Multiple choice

Question 1

As the magnet falls it will speed up, due to the effects of gravity. This means that the rate of change of flux will increase. This means that the graph will be steeper on the way out than on the way in. So the best option is B. It won't look like C or D because the direction of the field does not change.

∴ **B (ANS)**

Question 2

The induced EMF is the negative gradient of the flux *v* time graph. It will start at zero, reach a maximum, and return to zero, (at the top of the graph); it will then reach another max, and then return to zero. The best answer is C.

∴ **C (ANS)**

Question 3 (2011 Q6, 2m, 63%)

The flux through the loop is going to vary sinusoidally, and the output will vary in a similar manner. If X and Y are connected to the split ring commutator the output will reverse direction every half cycle. This process is called rectification.

∴ **A (ANS)**

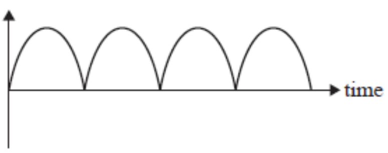
Question 4

The magnetic flux is the product of the field (**B**) and the area (A) that is being cut by the field. Faradays law states that if the flux changes there is an induced EMF (or output voltage). In this case **B** is constant, because the magnets do not alter, but the area of the coil is spinning so the amount of flux cutting through this area changes.

∴ **A (ANS)**

Question 5

The role of the split ring commutator is to reverse the direction of the EMF every half cycle. This will mean that the output will look like



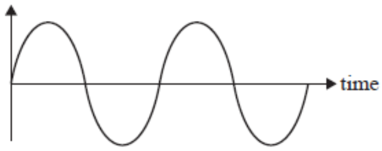
This is best described as a DC voltage whose size varies with time.

∴ **D (ANS)**

The output is DC as the 'direction' remains the same, i.e. always positive.

Question 6

The slip rings maintain constant contact so the output will be sinusoidal. The output will look like



∴ **A (ANS)**

Question 7 (2011 Q8, 2m, 35%)

The maximum flux through the coil is given by

$\Phi_{max} = BA$

$\therefore \Phi_{max} = 2.0 \times 0.02$

$\therefore \Phi_{max} = 0.04$ Wb

The value in orientation C is less than the maximum value but greater than zero.

∴ **B (ANS)**

The dot point states **the qualitative effect of differing angles between the area and the field** so there isn't any need to do an actual calculation of the exact flux through the coil when it is at 45^0.

Remember that flux is the field through ONE loop. The answer 1.5 Wb was there for the people that didn't know this. Be careful!

Question 8

The flux changes from its maximum value of 0.04 Wb (from Q7) to zero and then back to 0.04 Wb but in the opposite direction. Therefore the change is 2 × 0.04 = 0.08 Wb.

∴ **C (ANS)**

Question 9

The flux doesn't change when it completes a full cycle.

∴ **A (ANS)**

Question 10 (2011 Q9, 2m, 80%)

The loop takes 40 ms for each revolution, therefore it will take 10 ms for a quarter revolution. To find the average emf use:

$$\varepsilon = -n\frac{\Delta\Phi}{\Delta t}$$

$$\varepsilon = -50 \times \frac{0.04}{10 \times 10^{-3}}$$

∴ 200 V

∴ **D (ANS)**

Question 11 (2015 Q12b, 1m, 80%)

The split ring commutator will reverse the direction of the output every half cycle.

∴ B (ANS)

Question 12 (2012 Q8a, 1m, 80%)

The flux will start at zero, increase linearly to a maximum value, remain at the maximum for a while and then the flux will reduce linearly to zero. The gradient will be a positive constant, zero, and then the same (negative) gradient as initially.

∴ A (ANS)

Question 13 (2012 Q8b, 1m, 80%)

The induced EMF is the negative gradient of the flux vs time graph.
Would prefer a graph that was the negative of D, but D is by far the closest correct answer.
The direction of the EMF may be hard to justify in this scenario.

