.5 \times \sqrt{2}$ = 4.95 amp ~ 5 amp

The output voltage will look a little like this.



This means that the average value of this graph is the middle. ∴ the average is zero.

∴ **C (ANS)**

Question 7

Power = V × I = $I^2 \times R$

$= \frac{V^2}{R}$

∴ 15 kW = $\frac{V^2}{0.8}$

(Don't forget the kW)

15 000 × 0.8 = V^2

∴ V^2 = 12 000

∴ V = 109.5

∴ V = 110 Volt

120 Volt is the best answer because the motor needs *at least* 15 kW.

∴ **D (ANS)**

Question 8 (2010 Q18, 2m, 65%)

The power supply was set to 20.8 $V_{RMS.}$

Therefore $V_P = 20.8 \times \sqrt{2}$

= 29.4 V,

∴ $V_{P\ to\ P}$ = 29. 4 x 2

= 58.8

∴ **D (ANS)**

Question 9

The power delivered in the system is given by P = V × I. The energy lost in the resistive elements of the cables is given I^2R. The resistance of the cables is "effectively" fixed, so to reduce energy losses in transmission you need to minimise current.

To deliver a fixed amount of power, this means that you need high voltages.

∴ **D (ANS)**

Question 10

Use P = V × I.
With a DC supply, the voltage (and hence current in the circuit) are constant.

∴ **A (ANS)**

With an AC supply, to get 120 W_{RMS} you need to have a peak wattage of 240.

∴ **C (ANS)**

Another way of thinking about answer C is to convert the voltage and current into RMS values.

$$\therefore 18\ V_{PEAK} = \frac{18}{\sqrt{2}}$$
$$= 12.7\ V_{RMS}$$
$$\therefore 15\ A_{PEAK} = \frac{15}{\sqrt{2}}$$
$$= 10.6\ V_{RMS}$$

Therefore W_{RMS} = 135 W.

Option B gives a **peak** wattage of 120 W
Option D gives a peak to peak wattage of 340 which is equivalent to 43 W_{RMS}.
The answer in the back of the book only gives one answer but the question asks for two.

Question 11 (2018 Q4, 1m, 84%)

Use $\frac{n_1}{n_2} = \frac{V_1}{V_2}$ to get

$$\frac{240}{12} = \frac{20}{1}$$

∴ **D (ANS)**

Question 12 (2018 Q5, 1m, 51%)

Use power = V × I

∴ 48 = 12 × I

∴ I = 4.0 A

The question asks for I_{peak} therefore multiply by $\sqrt{2}$ to get

$I_{peak} = 4 \times \sqrt{2}$

∴ I_{peak} = 5.7 A

∴ **C (ANS)**

Unfortunately over one third of the state gave the answer s 4.0 A. Suggesting to me that they didn't read the question carefully enough.

Extended questions

Question 13a

You need to transform the voltage from 240 V down to 12 V. This requires a step-down transformer with a ratio of 240/12 which is 20/1 in the primary / secondary.

∴ **20:1 (ANS)**

Question 13b

The transformer works on the principle that an AC current in the primary coil will induce a changing magnetic field in the iron of the transformer (because the field associated with a current carrying wire varies with the current in the wire). The changing magnetic flux in the iron core will induce an EMF in the secondary coil.
If the current in the primary coil is constant i.e. DC, then the field in the iron core is constant, so there is not an induced EMF (and current) in the secondary coil.

Question 14a

The ratio of the number of turns is the same as the ratio of the input and output voltages.

$\frac{n_1}{n_2} = \frac{V_1}{V_2}$ which becomes

$\frac{n_2}{n_1} = \frac{V_2}{V_1}$ for this problem

$$\therefore \frac{n_2}{n_1} = \frac{330kV}{15kV}$$

= 22 (ANS)

You need to realise that this has to be a step-up transformer, so the secondary coil has to have more turns than the primary coil.

