Page 420 Test yourself on prior knowledge

1 a) The force is out of the page

b) B = F/Il

= 2×10^{-3} N/2 A × 0.03 m

= 0.033 T

2 a) F = BQv

= 1×10^{-3} T × 1.6 x 10^{-19} C × (0.01 × 3 × 10^{8}) m s^{-1}

= 4.8×10^{-16} N

b) The force becomes zero.

Page 422 Test yourself

1 ϕ = B A

= 0.03T × (0.02 × 0.06) m^2

= 3.6×10^{-5} Wb

2 ϕ = BA cos θ

= 53×10^{-6} T × 3.0×10^{11} m^2 × cos 20^0

= 1.5×10^{7} Wb

3 a) Maximum cross-sectional area = πr^2

= 9.0 π

= 28 m^2

so ϕ = B A

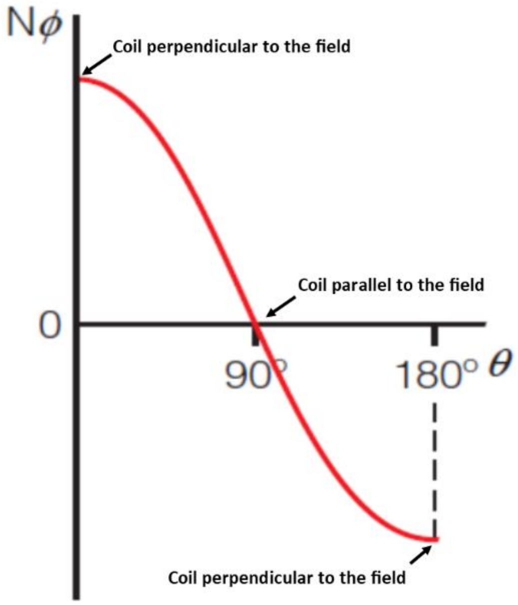
= 2.0 × 28

= 56 Wb

b) The magnetic flux does not change because the flux density and cross-sectional area do not change.

4 a) Nϕ = BAN = 0.08 T × 0.12^2 m^2 × 250 = 0.288 Wb turns

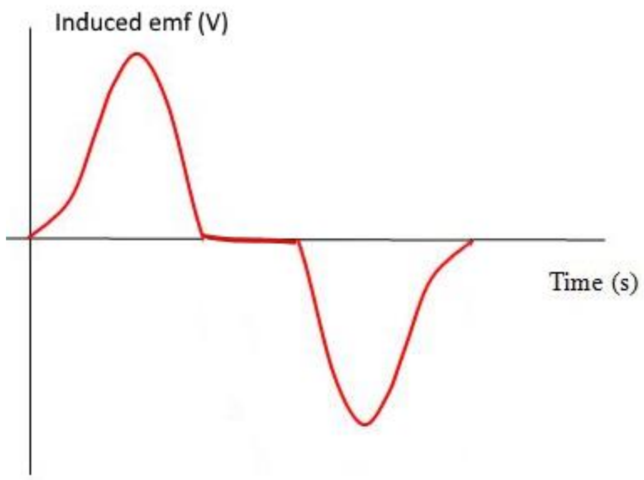
b) BAN cosθ = 0.288 Wb turns × cos 60 = 0.144 Wb turns c)



Page 426 Test yourself

5 a) An emf is induced in the coil, because the flux linkage in the coil is changing. A north pole is induced in the end of the coil facing the north pole of the magnet.
When the magnet does not move, the coil has no emf and no magnetic poles.
When the magnet is pulled out, a south pole is induced in the end of the coil facing the magnet. Again an emf is induced because the flux linkage in the coil is changing.

b) The precise shape of the curve will depend on how the magnet is moved. If it is moved at constant speed, the induced emf will gradually increase (then decrease once the magnet has fully entered the coil and the flux linkage stops changing. It will be zero while the magnet rests in the coil. As the magnet is removed the emf will increase then decrease in the opposite direction to the same magnitude if the speed is the same as before.



6 **a)** $N\phi = BAN$

$= 0.20\ T \times 2.0 \times 10^{-4}\ m^2 \times 500$

$= 2.0 \times 10^{-2}$ Wb turns when t = 0

$N\phi = BAN$

$= 0.60\ T \times 2.0 \times 10^{-4}\ m^2 \times 500$

$= 6.0 \times 10^{-2}$ Wb turns when t = 10 ms

b) $E = -\Delta(N\phi)/\Delta t$

$= (6.0 - 2.0) \times 10^{-2}$ Wb turns/0.01 s

= 4.0 V

c) If the coil was held at 30° to the field, the maximum flux would be BAN cos 30, so the induced voltage would be 4.0 V × cos 30 = 3.5 V