∴ D (ANS)

Question 14 (2012 Q8c, 3m, 33%)

As the loop moves from position 2 to position 3, initially, the flux remains constant. When the loop reaches the edge of the field, then the flux through it will be decreasing, as it moves out of the field. Therefore the induced EMF will generate a current to reinforce the flux. As viewed from the South Pole, the current will go from X to Y in the square loop, so that the induced current is adding to the decreasing flux.
When the loop is outside the field, the flux is 0, and constant, so no current is induced.

∴ C (ANS)

Question 15 (2014 Q12a, 1m, 40%)

To create a current there needs to be an induced EMF. This occurs when the flux changes.
There will not be any change in flux in options A and B.
C and D will both result in a change in flux. As the loop in complete an induced current will flow.

∴ C, D (ANS)

Question 16 (2017 Q6, 1m, 60%)

The induced Emf is given by

$\xi = -n \frac{\Delta\Phi}{\Delta t}$ where $\Delta\Phi = \Delta(BA)$

This infers that the induced Emf, is the negative gradient of the flux vs time graph. Initially the gradient is a positive constant, so the Emf should be a negative constant (horizontal line on the graph). Then the gradient is a constant negative, so the Emf should be a positive constant (horizontal) line.

∴ D (ANS)

Extended questions

Question 17

The induced EMF is given by

$\xi = -n \frac{\Delta\Phi}{\Delta t}$

$\Delta\Phi = \Delta(BA) = 0.05 \times 0.2 = 0.01.$
$\Delta t = 0.15 - 0 = 0.15$ secs.

$\text{EMF} = 100 \times \frac{0.01}{0.15}$

= 6.7 Volt (ANS)

Question 18a

The induced EMF is given by

$\xi = -n \frac{\Delta\Phi}{\Delta t}$ $\Delta\Phi = \Delta(BA)$

So in this case the change in flux is due to the change in the strength of the field, not a change in the area under the field. So the rate of change of the flux is the Area × gradient of the magnetic field vs time graph.
So between time $t = 0$ and $t = t_1$ the magnetic field is constant, so the gradient is zero. From time $t = t_1$ to $t = t_2$ the gradient of the magnetic field graph is negative. So the induced EMF is a positive constant. As per the graph.

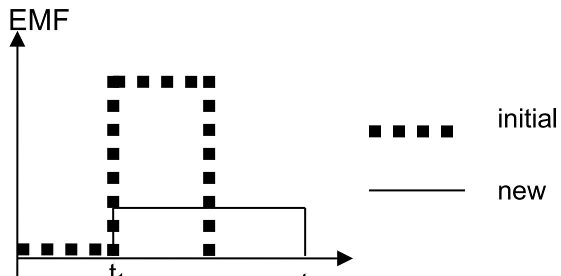
Question 18b

The induced EMF is given by

$\xi = -n \frac{\Delta\Phi}{\Delta t}$

$\Delta\Phi = \Delta(BA)$

As the field is only halved then the change in the flux is 1/2 of the original. It takes twice as long for the change to happen, this will halve the EMF again. So the induced EMF will be 1/4 of the original, and will be over twice the time.



Question 18c

The induced EMF is given by

$$\xi = -n \frac{\Delta\Phi}{\Delta t}$$

$= - 1 \times (200 \times 10^{-3} \times 0.15)/ 25 \times 10^{-3}$

= 1.2 volt (ANS)

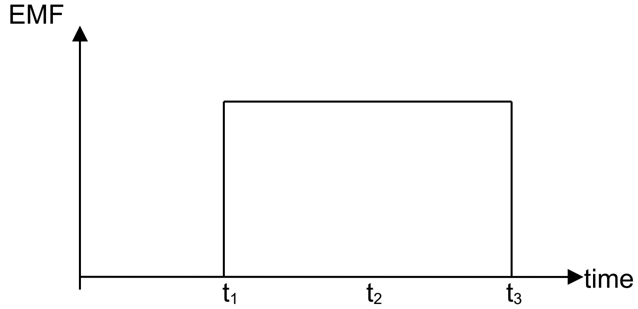
You need to assume that this question is based on the original set of data. This is a reasonable assumption. You can cover yourself by making sure that you show all your working and assumptions.