Question 14b

If the transformer is ideal (100% efficient) then the power in = power out.
∴ $VI_{in} = VI_{out}$.
This means that if the voltage steps down by a factor of 9 000 to 110, then the current must step up the same amount.

The voltage steps down by $\frac{9000}{110}$ = 81.82
So the output current will be 81.82 times the input current.

∴ 81.82 × 1.5 = 122.7

= 123 Amp (ANS)

Question 14c

There is always a voltage drop across a resistor, (assuming that there is a current). For most situations the resistance of the wires in the circuit are so small in comparison to the resistance of the appliance that it is appropriate to assume that the voltage drop across the wires is zero.
When we have very long cables this assumption is not reasonable. There will be a noticeable potential drop along the cable. In this case the drop is 5 000V. It is given by $V = iR$. Where I is the current and R the resistance of the wires.

Question 15a

There is always a voltage drop across a resistor, (assuming that there is a current). For most situations the resistance of the wires in the circuit are so small in comparison to the resistance of the appliance that it is appropriate to assume that the voltage drop across the wires is zero.
When we have very long cables this assumption is not reasonable. There will be a noticeable potential drop along the cable. It is given by $V = iR$. Where I is the current and R the resistance of the wires.
As more appliances are being used then the current being drawn increases. This means that the potential drop along the cable increases, so the voltage supplied to the house is decreased.

Question 15b

If $V = iR$, then the voltage drop along the cable is given by $\Delta V = 240 - 225 = 15$ volt.
So if the current is 45 amp, then the resistance comes from $V = iR$

$\therefore R = V/i$
$= 15/45$
$= 0.33\ \Omega$ (ANS)

Question 16a

The ratio of the turns is the same as the ratio of the voltages.
The input voltage is 240 with an output of 6, so there must be (240/6) times as many turns on the primary side of the coil. $240 \div 6 = 40$.
So the number of turns on the output (secondary) side of the coil is $960 \div 40$
= 24 turns (ANS)
(Remember: The more turns the greater the voltage.)

Question 16b

The voltage loss across the cables will now be
$\therefore \Delta V = I \times R$
where $I = 3.5$ amp and $\Delta V = 1.0$ Volt
$\therefore R = \Delta V \div I$
$= 0.288$
$\therefore R = 0.29\ \Omega$ (ANS)
The answer in the back of the book says W. I think that this is a misprint.

Question 16c

Power loss in cables
$= \Delta V \times I$
$= 1.0 \times 3.5$
$= 3.5$ Watt
This answer could also be found by using power loss in cables
$= i^2 \times R$
$= 3.5^2 \times 0.29$
$= 3.5$ W (ANS)

Question 17a

Power losses due to heating in transmission lines are given by $P = i^2R$.
To minimise this we need to minimise I. Since the power input is $P = V \times I$, this means we need to increase V as much as possible.
We use a step-up transformer at 'A' so that the current in the lines is minimal. We then need to use a step-down transformer at the pump, to reduce the voltage to 240 V.

Question 17b

The power being used by the pump is
$P = V \times I$
$= 240 \times 20$
$= 4\ 800$ W
So this must be the power being supplied to transformer B
So the $V \times I$ (in the wires) = 4 800
$V = 4\ 800 / 0.8$
= 6 000 V (ANS)

Question 17c

Assume that the voltage $V_{PQ} = 6\ 000$ V. (On the exam, if you weren't able to calculate this, then you are to substitute in any number and explain it) The ratio of the number of turns in the primary coil : secondary coil is the same as the input voltage : output voltage. Remember always think about the 'voltages'.

