Module 6.3 Electromagnetism

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| **Topic area** | **Text book pre-reading** | **Syllabus ref** | **Max possible score in exam questions** | **Your score in exam questions** |
| Magnetic fields and forces | p146-148 | 6.3.1 | 8 |  |
| Magnetic flux density | p149-152 | 6.3.1 | 7 |  |
| Particles in magnetic fields | p154-158 | 6.3.2 | 13 |  |
| Magnetic flux and flux linkage | p159-162 | 6.3.3 | 12 |  |
| Faraday and Lenz’s Laws | p163-164 | 6.3.3 | 7 |  |
| Investigating magnetic flux with search coils | p165-167 | 6.3.3 | 6 |  |
| Generators | p168-169 | 6.3.3 | 6 |  |
| Transformers | p169-172 | 6.3.3 | 16 |  |
| **Total** | | | 75 |  |

**By the end of this topic you should be able to….**

* Describe how magnetic fields can be created and use magnetic field lines to map magnetic fields around a wire, coil and solenoid
* Use Fleming's left-hand rule to give the direction of a force and calculate the magnitude of this force
* Describe an experiment to determine the uniform magnetic flux density between the poles of a magnet using a wire and balance
* Calculate the force on particles traveling at right angles through a uniform magnetic material and describe their motion
* Describe the motion of particles within an electric and magnetic field
* Define magnetic flux and magnetic flux linkage, and describe experiments to investigate this with search coils
* Describe Faraday's law of electromagnetic induction and link this to Lenz's law
* Describe how an a.c. generator works
* Describe how a transformer works and perform calculations of the current and voltage of these based on the number of coils