Question 18d

The induced EMF is given by

$$\xi = -n \frac{\Delta\Phi}{\Delta t}$$

The graph needs to reflect the negative gradient of the field vs time graph. From 0 to t_1 the gradient is zero. (so the EMF is zero) From t_1 to t_2 and from t_2 to t_3 the gradient is constant, so the EMF will be constant.



You also need to show that the induced EMF is zero between 0 and t_1 and after t_3.

Question 19a

To produce an AC voltage output, the output of the loop needs to be connected via slip rings, so that the output from one side of the loop is always connected to the same side of the voltmeter. Then as the direction of the current flowing in the loop reverses every half cycle, we will get an AC output.

Question 19b

To get a DC output, we need to reverse the direction of the contacts every half cycle. We use a commutator to do this.

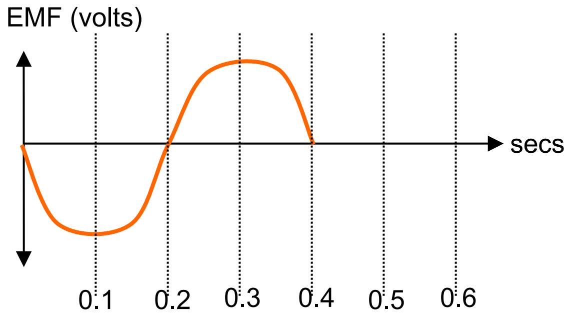
Question 20a

The induced EMF is given by

$$\xi = -n \frac{\Delta\Phi}{\Delta t}$$

So in this case the induced EMF is the negative gradient of the Flux *v* time graph. You need to assume that this is a stylised sine graph.

So at 0.1 secs the gradient was max, at 0.0 and 0.2 the gradient was zero, etc.



You don't need to worry about a scale on the vertical axis (because at this point you don't know how many turns are in the coil).

Question 20b

The induced EMF is given by

$$\xi = -n \frac{\Delta\Phi}{\Delta t}$$

Between 0.4 and 0.6 secs the flux changes from 0.01 to 0.024 Wb m^{-2}.

It takes 0.2 secs for this change to occur and there are 50 turns on the coil.

$\therefore$ EMF = $50 \times (0.024 - 0.01)/0.2$

= 3.5 Volt (ANS)

Question 20c

Assume that the total resistance of the circuit is 4.5 Ω.

Use V = iR

$\therefore$ I = 3.5/4.5

$\therefore$ I = 0.78 Amp (ANS)

Question 21a (2012 Q5a, 2m, 75%)

The frequency = $\frac{1}{T}$

$= \frac{1}{100 \times 10^{-3}}$

= 10 Hz (ANS)

Question 21b (2012 Q5b, 1m, 90%)

The RMS voltage is the average voltage

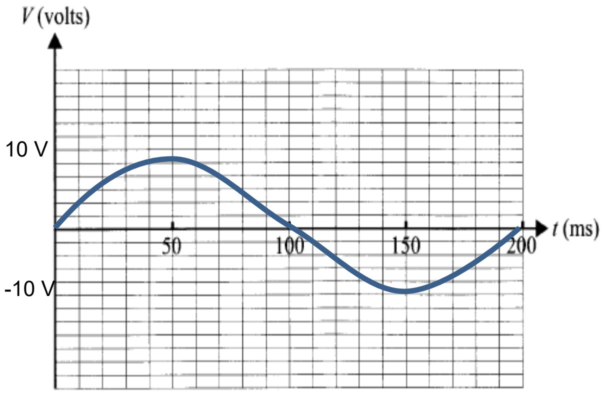
$V_{RMS} = \frac{V_{peak}}{\sqrt{2}}$

$= \frac{20}{\sqrt{2}}$

= 14 V (ANS)

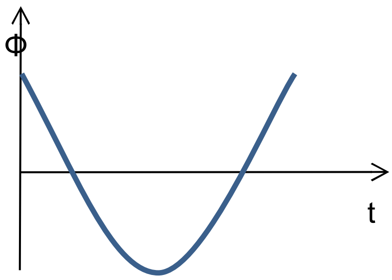
Question 21c (2012 Q5c, 3m, 77%)