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$\therefore \quad \frac{240}{6000} = \frac{100}{'x'}$

$\therefore x = \frac{6000 \times 100}{240}$

∴ x = 2500 turns (ANS)

Question 17d

If the Power loss is given by i^2R

$\therefore P = 0.8^2 \times 4$

$= 2.56$ W

= 2.6 W (ANS)

(correct to 2 sig. figs)

Question 17e

If the Power loss is given by i^2R

$\therefore P = 10^2 \times 4$

$= 400$ W

= 4.0 × 10^2 W (ANS)

(correct to 2 sig. figs)

Question 18a

If the transformer is ideal (100% efficient) then the power in = power out.

$\therefore VI_{in} = VI_{out}$. This means that if the voltage steps down by a factor of 20, then the current must step up the same amount. So the output current will be 20 times the input current.

∴ 10 × 20 = 200 Amp (ANS)

Question 18b

Since V = IR, if you use a step-down transformer, you have lowered V to 12 volts. This makes it very difficult to get a large current in any circuit, because you need R to be small, to allow I to be large.

Question 19 (2012 Q3, 2m, 70%)

The power is given by $P = \frac{V^2}{R}$

Need to use RMS value, not peak value, $\frac{150}{\sqrt{2}}$

AC $\quad P = \frac{150^2}{(\sqrt{2})^2 \times 6} = 1875$ W

DC $\quad P = \frac{120^2}{7} = 2057$ W

∴ DC will provide more power (ANS)

Question 20a (2012 Q4a, 2m, 90%)

Power = VI

= 900 x 50

= 45 kW (ANS)

Question 20b (2012 Q4b, 2m, 55%)

Use V = iR

Where V = 1000 V, and R is a total of 25 A

∴ 1000 = i x 25

∴ i = 40 A (ANS)

Question 20c (2012 Q4c, 3m, 50%)

There will be a voltage drop along the wires. This is given by V = iR

∴ V = 40 x 7

$\therefore V_{drop} = 280$ V

$\therefore V_{supplied\ to\ motor} = 1000 - 280$

$= 720$ V

The motor will not run properly, as it requires 900 V.

∴ the pump will not operate correctly.

Question 20d (2012 Q4d, 4m, 50%)

First change

Use step-up transformer to increase the voltage that the power is delivered along the lines, and then use a step-down transformer at the other end.

Since the power delivered is given by P = VI, if V is increased then I will decrease to deliver the same power.

The energy losses in the wire are given by I^2R, so this will lower the energy losses due to heating in the wire.

Second change

Change the material that the wire is made from to one of lower resistance. This will lower the voltage drop across the transmission lines, which will lead to more power being available for the motor.

Question 21a (2012 Q6a, 1m, 90%)

$$\frac{V_{out}}{V_{in}} = \frac{n_{secondary}}{n_{primary}}$$

Use

$$\frac{V_{out}}{20} = \frac{150}{600}$$

∴ Vout = 5 V (ANS)

Question 21b (2012 Q6b, 2m, 35%)

The constant voltage of the 20 V volt battery will supply a constant current. Therefore there will not be any change the flux. Therefore from Faraday's law there will not be an induced EMF.

Question 22a (2013 Q15a, 1m, 80%)

The ratio of the number of turns is 1:6
∴ the ratio of the voltages will be the same
∴ 3.0 : 18.0
∴ 18.0 V (ANS)

Question 22b (2013 Q15b, 1m, 80%)

Peak voltage = 18.0 x $\sqrt{2}$
∴ 25.5 V (ANS)

Question 22c (2013 Q15c, 2m, 65%)

Power is always calculated using RMS values.

∴ P = $\frac{V^2}{R}$

∴ P = $\frac{18^2}{1200}$

∴ P = 0.27 W (ANS)

Question 22d (2013 Q15d, 3m, 37%)

As the switch closes, the current changes from 0 to a maximum value.
This change in current creates a changing flux in the iron core of the transformer. This change in flux induces and EMF across the secondary coil. As the circuit is complete this will lead to a brief current through the resistor. This is an application of Faraday's law.
Once the switch is closed, there won't be any change in the current, therefore no change in the flux, therefore no induced current.