**By the end of module 6.5 you need to be able to define the following key terms:**

Magnetic flux

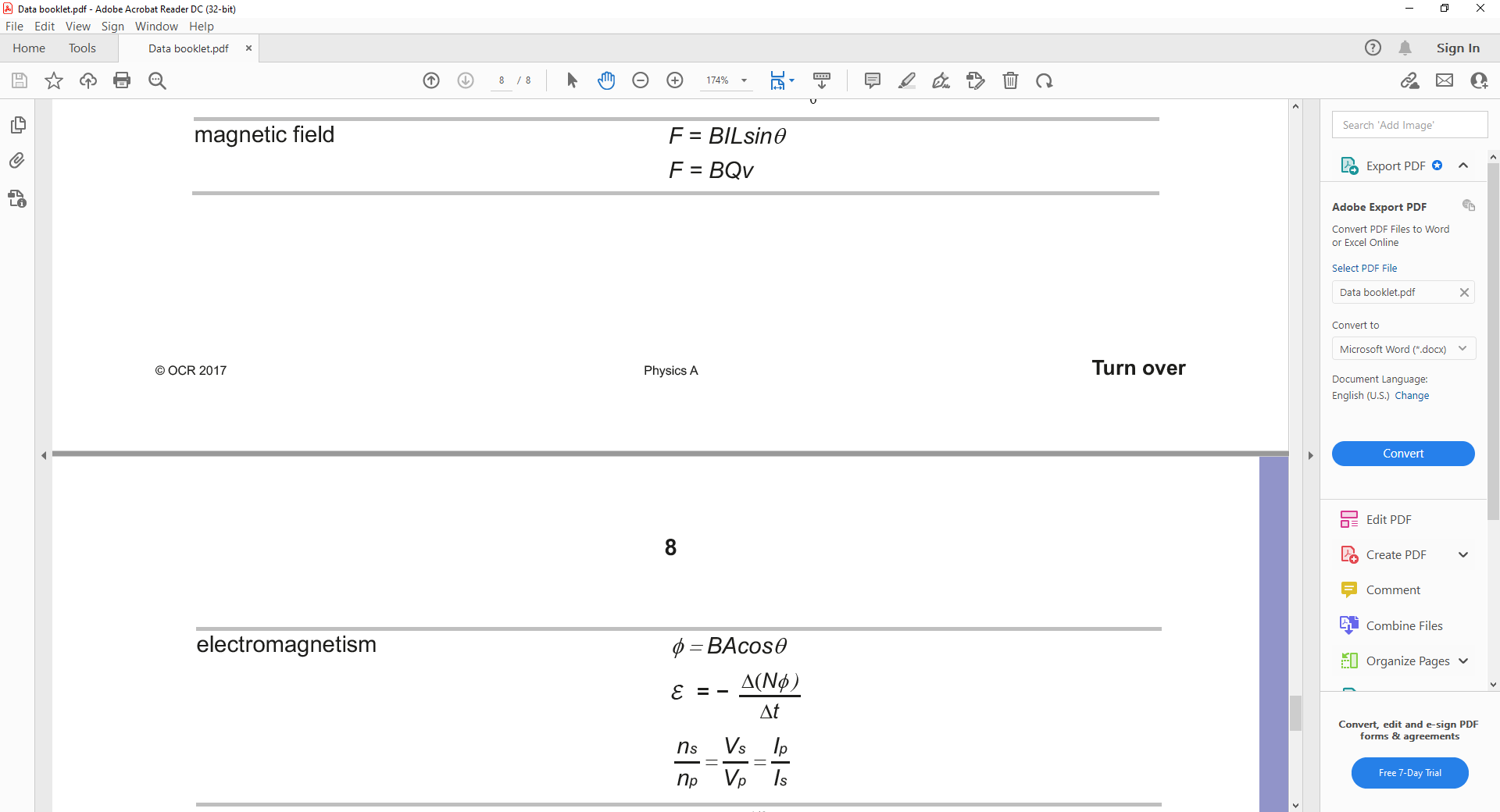
Magnetic flux density

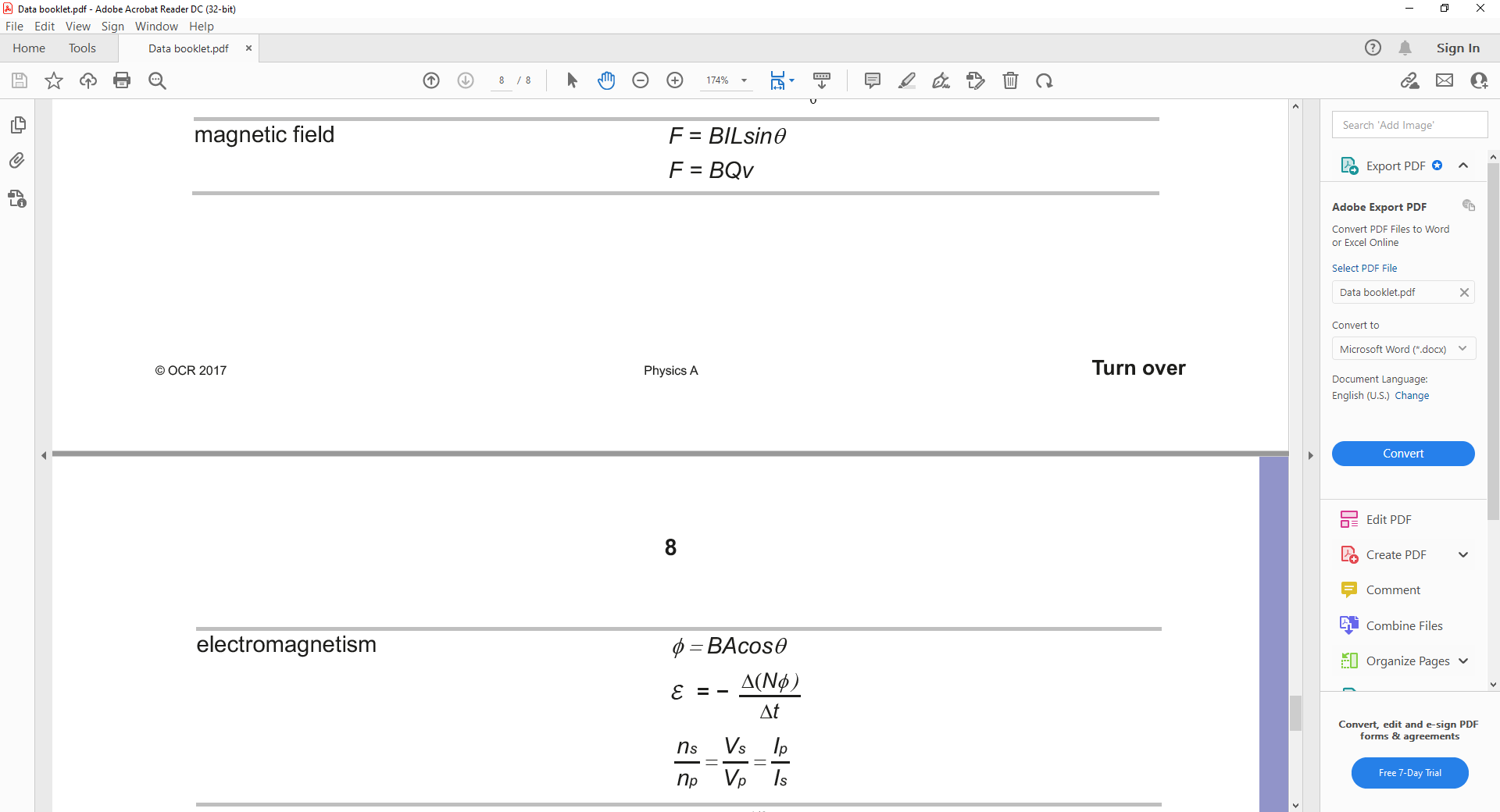
Magnetic flux linkage

Faraday’s Law

Lenz’s Law

**Equations given in exam**





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|  | **Magnetic fields and forces**   |  |  | | --- | --- | |  |  | | **1.** | Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is held in tension T by the clamps at each end. The length of the wire in the magnetic field of flux density 0.032 tesla is 6.0 cm.    A direct current I of 2.5 A is passed through the wire as shown.   1. On Fig. 5.1 draw an arrow to indicate the direction of the force F on the wire.   **[1]**   1. Calculate the magnitude of F.   F = .......................................... N **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **2.** | This question is about electric fields.  Fig. 2.1 shows the electric field pattern drawn by a student for two oppositely charged plates.    State **two** errors made by the student in this drawing of the field pattern.      **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **3.** | The diagram shows four magnetic compasses placed at the same distance from point **X**.     |  | | --- | |  |   Which of the following is most likely to be at point **X**?     |  |  | | --- | --- | | **A** | permanent magnet | | **B** | current-carrying solenoid | | **C** | current-carrying flat coil | | **D** | straight current-carrying wire |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **4.** | Fig. 2.1 shows a horizontal current-carrying wire placed in a uniform magnetic field.    