1

(a) **(i)** product of number of turns of coil, magnetic flux density and area perpendicular to the magnetic field.

(ii)

$$\phi = B\pi r^2$$
$$= 0.17 \times \pi(0.36)^2$$
$$= 6.9 \times 10^{-2}\ Wb$$
$$T = \frac{1}{25}$$
$$\epsilon = \frac{\Delta\phi}{\Delta t}$$
$$= 0.069 \times 25$$
$$= 1.7\ V$$

(iii) current in disc is perpendicular to magnetic field causing force to act on disc. This force opposes rotation of disc and by Fleming's left-hand rule, it indicates current is from rim to axle.

(b) **(i)** The ring cuts magnetic flux and causes induced e.m.f. in ring. This results in induced e.m.f. causing eddy currents to flow in the ring. The currents in ring cause magnetic field around ring and the two fields interact to cause opposing force

(ii) current cannot pass all the way around the ring so there is no induced current and the resistive force will be absent.

2

(a) The steel string is made of magnetic material, and so it causes changes in the magnetic field from the permanent magnet that the coil is situated in. As the string vibrates, the magnetic field near the (pickup) coil changes over time. A changing (periodically increasing and decreasing) magnetic flux linkage through the coil induces an electromotive force in the coil proportional to the rate of change of magnetic flux. Because the vibration is periodic, the magnetic flux linkage also changes periodically and thus the e.m.f. induced is alternating.

(b) Larger amplitude of vibration with the same frequency causes greater change in magnetic field around the magnet and coil, so there will be a greater change in magnetic flux linkage in coil in the same period, hence greater magnitude of induced voltage.

(c)

$$|E| = NA\frac{\Delta B}{\Delta t}$$
$$N = \frac{|E|}{A\left(\frac{\Delta B}{\Delta t}\right)} = \frac{0.20}{(1.0 \times 10^{-6})(5.0 \times 10^{-2})(2 \times 880)}$$
$$N = 2270 \approx 2 \times 10^3$$

3

(i) At $t = 0.070\ s, I = 1.500\ A$

$$n = \frac{3000}{0.15} = 20000$$
$$B = \mu_0 nI = 4\pi \times 10^{-7} \times 20000 \times 1.500$$
$$= 3.77 \times 10^{-2}\ T$$

(ii) Using points $(0.070, 1.500)$ and $(3.80, 0.550)$ on the line in Fig. 5.2,

$$\frac{dI}{dt} = \frac{0.550 - 1.500}{0.380 - 0.070} = -3.0645 = -3.06$$

$$
\begin{aligned}
|E| &= \frac{d\phi}{dt} \\
&= \frac{d(NBA)}{dt} \\
&= NA\mu_0 n \frac{dI}{dt} \\
&= 1500 \times 2.5 \times 10^{-4} \times 4\pi \times 10^{-7} \times 20000 \times 3.0645 \\
&= 2.89 \times 10^{-2}\ V
\end{aligned}
$$

(iii) The current I in the solenoid flows from the positive terminal of the battery. By right-hand-grip rule, the magnetic flux density B produced points to the left.

Since I in solenoid decreases, B also decreases so by Lenz's law, the induced magnetic flux density B in the coil must point to the left. By right-hand-grip rule, the induced current I in the coil flows from left to right through the galvanometer.

4

(a) In the direction WXYZW.

(b) The changing magnetic flux linkage produces an induced emf, and hence current due to Faraday's law. The force due to this induced current opposes the motion by Lenz' law.

(c) **(i)** The flux through the frame is $\phi = (B\sin\theta)L^2$

(ii) $\phi = (B\sin\omega t)L^2$

$$|E| = \frac{d\phi}{dt} = BL^2\omega\cos\omega t = BL^2\omega\cos\theta$$

(d)

$$
\begin{aligned}
P &= \frac{E^2}{R} \\
P &= \frac{B^2L^4\omega^2\cos^2\theta}{R} = P_0\cos^2\omega t \\
\langle P\rangle &= \frac{P_0}{2} \\
\langle P\rangle &= \frac{B^2L^4\omega^2}{2R} = \frac{1.0^2 \times 0.20^4 \times 10^2}{2 \times 0.50} = 16\ mW
\end{aligned}
$$

5

(a) $\Delta B = 5 - 50 = -45\ mT$

$$|E| = \frac{\Delta\phi}{\Delta t} = NA\frac{\Delta B}{\Delta t} = 180 \times \pi\left(\frac{5.3 \times 10^{-3}}{2}\right)^2 \times \frac{(45 \times 10^{-3})}{0.30}$$
$$= 6.0 \times 10^{-4}\ V$$

(b) As the coil moves away from the magnet, there is a rate of change of magnetic flux linkage through the coil due to the decreasing magnetic flux density resulting in an induced e.m.f. in the coil, according to Faraday's law.
With the resistor connected in a closed loop with the coil, a current is induced in the closed loop that opposes the motion of the coil, according to Lenz's law. As work is done to move the coil away at constant speed, this gives rise to the heating effect of induced current (in resistor).