Question 23a (2013 Q18a, 2m, 65%)

Use V = iR
∴ 24 = 6 x R
∴ R = 4 Ω (ANS)

Question 23b (2013 Q18b, 2m, 70%)

Use P = VI
∴ 1200 = V x 6
∴ V = 200 V (ANS)

Question 23c (2013 Q18c, 3m, 63%)

$$\frac{\text{power loss in the transmission lines}}{\text{power input to the transmission lines}}$$

$= \frac{6 \times 24}{1200}$

$= \frac{6 \times 2}{100}$

= 12% (ANS)

Question 23d (2013 Q18d, 3m, 53%)

To find the current in the new transmission lines,
Use V = iR
∴ 10 = i x 2
∴ i = 5 A

Then use P = VI
∴ 1200 = V x 5
∴ V = 240 V (ANS)

Question 24a (2014 Q14a, 1m, 30%)

For a transformer to operate it requires a changing voltage as an input.
The DC voltage will be constant. Therefore the transformer will not operate.
∴ 0 V (ANS)

Question 24b (2014 Q14a, 2m, 70%)

The turns ratio is 130:5200.
This is the equivalent of 1:40.
If the output voltage is 400, this is from a RMS input of 10 V.

∴ peak voltage = 10 × $\sqrt{2}$
14.1 V (ANS)

Question 25a (2014 Q15a, 1m, 80%)

The power supply is at 13 V, and 3 V is across the light globe.
∴ ΔV = 13 – 3
∴ ΔV = 10 V (ANS)

Question 25b (2014 Q15b, 1m, 70%)

For the light globe, use P = $\frac{V^2}{R}$

∴ P = $\frac{3^2}{1.5}$

∴ P = 6 W (ANS)

Question 25c (2014 Q15c, 1m, 60%)

For the connecting wires use V = iR.
∴ 10 = i × 5
∴ i = 2 A (ANS)

Check your answer using the light globe.
∴ V = iR
∴ 3 = i × 1.5
∴ i = 2 A
This is as required as the globe is in series with the long wires, therefore it must have the same current.

Question 25d (2014 Q15d, 3m, 47%)

If the voltage across the light globe is to be 6 V, then from V = iR,

$6 = i \times 1.5$

$\therefore i = 4$ A.

This means that the voltage drop across the transmission lines will be, V = iR,

$\therefore V = 4 \times 5$

$\therefore V = 20$ V

This means that the supply voltage needs to be 20 + 6

∴ 26 V (ANS)

Question 26 (2014 Q16, 4m, 43%)

To deliver a fixed amount of power, a step up transformer is used at the beginning. This transformer increases the voltage, and decreases the current whilst delivering the same power. Since the power, $VI_{in} = VI_{out}$ in an ideal transformer.

The definition of transmission losses is: the power losses in transmission lines, given by I^2R.

So a decrease in I, results in an I^2 reduction in the energy losses in the wires.

A step-down transformer is used at the other end of the transmission lines to bring the voltage down to a suitable level for appliances etc.

Question 27a (2015 Q14a, 2m, 65%)

Use $f = \frac{1}{T}$

Where T = 40 ms, from the graph.

$\therefore f = \frac{1}{40 \times 10^{-3}}$

∴f = 25 Hz (ANS)

Question 27a (2015 Q14b, 2m, 60%)

Use $\frac{V_P}{V_S} = \frac{N_P}{N_S}$

This is a step down transformer, therefore the input voltage $V_P = 45 \times 300$

$\therefore V_P = 13\,500$ V

$\therefore V_{RMS} = \frac{13\,500}{\sqrt{2}}$

$\therefore V_{RMS} = 9\,546$

∴ $V_{RMS} = 9.5 \times 10^3$ V (ANS)

Question 28a (2015 Q16a, 2m, 75%)

Use P = VI

$\therefore 4 = 2 \times I$

∴ I = 2 A (ANS)