7 ϕ = BA and $\varepsilon = \frac{N\phi}{t}$

so $B = \varepsilon t/AN$

$= (0.9\ V \times 5 \times 10^{-3}\ s)/(1 \times 10^{-4}\ m^2 \times 2500$ turns)

= 0.018 T

8 **a)** An emf is induced in the wire by the changing magnetic field. A current flows in the loop since it forms a closed circuit. The resistance of copper is low so the current is large and causes the ring to heat up.

b) The emf induced in the wire with three coils is the three times greater, but the resistance is also three times greater, as the wire is three times longer, so the current remains the same.

c) The falling magnet causes a change in magnetic flux in the copper which induces an emf and causes a current to flow in the metal.
The direction of the induced emf below the magnet causes a repulsive force (Lenz's law) and the direction of the induced emf above the magnet causes an attractive force which slow the magnet.
No currents are induced in the plastic pipe.

9 When the earth vibrates, the metal rod vibrates which makes the magnet vibrate.
The magnet moves in and out of the coil which changes the flux linkage.
This induces an emf in the coil of wire.
Since $E = -\Delta(N\phi)/\Delta t$, larger or quicker vibrations increase the rate of change, which increases the peak of the induced emf.

Page 429 Test yourself

10 $E = \Delta\phi/\Delta t$

In one second, the length l of wire moves through a distance v, so $\Delta\phi/\Delta t = B \times lI$

$E = Blv$

$= 1.2\ T \times 0.15\ m \times 0.05\ m\ s^{-1}$

$= 9\ mV$

11 a) As the wire falls it accelerates, so the rate flux is cut increases and the induced emf increases.

b) Flux cut per second $= Blv$

$= 5.0 \times 10^{-3}\ T \times 0.08\ m \times 3.2\ m\ s^{-1}$

$= 0.013\ Wb\ s^{-1}$

Since $E = \Delta\phi/\Delta t$, the induced emf is 0.013 V

12 a) Angular frequency, $\omega = 2\pi f = 2\pi \times 3\ Hz = 6\pi\ rad\ s^{-1}$

b) $\varepsilon = BAN\omega \sin\omega t$

so $\varepsilon_{max} = BAN\omega$

$= 2.4\ T \times \pi \times (5 \times 10^{-3})^2\ m^2 \times 800 \times 6\pi$

$= 2.8\ V$

c) $\varepsilon = BAN\omega \sin\omega t = \varepsilon_{max} \sin\omega t$

$= 2.8 \sin(6\pi \times 0.36)$

$= 1.3\ V$

Pages 430–433 Test yourself

1 C

2 A

3 C

4 A

5 B

6 D

7 C

8 C

9 B

10 C

11 a) An electric generator converts mechanical energy in the form of the rotation energy of a coil of wire [1]
into electrical energy [1].

b) Maximum flux linkage = BAN $= 0.049\ \text{T} \times 3.0 \times 10^{-3}\ \text{m}^2 \times 600$ [1]

$= 0.088$ Wb turns value [1] units [1]

c) The cross-sectional area of the coil facing the fixed field changes [1]
it is a maximum is when the coil is perpendicular to the field and zero when parallel: [1]
it follows a cosine relationship. [1]

d) Max emf = $BAN\omega$ [1]

$= 0.088\ \text{Wb} \times 2\pi f$

$= 0.088\ \text{Wb} \times 2\pi/0.02\ \text{s}$ [1]

$= 27.7$ V value [1] units [1]

(Also equal to the maximum gradient of the graph.)

e) 0.005 s and 0.025 s [1]
the gradient has is maximum negative value at these points. [1]

f) Δt doubles [1]
so the maximum emf halves [1]

12 a) Weber, Wb

b) The millivoltmeter flicks on in one direction and back to zero when the circuit is turned on [1]
then it flicks in the opposite direction and back to zero when the circuit is turned off. [1]
Coil A becomes an electromagnet when the circuit is turned on. Its magnetic field increases, increasing the flux linkage with coil B and inducing an emf in coil B. [1]
Zero readings occur when the magnetic field is steady. [1]
When coil A is turned off, its magnetic field changes to zero so the flux linkage for coil B decreases, inducing an emf in coil B in the opposite direction. [1]

c) Using a second cell increases the size of the induced field [1]
so the ammeter flicks to a higher reading. [1]

13 a) Magnetic flux is magnetic flux density × area of the surface cut by the field,
but magnetic flux linkage is magnetic flux × number of turns in a coil in the field. [1]

b) Induced emf, $E = \Delta\phi/\Delta t = BA/t$

But the area swept out by the wire per second = wire length, l × velocity, v

so E = Blv per second [1]