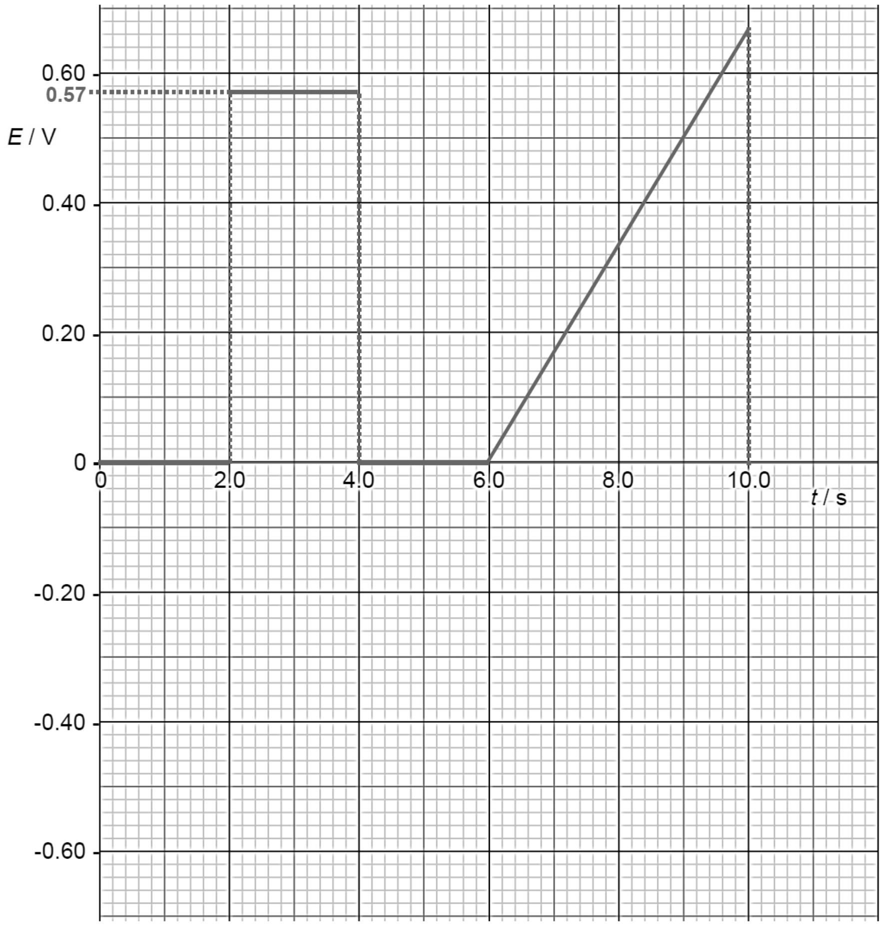
6

(a) $\Phi = NBA = (500)(0.060)(\pi \times 0.12^2)$

$= 1.3572 = 1.4\,Wb$

(b) $|E| = \frac{d\Phi}{dt} = NA\frac{dB}{dt}$
$= 500 \times \pi \times 0.12^2 \times \left|\frac{0.050 - 0}{2.0 - 4.0}\right|$
$= 0.57\,V$

(c)



