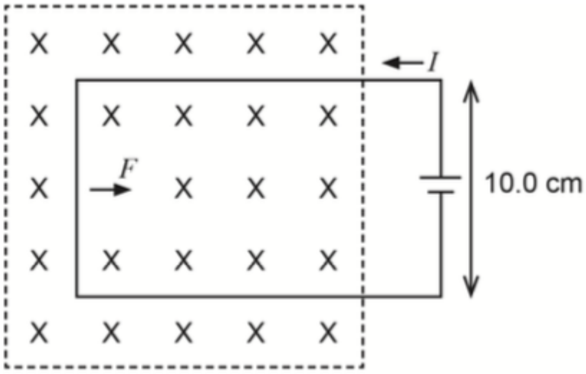
**YEAR 12 PHYSICS**
**ASSIGNMENT 5 - INDUCED EMF**

**Name:** ______________________ **Mark:** $\frac{}{46}$

1. A rectangular wire loop is placed into a uniform magnetic field, with the plane of the loop perpendicular to the magnetic field. The wire carries a current ***I*** of 0.250 A. The magnetic field is directed into the page. A force ***F*** of 3.20 × 10$^{-2}$ N is measured. Calculate the magnitude of the magnetic field strength. Include appropriate units. (3 marks)




$F = IlB$

$\Rightarrow B = \frac{F}{Il}$

$= \frac{3.20\times10^{-2}}{(0.250)(0.100)}$ (1)

$= 1.28\,T$

Answer: 1.28 (1) Units: T (1)

2. An AC generator has 131 coils in a square of side length 0.137 m which rotates at 309 rpm in a magnetic field of strength 0.113 T. Determine both the peak EMF and the rms EMF generated. (4 marks)

$EMF_{max} = 2\pi NBAF$ (1)

$= 2\pi(131)(0.113)(0.137)^2\left(\frac{309}{60}\right)$ (1)

$= 8.99\,V$

$EMF_{rms} = \frac{EMF_{max}}{\sqrt{2}}$

$= \frac{8.99}{\sqrt{2}}$

$= 6.36\,V$

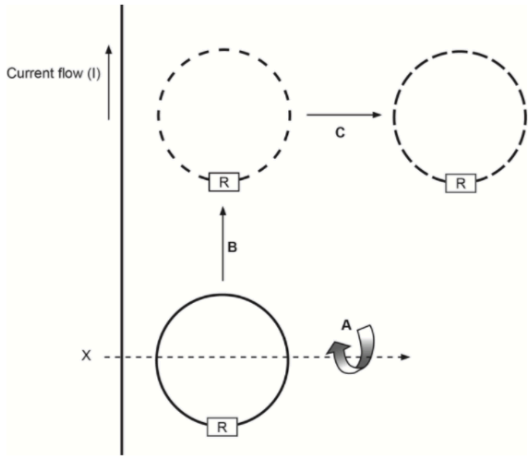
Answer (peak): 8.99 V (1)

Answer (rms): 6.36 V (1)

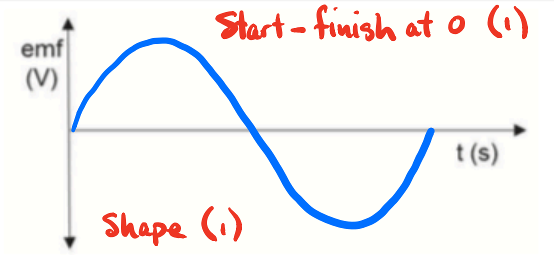
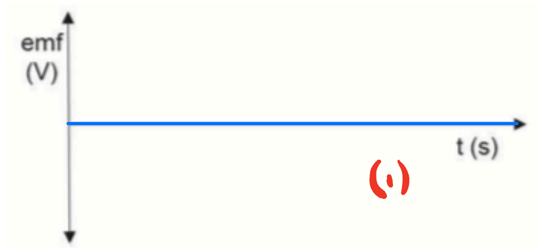
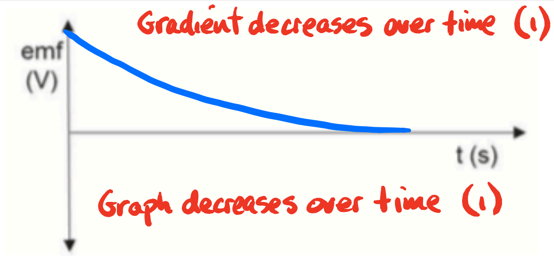
3. A circular wire loop is placed near a long, straight wire carrying a constant current in the direction shown. The loop moves three times:

- A – it rotates once, uniformly along the X-axis with the resistor R moving out of the page initially.
- B – it moves parallel to the straight wire with constant speed.
- C – it moves away perpendicularly from the straight wire with constant speed.

