1  a) \[ B_H = (66 \times 10^{-6} \text{ T}) \sin 25^\circ \]
   \[ = 28 \mu\text{T} \]
   \[1\] 

   b) \[ B_V = (66 \times 10^{-6} \text{ T}) \cos 25^\circ \]
   \[ = 60 \mu\text{T} \]
   \[1\] 

   [Total 3 marks]

2  Answer A  \[1\] 

3  Answer B  \[1\] 

4  Answer A  \[1\] 

5  Answer B  \[1\] 

6  The transformer formula is \[ I_P V_P = I_S V_S \], where \[ I_P V_P = 60 \text{ mW} \] and \[ V_S = 12 \text{ V} \] 

   Rearranging: 
   \[ I_P = \frac{60 \text{ mW}}{12 \text{ V}} \]
   \[ = 5.0 \text{ mA} \]
   \[1\] 

   [Total 3 marks]

7  Answer D  \[1\] 

8  No calculation is possible, because the angle between the Earth’s magnetic field and the direction of the cable is not given, i.e. you need to know that in \[ B I_s \ell \sin \theta \], a value for \[ \theta \] is not given. 

   You need to know the magnitude of the vertical component of the Earth’s magnetic field, i.e. the angle that the Earth’s field makes with the vertical.  \[2\] 

   [Total 3 marks]

9  If a charge \[ Q \] is travelling with speed \[ v \] at an angle \[ \theta \] to a magnetic field \[ B \], it experiences a force 

   \[ F = B \sin \theta Qv \]

   The force will therefore be zero when \[ \theta = 0 \]. 

   This means the charge must be travelling \textit{parallel} to the magnetic field.  \[1\] 

   [Total 3 marks]
6 Magnetic fields

**10** There is no force on conductor OQ as it is parallel to the magnetic field.

Force on OP is

\[ F = B_A I \ell = (0.25 \times 10^{-3} \text{T}) \times 2.0 \text{ A} \times 0.50 \text{ m} = 2.5 \times 10^{-4} \text{ N} \]

In calculating the force on OR, we need consider the length of OR that is perpendicular to the field. From the diagram in the question we can see that this is 0.50 cm. Therefore:

\[ F = B_A I \ell = (0.25 \times 10^{-3} \text{T}) \times 2.0 \text{ A} \times 0.50 \text{ m} = 2.5 \times 10^{-4} \text{ N} \]

(This is exactly the same force that is exerted on OP because the component of OR that is perpendicular to the field is effectively OP.)

Using the left-hand rule, the forces on OP and OR are both vertically upwards.

**11** Answer C

**12** We need \( \Phi = BA \sin \theta \) and \( A = \pi r^2 = \pi \times (8.0 \times 10^{-3} \text{ m})^2 = 2.0 \times 10^{-4} \text{ m}^2 \). Then:

a) maximum value of \( \Phi \) is when \( \sin \theta = 1 \)

\[ \Phi_{\text{max}} = (2.0 \times 10^{-4} \text{ m}^2) \times 1.5 \text{ T} = 3.0 \times 10^{-4} \text{ Wb} \]

Minimum value of \( \Phi \) is when \( \sin \theta = 0 \)

\[ \Phi_{\text{min}} = 0 \]

b) \[ \varepsilon = \frac{\Delta \Phi}{\Delta t} = \frac{3.0 \times 10^{-4} \text{ Wb}}{0.30 \text{ s}} = 1.0 \times 10^{-3} \text{ V or 1.0 mV} \]

**13** a) As the centripetal acceleration is \( a = \frac{v^2}{r} \), only the radius of its circular path is needed.

(Note that this does not need any knowledge of magnetic fields!)

b) As the acceleration is always at right angles to its direction of motion, its speed does not change. (Its velocity changes as it is continually changing direction as it moves round the circle.)

**14** The number of turns has doubled, but the area is only one quarter of the original.

**15** a) \[ \frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow N_p = N_s \times \frac{V_p}{V_s} \]

\[ = 200 \text{ turns} \times \frac{240 \text{ V}}{12 \text{ V}} = 4000 \text{ turns} \]

b) \[ I_s V_s = I_p V_p \Rightarrow I_s = \frac{I_p V_p}{V_s} = \frac{1.5 \times 10^{-3} \text{ A} \times 240 \text{ V}}{12 \text{ V}} \]

\[ = 0.030 \text{ A or 30 mA} \]
6 Magnetic fields

Answers to Exam practice questions

16 Suppose a length $\ell$ of wire levitates; then $B\ell I = \mu \ell g$ so the $\ell$ cancels.

\[ B = \frac{\mu g}{I} = \frac{80 \times 10^{-3} \text{ kg m}^{-1} \times 9.8 \text{ N kg}^{-1}}{5.6 \text{ A}} \]

\[ = 0.14 \text{ N A}^{-1} \text{ m}^{-1} = 0.14 \text{ T} \]

[Total 4 marks]

17 The answer here is to reword the caption to Figure 6.13 – ‘whatever you try to do produces a result that tries to stop you’ – in your own words.

[Total 4 marks]

18 We need to use $F = B \perp Q \mathbf{v}$

a) $\theta = 90^\circ \Rightarrow F = (0.15 \text{ T})(3.2 \times 10^{-19} \text{ C})(5.0 \times 10^6 \text{ m s}^{-1})$

\[ = 2.4 \times 10^{-13} \text{ N} \]

b) $\theta = 45^\circ \Rightarrow F = \sin 45^\circ \times 2.4 \times 10^{-13} \text{ N} = 1.7 \times 10^{-13} \text{ N} \]

c) $\theta = 30^\circ \Rightarrow F = \sin 30^\circ \times 2.4 \times 10^{-13} \text{ N} = 1.2 \times 10^{-13} \text{ N} \]

[Total 5 marks]

19 a) Your argument should include the following points:

- There will be a sudden rise in the current $I_L$ in the left circuit as the switch is closed. This current will quickly settle to a steady value.
- As $I_L$ rises from zero, a rising magnetic field $B$ will be produced in the left coil.
- This $B$-field will link with the coil in the right circuit, but only as this field changes will a current $I_R$ be induced in the right coil.
- Thus there will be a sudden rise in the current in the right coil, but this induced current will quickly fall back to zero as the linking magnetic field settles to a steady value.