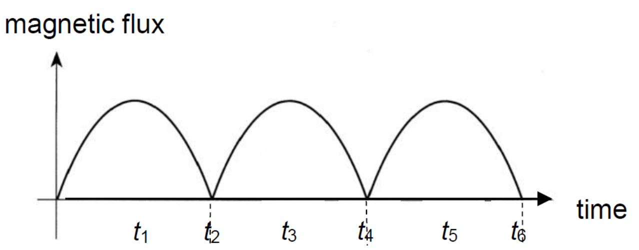
7

(a) **(i)** This increases the magnetic flux linkage with secondary coil

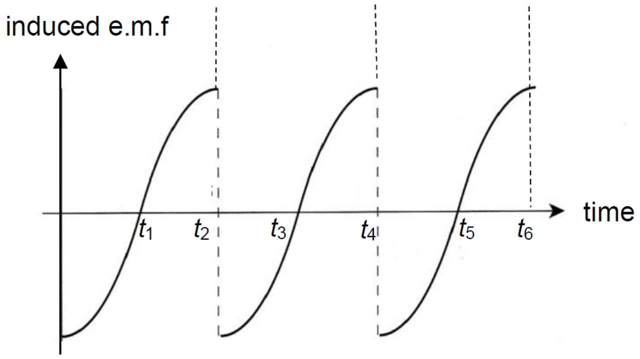
(ii) This reduces heat/energy losses caused by eddy currents in the core

(b) The changing current in the primary coil gives rise to changing magnetic field and hence changing magnetic flux in the iron core. The iron core links the magnetic flux in the primary to the secondary coil. From Faraday's law, the changing flux in the secondary coil induces e.m.f. in secondary coil.

(c) **(i)**



(ii)



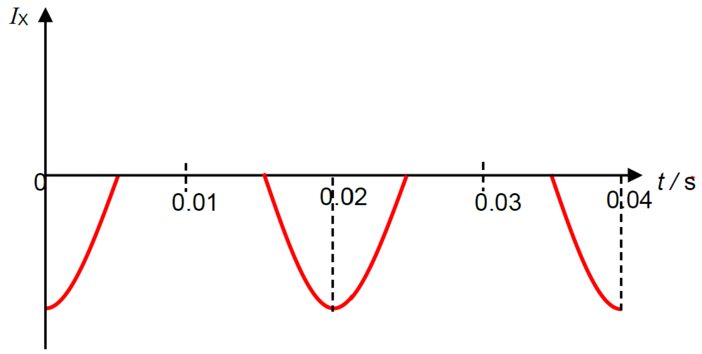
(iii) 1. If the number of turns in the primary coil increases, the e.m.f. induced in the secondary coil decreases, assuming the number of turns in the secondary coil remains the same.
This is because the e.m.f. induced in the secondary coil is inversely proportional to the number of turns in the primary coil when the input p.d. also remains constant.

(iii) 2. If the number of turns in the secondary coil increases, the e.m.f. induced across the secondary coil increases, assuming the number of turns in the primary coil remains constant.
This is because the e.m.f. induced in the secondary coil is directly proportional to the number of turns in the secondary coil when the input p.d. also remains constant.

8

(a) When S is opened, current in coil Y stops flowing and the magnetic flux produced by the current in coil Y decreases. Hence magnetic flux density through coil X decreases. By Faraday's Law, an electromotive force is induced in coil X.
By Lenz's Law, the induced emf in coil X would be in a direction so as to produce effects to oppose the decrease in the magnetic flux density. The induced emf would have produce current, in coil X in the clockwise direction when viewed from Q. But since this current would be in reversed biased direction, LED remain unlit.

(b)



9

(a) $E = \frac{d\Phi}{\mathrm{dt}} = Bw\frac{dx}{dt}$
Flux linkage is Φ and x is the distance AB has moved past P.

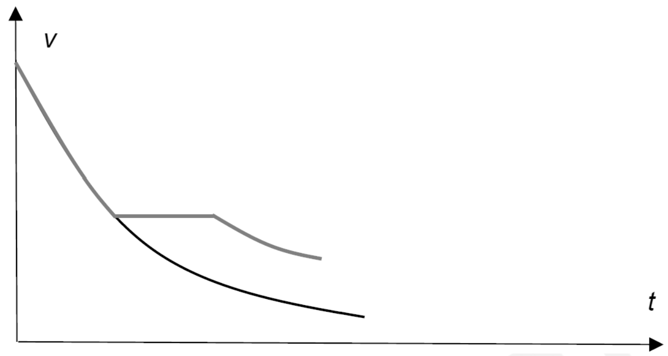
$E = Bwv$

(b) (i) As AB moves from P towards Q, magnetic flux linkage over the area ABCD enclosed by the frame increases resulting in an induced e.m.f. generated in the frame by Faraday's Law.

Since it is a closed circuit, by Lenz's Law, an induced current will flow such that it opposes the increase in magnetic flux linkage. (current flows in anticlockwise direction)
Consequently, a magnetic force acts on AB towards the left, causing it to slow.