The magnetic field of flux density 0.070 T is at right angles to the wire and into the plane of the paper. The weight of a 1.0 cm length of the wire is 6.8 × 10−5 N. The current I in the wire is such that the vertical upward force on the wire due to the magnetic field is equal to the weight of the wire.   1. Calculate the current I in the wire.      |  | | --- | | I = ........................................................... A **[2]** |  1. Suggest why it would be impossible for overhead cables carrying an alternating current to float in the Earth's magnetic field.     **[1]**  **Magnetic flux density** | | |
|  | | |  |  | | --- | --- | |  |  | | **5.** | A thin rectangular slice of semiconductor is mounted and used as a measuring instrument called a Hall probe.  A cell is connected to provide the current in the slice. The potential difference across the slice is measured by  a separate voltmeter.  A student wants to measure the magnetic flux density between the poles of two magnets mounted on a steel yoke as shown in Fig. 2.2. The magnitude of the flux density is between 0.02 T and 0.04 T.    **Fig. 2.2**   1. Suggest **one** reason why this Hall probe is **not** a suitable instrument to measure the magnetic flux density for the arrangement shown in Fig. 2.2.       **[1]**   1. Another method of measuring the magnetic flux density for the arrangement shown in Fig. 2.2 is to insert a current-carrying wire between the poles of the magnet. Explain how the magnetic flux density can be determined using this method and discuss which measurement in the experiment leads to the greatest uncertainty in the value for the magnetic flux density.               **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **6.** | The unit of magnetic flux density is the tesla, T. Express this unit in terms of kg, C and s.  T = ........................................................... **[2]** | |