$Voltage_{max}$ = 10 V
Period = 200 ms



Question 22a (2012 Q7a, 2m, 45%)

The magnetic flux will vary sinusoidally as the loop rotates.
It will start at a maximum value and drop to zero (a quarter of a cycle later) and then to an identical negative maximum value (half a cycle later). It will then return to zero and then back to its original maximum value. (One complete cycle)



Question 22b (2012 Q7b, 3m, 60%)

The induced EMF = $-n\frac{\Delta\phi}{\Delta T}$

$= -n\frac{\Delta BA}{\Delta T}$

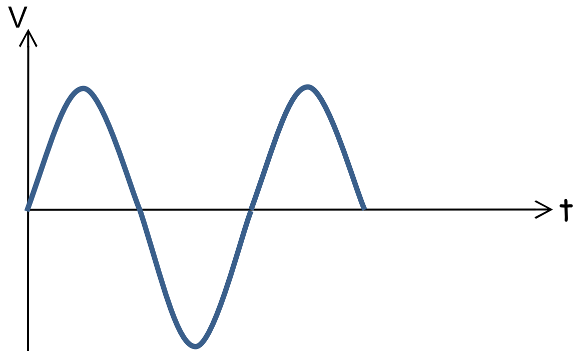
$3.6 = -n\frac{0.030 \times (0.30 \times 0.40)}{1/8}$

As the coil rotates at 2 rotations per second, it will take 0.5 seconds to complete on revolution.
∴ it will take 1/8 of a second to complete a ¼ cycle, which is how long it takes to change from maximum flux to zero flux.
∴ 3.6 = -n(0.030 x (0.3 x 0.4) x 8)

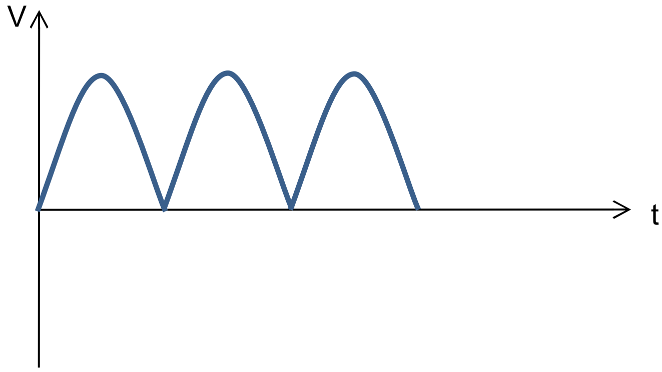
∴ n = 125 turns (ANS)

Question 22c (2012 Q7c, 2m, 60%)

Original



Final



Question 23a (2013 Q17a, 2m, 57%)

The induced EMF is given by

EMF = $\frac{\Delta\Phi}{\Delta t}$

$= \frac{0.6 - 0.2}{0.5}$

= 0.8 V

THEN use V = iR
0.8 = i x 0.1

$\therefore$ **i = 8 A (ANS)**

Question 23b (2013 Q17b, 2m, 45%)

The EMF will be zero when the gradient of the flux vs time graph is zero.

After t = 0, and before t = 2.0 gives

0.5, 1.0, 1.5 secs (ANS)

Question 23c (2013 Q17c, 4m, 27%)

The current will be clockwise when viewed from above.
The induced current will oppose the changing flux that is creating it. The ring has increasing flux, therefore the current will be clockwise, to create a field downwards to oppose this increase in flux.
This is an application of Lenz's law.

Question 23d (2013 Q17d, 2m, 24%)

At point A: (0), 2.0
At point B: 1.0
At point C: 0.5, 1.5, (2.5)

The flux is lowest when the ring is furthest from the magnet, this is at positions A and B. The flux is a maximum at position C. The ring starts at A, and returns here at 2.0 s.