$v = E/Bl$

$= 14 \times 10^{-6}\ \text{V}/(0.3 \times 10^{-3}\ \text{T} \times 0.124\ \text{m})$ [1]

$= 0.38\ \text{m s}^{-1}$ [1]

14 a) Area swept out in 1 s = $\pi r^2/4$

$= \pi \times 2.3^2/4 = 4.15\ \text{m}^2$ [1]

b) E = BA/t [1]

= 4.15 m^2 × 1.2 T = 4.98 V [1]

15 a) The angular frequency of the coil, ω is $2\pi f = 2\pi \times 4$ Hz = 25 rad s^{-1} [1]

Maximum flux linkage, $N\phi$ = BAN [1]

= 0.03 T × 15 × 10^{-4} m^2 × 600

= 0.027 Wb turns value [1] units [1]

b) $\varepsilon = BAN\omega \sin\omega t$ [1]

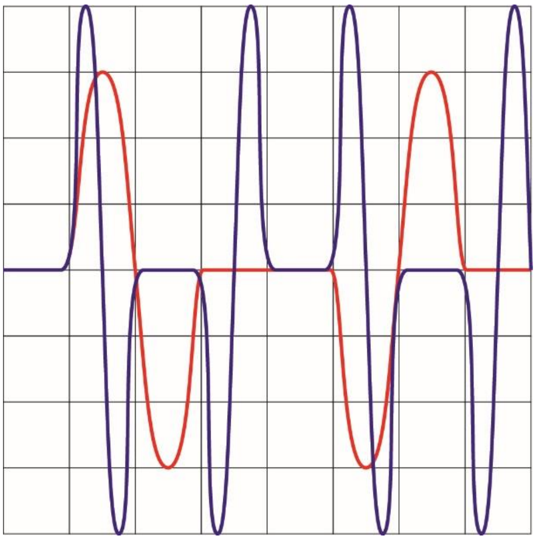
The maximum value of $\sin\omega t$ is 1, so the maximum emf = $BAN\omega$ = 0.027 × 25 = 0.68 V [1]

c) Flux linkage is ¼ of a cycle ahead of induced emf (see Figure 22.22, page 429). [1]
Frequency = 4 Hz, so a complete cycle takes 0.25s and ¼ of a cycle is 0.0625 s.
The emf is first at a maximum at 0.0625 s. [1]

16 a) When a north pole approaches there is a positive p.d. induced and therefore a negative p.d. induced as the north pole goes away. This happens the other way round when a south pole approaches and then goes away from the coil. [1]

b) i) red trace [1]

ii) blue trace [1]



c) i) There are four divisions between the first magnet beginning to induce an emf across the solenoid and the second doing the same. [1]

If the oscilloscope timebase is set to 0.02 s $division^{-1}$, then
t = 4 divisions × 0.02 s $division^{-1}$ = 0.08 s [1]

ii) The diagram shows six magnets arranged around the circumference of the turbine, so time for one rotation, T = 6 × 0.08 s = 0.48 s [1]

iii) f = 1/T

= 1/0.48 = 2.1 rotations/sec [1]

Pages 433–434 Stretch and challenge

17 a) $\varepsilon = Blv$ (see solution to question 13b, above)

$= 50 \times 10^{-6}$ T $\times 20 \times 10^{3}$ m $\times 8000$

$= 8.0 \times 10^{3}$ V

b) This figure assumes the tether is vertical but the tether is moving so it is likely to be at an angle to the magnetic field and the emf is, therefore, likely to be overstated.
Suggest values between 4.0×10^{3} V to 7.5×10^{3} V

18 Initially, when the ring is outside the field, there is no flux linkage, no induced emf and no current flows in the ring. As the ring enters the field, the the flux linkage increases so there is an induced emf. Using Lenz's law, the emf is in a direction to oppose the downward motion i.e. the magnetic field as a result of the induced emf is out of the page. This means the current flows anticlockwise.

Whilst the entire ring is inside the field, the flux linkage is constant so there is no induced emf or current.

As the ring leaves the field, the flux linkage decreases so there is an induced emf in a direction to oppose the downward motion. The flux decreases so the field must be inwards. The emf induces a current that flows in the opposite direction to that in B, i.e. clockwise. The magnitude of the emf and current is also greater than when it entered the field, because the ring is, at this point, falling more quickly.

19 The height of the peaks increases because the magnet falls faster so the rate of change of flux is greater.

The width of the peaks, and gaps between the peaks decreases because the magnet falls faster so it takes less time to enter and leave each coil, and to travel between the coils.

The direction of the peaks changes because the flux increases when the magnet enters the coil and decreases when the magnet leaves the coil.

The area under each peak is the same because the change in flux is the integral of εdt and is the same for each coil.