**Particles in magnetic fields**

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|  | |  |  | | --- | --- | |  |  | | **7(a).** | **Fig. 22.1** shows the circular track of a positron moving in a uniform magnetic field.    The magnetic field is perpendicular to the plane of **Fig. 22.1**. The speed of the positron is 5.0 × 107 m s−1 and the radius of the track is 0.018 m.  State the direction of the force acting on the positron when at point **A** and explain why this force does **not** change the speed of the positron.      **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Calculate the magnitude of the magnetic flux density of the magnetic field.  magnetic flux density = .......................................... T **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **8.** | Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.     |  | | --- | | **Fig. 20** |   A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.  A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.  Each rubidium ion has charge +1.6 × 10–19 C and speed 4.8 × 104 m s–1. The radius of the semi-circular path of the ions is 0.18 m. The mass of a rubidium ion is 1.4 × 10–25 kg.  Calculate the magnitude of the magnetic flux density B of the magnetic field.     |  | | --- | | B = ......................................................T **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **9(a).** | Fig. 2.1 shows the circular path described by a helium nucleus in a region of uniform magnetic field in a vacuum.    The direction of the magnetic field is perpendicular to the plane of the paper. The magnetic flux density of the magnetic field is 0.20 mT. The radius of the circular path is 15 cm. The helium nucleus has charge + 3.2 × 10−19 C and mass 6.6 × 10−27 kg.  Calculate the magnitude of the momentum of the helium nucleus.     |  | | --- | | momentum = ........................................................... kg m s−1**[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | A uniform electric field is now also applied in the region shaded in Fig. 2.1. The direction of this electric field is from **left** to **right**. Describe the path now followed by the helium nucleus in the electric and magnetic fields.    **[2]** | | | | |
|  | |  |  | | --- | --- | |  | **Magnetic flux and flux linkage** | | **10.** | Fig. 5.2 shows the magnetic field from the north pole of a vertically held bar magnet.     1. A small flat coil is placed at **A**. The coil is moved downwards from position **A** to position **B**. The plane of the coil remains horizontal between these two positions. Explain why there is no induced e.m.f. across the ends of the coil.     **[1]**   1. Fig. 5.3 is a graph showing how the magnetic flux density B varies along the horizontal line **XY** in Fig. 5.2.     The same small flat coil from **(i)** is moved at a constant speed from **X** to **Y**. The plane of the coil remains horizontal between **X** and **Y**.  On the axis provided in Fig. 5.4, sketch a graph to show the variation of the induced e.m.f. E across the ends of the coil with distance from **X**.   |  | | --- | |  | | | | | |
|  | | |  |  | | --- | --- | |  |  | | **11.** | **Fig. 5.3** shows the poles of a powerful electromagnet producing a uniform field in the gap between them. The dimension of each pole is 0.10 m by 0.080 m. There is no field outside the gap. A circular coil of 80 turns is placed so that it encloses the total flux of the magnetic field.     1. The current in the electromagnet is reduced so that the field falls linearly from 0.20 T to zero in 5.0 s.  Calculate the initial flux in the gap and hence the e.m.f. generated in the coil during this time.   induced e.m.f. = .......................................... V **[2]**   1. The coil is part of a circuit of total resistance *R* so that a current is generated in the circuit while the field is collapsing.  Draw on the coil in **Fig. 5.3** the direction of this induced current.  State how you applied the laws of electromagnetic induction to deduce the direction of this current.       **[2]** | | | |
|  | | | |  |  | | --- | --- | |  |  | | **12.** | Fig. 6.2 shows a soft iron ring of variable circular cross-section. It has four coils containing 2, 3, 4 and 5 turns wound around it. The cross-sectional area of the ring is different for each coil.  A cell is connected across the coil with three turns.     1. Draw on Fig. 6.2 the complete paths of **two** lines of magnetic flux produced by the three-turn coil when there is a current in it.   **[1]**   1. State which **one** of the following three quantities,      |  |  |  | | --- | --- | --- | | magnetic flux | magnetic flux density | magnetic flux linkage |   is most nearly the same for all four coils in Fig. 6.2. Give a reason for your answer.    **[1]**   1. Write down **one** of the **other** two quantities in **(ii)** above. State in which coil this quantity has the largest value. Give a reason for your answer.     **[2]** | | |
|  | | | **Faraday and Lenz’s Law**   |  |  | | --- | --- | |  |  | | **13.** | 1. State Faraday's law of electromagnetic induction.       **[1]**   1. A coil rotates in a uniform magnetic field. Fig. 3.1 shows the variation of magnetic flux linkage with time t.     On Fig. 3.2 sketch a graph to show the variation of the induced e.m.f. E across the ends of the coil with time t.  **[2]** | | |
|  | | | | |  |  | | --- | --- | |  |  | | **14.** | Fig. 3.1 shows the design of a ‘mechanical’ torch.     |  | | --- | | **Fig. 3.1** |   There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance h through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.     |  | | --- | | **Fig. 3.2** |   Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance h.     |  | | --- | | **Fig. 3.3** |   Explain the shape of the curve in Fig. 3.3.                **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **15.** | A coil with 500 turns is placed in a uniform magnetic field. The average cross-sectional area of the coil is 3.0 × 10–4 m2. The magnetic flux through the plane of the coil is reduced from 1.8 × 10–4 Wb to zero in a time t. The average electromotive force (e.m.f.) induced across the ends of the coil is 0.75 V.  What is the value of t ?     |  |  | | --- | --- | | **A** | 3.6 × 10–5 s | | **B** | 2.4 × 10–4 s | | **C** | 0.12 s | | **D** | 8.3 s |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