(8 marks)

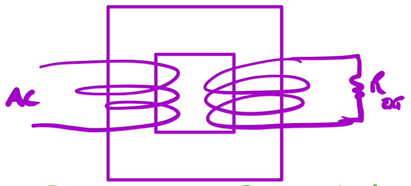



Complete the table in terms of Motions A, B and C by sketching the EMF induced in the loop and state whether the direction of EMF is clockwise, anticlockwise or not relevant.

| Motion | Possible induced emf in the circular loop with respect to time | The direction of emf (clockwise/anticlockwise/ not relevant) |
|---|---|---|
| A |   | Not relevant (1) (accept clockwise) |
| B |   | Not relevant (1) |
| C |   | clockwise (1) |

4. A generator is capable of producing $3.00 \times 10^2$ kW of electricity at 415 V AC. Its output is stepped up to 11.0 kV for transmission.

(a) Determine the primary to secondary turns ratio of the step-up transformer used at the power station. (2 marks)




$P_p = 300\,kW$ $\quad P_s = 300\,kW$

$V_p = 415\,V$ $\quad V_s = 11.0\,kV$

$I_p = ?$ $\quad I_s = ?$

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

$$\Rightarrow \frac{415}{11.0 \times 10^3} = \frac{N_P}{N_S} \quad (1)$$

$$\Rightarrow \underline{N_P = 3.77 \times 10^{-2} N_S} \quad (1 : 26.5) \quad (1)$$

(b) Determine the current available at the output of the step-up transformer. (2 marks)

$$P_s = V_s I_s$$

$$\Rightarrow I_s = \frac{P_s}{V_s}$$

$$= \frac{3.00 \times 10^5}{11.0 \times 10^3} \quad (1)$$

$$= \underline{27.3\ A} \quad (1)$$

5. A tram is powered by four identical electric motors. Each motor has a maximum power output of 30.0 kW. The motors are connected in parallel and powered by $6.00 \times 10^2$ V DC from overhead power lines. When the motors are operating at maximum power output, there is a back EMF of $5.20 \times 10^2$ V with an internal resistance of 1.39 Ω.

(a) Calculate the current drawn by each motor when operating at maximum power output. (4 marks)

$$V_{effective} = V_s - V_{back} \quad (1)$$

$$= 6.00 \times 10^2 - 5.20 \times 10^2$$

$$= 80.0\ V \quad (1)$$

$$V_{eff} = IR$$

$$\Rightarrow I = \frac{V_{eff}}{R}$$

$$= \frac{80.0}{1.39} \quad (1)$$

$$= \underline{57.6\ A} \quad (1)$$

$$P_{output} = V_{Back} I \quad (1)$$

$$\Rightarrow I = \frac{P_{out}}{V_{back}} \quad (1)$$

$$= \frac{30.0 \times 10^3}{5.20 \times 10^2} \quad (1)$$

$$= \underline{57.7\ A} \quad (1)$$

[Either method is OK]

(b) After operating for a while, one of the motors becomes jammed. Describe, with a reason, what happens to the current in that motor when it becomes jammed.

(2 marks)

- The current increases significantly. (1)
- No back EMF exists to oppose the flow of current due to the applied voltage. (1)

6. A rectangular coil of a car alternator (AC generator) has $3.20 \times 10^2$ turns, a radius of 7.00 cm and a length of 6.00 cm. The coil rotates in a uniform magnetic field supplied by electromagnets. The alternator is designed to produce sufficient output voltage to recharge the car battery, even when the alternator rotates at $6.00 \times 10^2$ rpm. The output voltage is steady at 14.5 $V_{rms}$.

(a) Determine the peak voltage output of this alternator. (1 mark)

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

$$\Rightarrow V_{peak} = (14.5)\sqrt{2}$$

$$= \underline{20.5\ V} \quad (1)$$

(b) Calculate the magnetic field strength needed to produce this peak output voltage. If you were unable to obtain an answer for part (a), use 25.0 V.

(4 marks)

$$\varepsilon_{max} = 2\pi NBAf$$

$$\Rightarrow B = \frac{\varepsilon_{max}}{2\pi NAf}$$

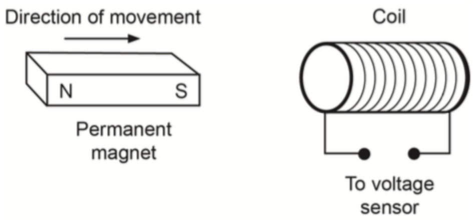
Calculation of area (1)

$$= \frac{20.5}{2\pi(3.20\times10^2)(2\times7.00\times10^{-2})(6.00\times10^{-2})\left(\frac{6.00\times10^2}{60.0}\right)} \quad (1)$$

$$= \underline{0.121\ T} \quad (1)$$

frequency (1)

7. A permanent magnet is moved toward a coil at a constant velocity, causing an EMF to be induced across the ends of the coil.