Question 24a (2014 Q12b, 3m, 60%)

The induced EMF is given by

$$\xi = -n\frac{\Delta\Phi}{\Delta t}$$
$$= -n \times A\frac{\Delta B}{\Delta t}$$
$$= -1 \times 0.080 \times \frac{0.050}{10\times10^{-3}}$$
$$= -0.40 \text{ V}$$

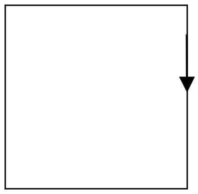
Use V = iR

$\therefore 0.40 = 0.020 \times R$

$\therefore$ **R = 20 Ω (ANS)**

Question 24b (2014 Q12c, 3m, 37%)

Initially the flux is down. As the magnetic field reduces to zero, the flux through the loop decreases. The induced EMF is going to create a field to oppose this change. Therefore the induced EMF is going to create its own field downwards.
In order for this to occur, the current in the loop needs to be clockwise. (From the right hand grip rule).



Question 25a (2014 Q18a, 3m, 37%)

The flux through the loop varies as the loop is rotated. The flux will vary sinusoidally. The induced EMF is given by: EMF = $-n\frac{\Delta\Phi}{\Delta t}$
Since the flux varies sinusoidally so will the induced EMF, as it is the gradient of the flux function.
Therefore the induced EMF will be AC.
The slip rings provide a constant connection, therefore the display on the CRO is AC.
If a split ring commutator was used the display would be DC.

Question 25b (2014 Q18b, 2m, 55%)

The loop will take 2 × 25 ms to complete a revolution.

$\therefore$ Period (T) = 50 ms.

The frequency is given by $f = \frac{1}{T}$

$\therefore f = \frac{1}{50\times10^{-3}}$

$\therefore$ **f = 20 Hz (ANS)**

Question 25c (2014 Q18c, 2m, 60%)

The magnitude of the induced EMF is given by

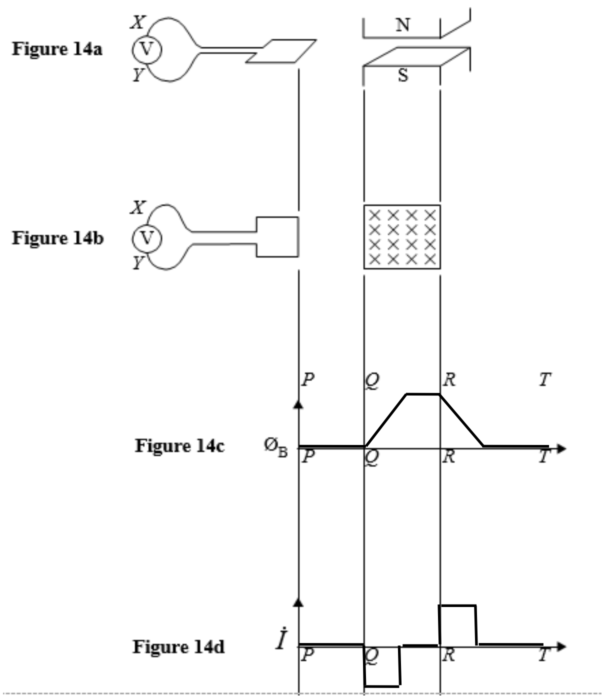
$$\xi = -n\frac{\Delta\Phi}{\Delta t}$$

If Δt is decreased (speed is increased), then the induced EMF will

Increase (ANS)

Question 26a/b

(2015 Q13a/b, 2m/2m, 20%/35%)



26a The flux increases from zero to a maximum, at a constant rate, whilst the loop is entering the field. Once the loop is completely immersed in the field the flux remains constant. When the loop begins to exit the field, the flux begins to decrease, at the same rate.

27b The magnitude of the induced EMF is the gradient of the flux versus time graph. The actual sign of the gradient depends on the external connections to the voltmeter, so the negative of this graph is also correct.

Question 26c (2015 Q13c, 4m, 45%)

X to Y
As the loop enters the region where the field exists, the flux through the loop increases. From Lenz's law, this change in flux will induce an EMF, this EMF will create a current whose magnetic field will oppose this change in flux. The original flux is downward, therefore the induced field will need to be upwards, to oppose the increase. The current in the loop needs to be anticlockwise, hence from X to Y through the voltmeter.