Question 28b (2015 Q16b, 2m, 55%)

The voltage drop along the lines is given by $V = iR_{Total}$

$\therefore V_{lines} = 2 \times 4$

$\therefore V_{lines} = 8$

The EMF = $V_{lines} + V_{globe}$

= 8 + 2

= 10 V (ANS)

Question 28c (2015 Q16c, 3m, 67%)

Power loss is given by i^2R_{lines}

$\therefore P = 2^2 \times 4$

∴ P = 16 W (ANS)

Question 28d (2015 Q16d, 3m, 57%)

The current in the globe remains at 2.0 A. As the step down transformer is ideal,

∴ power in = power out.

The step down transformer steps the voltage down by a factor of 10, therefore the output current has increased by a factor of 10.

∴ I_{line} = 0.2 A (ANS)

Question 28e (2015 Q16e, 2m, 65%)

Power loss is given by i^2R_{lines}

$\therefore P = 0.2^2 \times 4$

∴ P = 0.16 W (ANS)

Question 28f (2015 Q16f, 4m, 50%)

This model could represent the transmission of electrical power from the generators in the Latrobe Valley to houses in Melbourne.

For constant power through the transformer, a higher output voltage means a lower current. The power loss in the cables is given by i^2R, therefore the lower the current the lower the power loss in the cables.

Stepping the voltage up by a factor of 10 results in the current going down by a factor of 10, hence the energy losses in the cable reduce by a factor of 100, from 16 W to 0.16 W. The step down transformer enables the globe to operate correctly.

Question 29

Energy losses in cables become more of an issue as the distribution system increases in size. To minimise energy losses, you need to transmit the power at minimal current. This requires stepping up the voltage. You can't transform DC voltages, so you need to use AC.

Question 30a (2016 Q16a, 2m, 60%)

Use $P = \frac{V^2}{R}$

$\therefore P = \frac{18^2}{9}$

∴ P = 36 W (ANS)

Question 30b (2016 Q16b, 2m, 30%)

The circuit path containing the transmission lines and Globe B, has a
18 V potential drop and a total resistance of 12 Ω.
∴ V = IR
∴ 18 = I × 12
∴ I = 1.5
The total voltage drop across the transmission lines is given by
V = iR
∴ V = 1.5 × 3
∴ V = 4.5 V (ANS)

Question 30c (2016 Q16c, 3m, 33%)

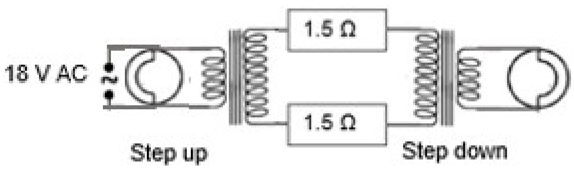
If the voltage drop across the transmission lines is 4.5 V, then the voltage drop across Globe B is 13. 5 V (18 – 4.5)

Use $P = \frac{V^2}{R}$

$\therefore P = \frac{13.5^2}{9}$

∴ P = 20.3 W (ANS)

Question 30d (2016, Q16d, 2m, 35%)



Question 30e (2016, Q16e, 3m, 53%)

For constant power through the transformer, a higher output voltage means a lower current.
The transmission losses are given by i^2R, therefore the lower the current the lower the transmission losses.
Stepping the voltage up by a factor of 10 results in the current going down by a factor of 10, hence the transmission losses reduce by a factor of 100.

Question 31a (2017, Q6a, 2m, 75%)

Power loss in the transmission lines is given by
$P = i^2R$
∴ $P = 200^2 \times 3$
∴ P = 120 000
∴ P = 120 kW (ANS)

Question 31b (2017, Q6b, 2m, 50%)

If the voltage is only a half of the original, then to deliver the same power, the current will need to double.
∴ the losses in the line will increase by a factor $\times 2^2$
∴ × 4 (ANS)