**Investigating magnetic flux with search coils**

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|  | |  |  | | --- | --- | |  |  | | **16.** | \* A student is to investigate the magnetic field inside and around a solenoid.  It is suggested that the magnetic field strength B inside a long solenoid is determined by various quantities, namely   where N is the number of turns, L is the length of the solenoid and I is the current in the wire.  Apparatus is set up for an experiment as shown in Figure 6.1.    A Slinky is a long spring about 70 mm in diameter which can be stretched easily and uniformly. The search coil has 5000 turns and the signal generator can produce a constant alternating current at a frequency between 0 and 1 kHz.  Plan an experiment using this equipment to investigate the validity of the relationship between B, at the centre of the solenoid, and **one** of the variables N or L. Explain how you will make your measurements, how sensitive they will be and the steps that you will take to make this a valid test.                      **[6]** | |

**Generators**

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|  | |  |  | | --- | --- | |  |  | | **17(a).** | Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.  **Fig. 21.1**  The coil has 85 turns of insulated wire. The cross-sectional area of the coil is 14 cm2. Fig. 21.2 shows the variation of magnetic flux density B through the plane of the coil with time t as it rotates.  **Fig. 21.2**   1. Explain why the electromotive force (e.m.f.) induced across the ends of the coil is a **maximum** at the times when B = 0.       **[1]**   1. Draw a tangent to the curve in Fig. 21.2 when B = 0, and hence determine the **maximum** e.m.f. induced across the ends of the coil.  |  |  |  | | --- | --- | --- | | maximum e.m.f. = |  | V **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig. 21.3 shows the variation of the e.m.f. induced across the ends of the coil with time t.  **Fig. 21.3**  The magnitude of the magnetic flux density of the uniform field is now halved and the coil is rotated at twice its previous frequency.     |  |  | | --- | --- | | On Fig. 21.3 sketch the new variation of the e.m.f. induced with time t. | **[2]** | | |

**Transformers**

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|  | |  |  | | --- | --- | |  |  | | **18.** | The number of turns on the coils of four ideal iron-cored transformers **A, B, C** and **D** are shown in the table below.     |  |  |  | | --- | --- | --- | | **Transformer** | **Number of turns on the secondary coil** | **Number of turns on the primary coil** | | **A** | 100 | 100 | | **B** | 50 | 200 | | **C** | 200 | 50 | | **D** | 500 | 100 |   Each transformer is connected in turn to an alternating 240 V supply.  Which transformer will give the largest output current?     |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **19(a).** | A student conducts an experiment to confirm that the uniform magnetic flux density B between the poles of a magnet is 30 mT.  A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.  The current I in the wire is changed and the force F experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.  **Fig. 22.1**  The student’s analysis is shown on the graph of Fig. 22.1 and in the space below.  Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.                                                **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig. 22.2 shows a transformer circuit.  **Fig. 22.2**  The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.   1. Use Faraday’s law of electromagnetic induction to explain why the filament lamp is lit.                 **[3]**   1. The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.    1. Calculate the current in the primary coil.      |  |  | | --- | --- | |  | current = ......................................... A **[2]** |  * 1. The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.         **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **20.** | Fig. 3.3 shows a diagram of a simple transformer.    Explain how an electromotive force (e.m.f.) is induced across the ends of the secondary coil.            **[2]** | |

**END OF QUESTION PAPER**