Question 27a (2015 Q12c, 3m, 43%)

If the shaft makes two complete turns every second, then the time it takes for a "quarter turn" is 0.125 sec.

Use EMF = $-n\dfrac{d\phi}{dt}$

= $-n\times\dfrac{B\times A}{t}$

= $-10 \times \dfrac{2.0\times10^{-3}\times(0.04)^2}{0.125}$

= 2.56×10^{-4}

= 0.256 mV (ANS)

Question 27b (2015 Q12d, 2m, 47%)

Replace the split ring commutator with a slip rings.
The slip rings maintain constant connection throughout the rotation.
The direction of the flux through the loop reverses every half turn, which results in AC being generated in the loop.

Question 28a (2016 Q15a, 2m, 75%)

Flux is given by BA
∴ Φ = BA
∴ Φ = 0.0050 × 0.0060
∴ $\Phi = 3.0 \times 10^{-5}$ Wb (ANS)

Question 28b (2016 Q15b, 3m, 37%)

The change in flux will induce an EMF in the coil. The flux to the left is decreasing, so the induced current will be such that it opposes this change. The induced current will produce a field in the same direction as B, (to oppose the loss of flux). The current will flow from right to left through the resistor.
∴ Right to Left (ANS)

Question 29a (2016 Q17a, 2m, 70%)

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

∴ $f = \dfrac{1}{40\times10^{-3}}$

∴ f = 25 Hz (ANS)

Question 29b (2016 Q17b, 1m, 90%)

Use $V_{RMS} = \dfrac{V_{peak}}{\sqrt{2}}$

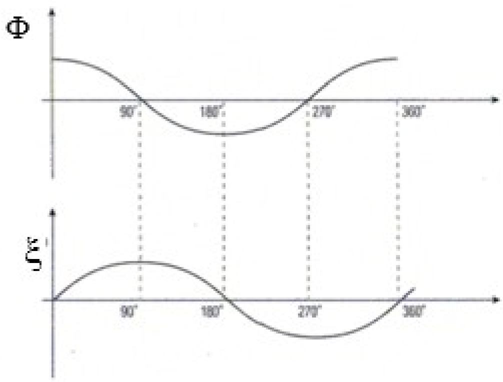
∴ $V_{RMS} = \dfrac{3.5}{\sqrt{2}}$

∴ $V_{RMS} = 2.47$

∴ 2.5 V (ANS)

Question 29c (2016 Q17c, 2m, 25%)

The flux vs angle graph and the induced EMF versus angle graph are shown. The induced EMF has a maximum value after a 90º rotation and a 270º rotation.
Therefore the maximum EMF is generated when the coil is horizontal.



Question 29d (2016 Q17d, 4m, 73%)

increase
increase
increase
no effect, (ANS)

Question 30a (2017 Q5a, 3m, 73%)

Use Φ = BA

$\therefore B = \frac{\Phi}{A}$

$\therefore B = \frac{0.2}{0.12}$

∴ B = 1.7 T (Wb m^{-2}) (ANS)

Question 30 (2017 Q5b, 3m, 53%)

Use EMF = $-n\frac{\Delta\Phi}{\Delta t}$

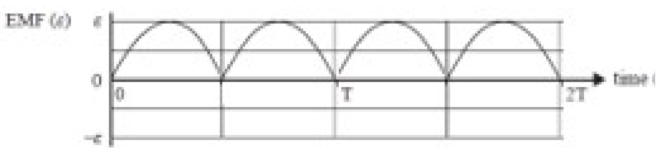
$\Delta t = \frac{1}{16}$ because it is a quarter of a turn and the coil rotates 4 times a second.

∴ EMF = - 10 × 0.2 × 16

∴ EMF = 32 V (ANS)

(The sign (direction) of the EMF is not needed).

Question 30c (2017 Q5c, 2m, 70%)



The effect of replacing the two slip rings with a split-ring commutator will be to reverse the direction of the output every half cycle. The magnitude of the EMF will remain the same and the period will not change.