Using an appropriate equation from the Formulae and Data booklet, explain why a larger EMF would be detected if the magnet was moved at a greater velocity toward the coil. (4 marks)

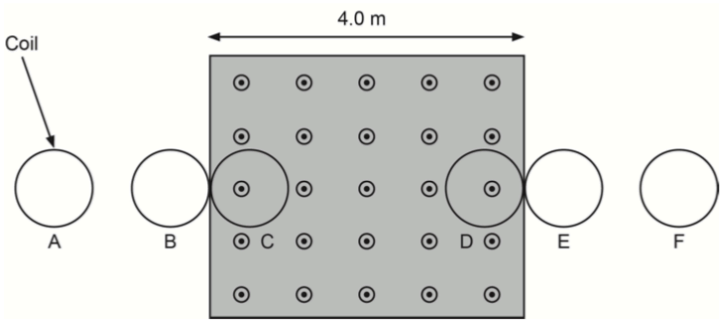
$$\varepsilon = \frac{-N\Delta\phi}{\Delta t} \quad (1)$$

$$\Rightarrow \quad \varepsilon \propto \frac{\Delta\phi}{\Delta t} \quad (1)$$

As velocity increases, $\Delta t$ decreases. (1)

$\rightarrow$ $\varepsilon$ increases (1)

8. A coil with a radius of 50.0 cm and 25 turns is moved at a constant velocity of 0.80 ms$^{-1}$ to the right of the page into, through and out of a uniform magnetic field of strength 0.280 T. The total distance from the centre of the coil at A to the centre of the coil at F is 8.00 m and the distance from A to B is the same as E to F.




(a) Calculate the average EMF induced as the coil moves from B to C. (4 marks)

Time for the coil to enter field:

$$v = \frac{s}{t}$$

$$\Rightarrow t = \frac{s}{v} = \frac{1.00}{0.800} = 1.25\,s \quad (1)$$

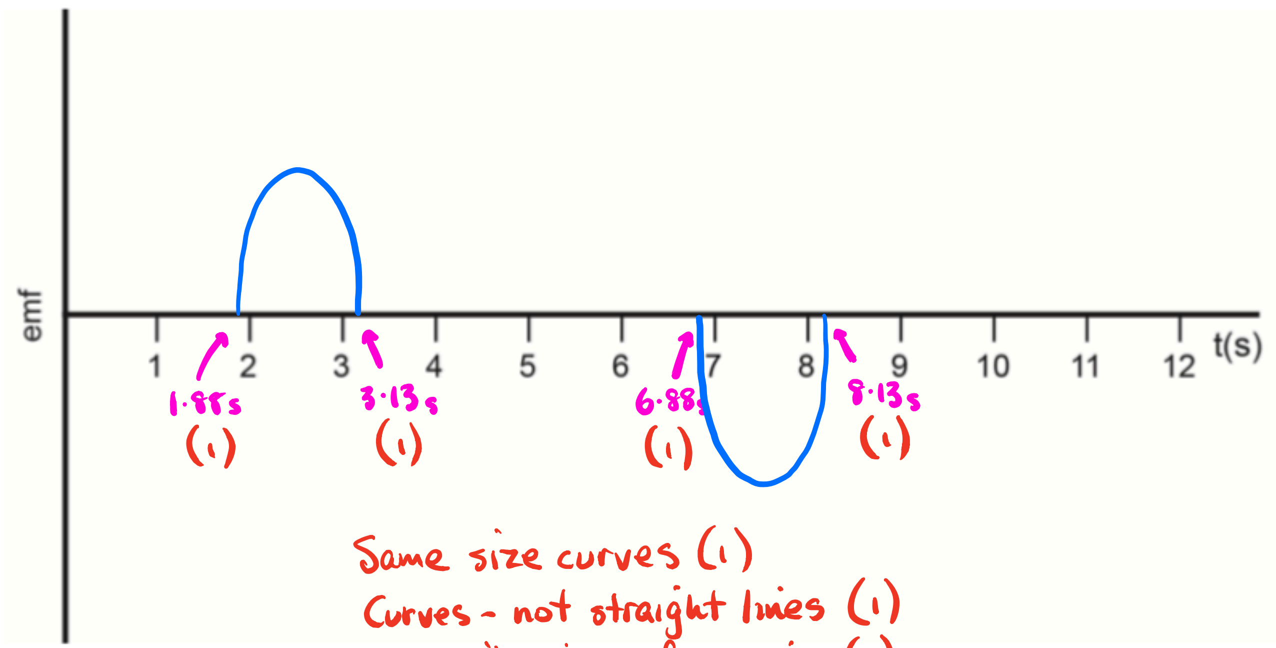
$$\mathcal{E} = \frac{-N\Delta\Phi}{\Delta t} = -\frac{NB\Delta A}{\Delta t}$$

Area (1)

$$= \frac{-(25)(0.280)(0-\pi(0.500)^2)}{1.25} \quad (1)$$

$$= \underline{4.40\ V} \quad (1)$$

(b) On the axes below, show the induced EMF versus time as the coil moves from A to F. (Note: only include specific values on the time axis.) (8 marks)




Same size curves (1)
Curves - not straight lines (1)
Opposite sides of x-axis (1)
Flat line between at zero (1)