[Total 4 marks]

(In a question such as this, marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. Broadly speaking, there would be one mark for each valid point provided there is a well-structured argument.)

Tip: Answers to questions of this kind are often best laid out as a series of bullet points. Examiners like this layout, as it often matches the mark scheme from which they are working.

20 a) $B \ell \mathbf{v} = (45 \times 10^{-6} \text{ T}) \times 36 \text{ m} \times 240 \text{ m s}^{-1}$

\[ = 0.39 \text{ T m}^2 \text{ s}^{-1} \]

b) From $F = B \ell I \Rightarrow T = N \text{ A}^{-1} \text{ m}^2 \text{ s}^{-1}$

\[ = \frac{N \text{ m}}{\text{A s}} = \frac{I}{C} \]

\[ = V \]

[Total 4 marks]

© Tim Akrill and Graham George 2015
21 From \( v = u + at \), the downward speed of the pole after 1.3 s is

\[
v = gt = 9.8 \text{ m s}^{-2} \times 1.3 \text{ s} = 12.7 \text{ m s}^{-1}
\]

Using \( B \ell v \)

The p.d. = \((18 \times 10^{-6} \text{ T}) \times 4.0 \text{ m} \times 12.7 \text{ m s}^{-1}\)

\[
= 9.2 \times 10^{-4} \text{ V or 0.92 mV}
\]

22 If the supply is sinusoidal we can write:

\[ V = V_0 \sin(2\pi ft) \]

From \( Q = CV \)

\[ Q = CV_0 \sin(2\pi ft) \]

Then

\[ I = \frac{dQ}{dt} = 2\pi f CV_0 \cos(2\pi ft) \]

The maximum current is therefore:

\[ I_0 = 2\pi f CV_0 \]

\[
= 2\pi(50 \text{ s}^{-1})(0.47 \times 10^{-6} \text{ F})(17 \text{ V})
= 2.5 \times 10^{-3} \text{ A or 2.5 mA}
\]

23 Some of the points you might make are:

- There are no toxic fumes from an electric car as it uses electric batteries and not petrol or diesel as its energy source.
- It is for this reason that such cars are thought to ‘produce no pollution’.
- However, the electrical energy used to propel an electric car has been produced in power stations that are less than 50% efficient.
- Also, the batteries that the car uses need to be manufactured, which in itself produces pollution, as would the many recharging points that need to be built and placed around countries that use electric cars.
- The main advantage of electric cars is that they do not pollute the atmosphere where they are being driven, for example in towns.
- A further advantage is that they are relatively quiet.

Tip: There is no ‘right’ answer to questions of this kind. What the examiner wants is to see is an argument, preferably one that does not come down wholly on one side or the other.
Stretch and challenge

24 Your discussion should include the following points:

- ‘Hybrid’ vehicles use petrol or diesel supplemented by energy from electric batteries.
- The braking action in these cars converts the car’s kinetic energy into electrical energy which is stored as chemical energy in the car’s battery.
- The d.c. motor that ‘drives’ the car spins in reverse as the car slows down. According to Faraday’s law of electromagnetic induction, the d.c. motor that drove the car now acts as a dynamo – it generates electricity.
- The rate of change of magnetic flux through the coils of what was the motor produces an induced e.m.f. and hence an induced current that charges the car’s batteries.
- This process is making use of the car’s kinetic energy to slow it down, and is called regenerative braking.

[Total 5 marks]

(As in question 19, marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. Broadly speaking, there would be one mark for each valid point provided there is a well-structured argument.)

25 Rough values for the strength of the Earth’s fields in England are:

\[ g \approx 10 \text{ N kg}^{-1}, \quad E \approx 200 \text{ N C}^{-1} \quad \text{and} \quad B \approx 50 \times 10^{-6} \text{ N A}^{-1} \text{m}^{-1} \]

The relevant relationships are:

\[ F_g = mg, \quad F_E = eE \quad \text{and} \quad F_B = Be \varepsilon \]

The mass of a proton is about \( 1.7 \times 10^{-27} \text{ kg} \), the charge on a proton is \(+1.6 \times 10^{-19} \text{ C}\) and the speed of light is \( 3.0 \times 10^8 \text{ m s}^{-1}\).

\[ \therefore \quad mg \approx 1.7 \times 10^{-26} \text{ N}, \quad eE \approx 3.2 \times 10^{-17} \text{ N} \quad \text{and} \quad Be \varepsilon \approx 2.4 \times 10^{-16} \text{ N} \]

[Total 6 marks]

Tip: You are reminded that within the context of Working as a Physicist, the Specification states that students ‘should be able to estimate values for physical quantities and use their estimate to solve problems’.

26 Faraday’s law of electromagnetic induction states that \( \varepsilon = -\frac{d\Phi}{dt} \)

Integrating both sides gives:

\[ \int_0^t \varepsilon \ dt = -\int_{\Phi_1}^{\Phi_2} d\Phi = \Phi_1 - \Phi_2 \]

The left-hand side of this equation is the area between the induced e.m.f. and the time axis, which therefore equals the change of magnetic flux in the experiment.

[Total 4 marks]