(b) **(i)** As AB moves from P towards Q, magnetic flux linkage over the area ABCD enclosed by the frame increases resulting in an induced e.m.f. generated in the frame by Faraday's Law.
Since it is a closed circuit, by Lenz's Law, an induced current will flow such that it opposes the increase in magnetic flux linkage. (current flows in anticlockwise direction)
Consequently, a magnetic force acts on AB towards the left, causing it to slow.

(ii)



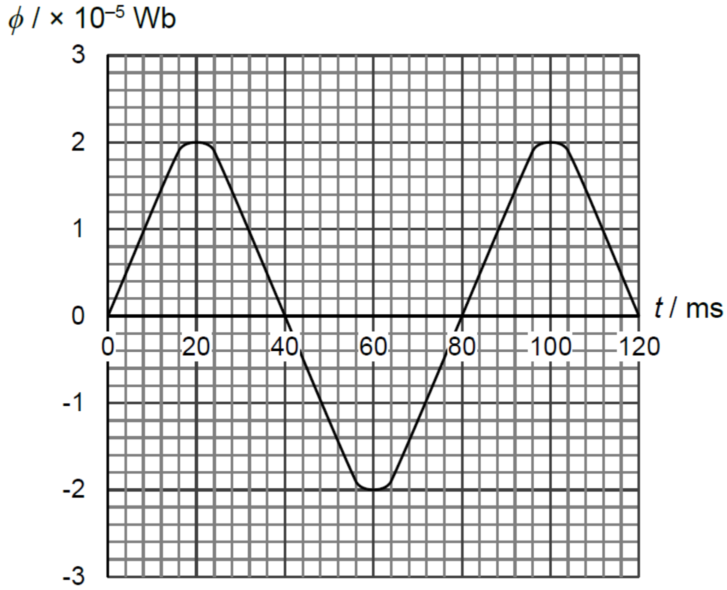
10

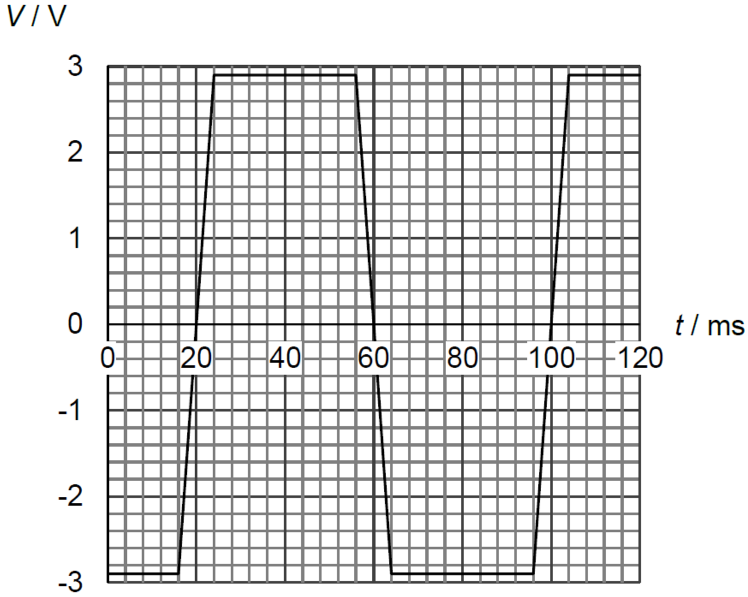
(a) The magnetic flux linkage is the product of the number of turns of the coil of wire and the magnetic flux through (each turn of) the coil of wire. The magnetic flux through an area is defined as the product of that area and the component of the magnetic flux density normal to the plane of that area.

(b) **(i)**
$$\phi_{\max} = B_{max}A$$
$$= \mu_0 n I_{max} A$$
$$= 1000 \times 4\pi \times 10^{-7}\left(\frac{1800}{0.12}\right)(1.05 \times 10^{-3})\left(\frac{\pi \times 0.036^2}{4}\right)$$
$$= 2.0 \times 10^{-5}\ Wb$$

(ii)
$$E_{induced} = N_Q A\frac{d(1000\mu_0 n I)}{dt}$$
$$= 1000\mu_0 N_Q A n\frac{dI}{dt}$$
$$\frac{dI}{dt} = \frac{[1.0-(-1.0)] \times 10^{-3}}{(24-56) \times 10^{-3}}$$
$$E_{induced} = 2.88\ V$$

(iii)


ϕ / × 10^{-5} Wb
3
2
1
0
-1
-2
-3
t / ms
0
20
40
60
80
100
120


V / V
3
2
1
0
-1
-2
-3
t / ms
0
20
40
60
80
100
120