5 The EZ-Link card is a “contactless” smartcard used for transportation payments in Singapore.

Fig. 5.1 shows part of the internal circuitry of an EZ-Link card. It consists of a transmitter which connects to 3 wire loops around the edge of the card. The transmitter requires electrical energy to communicate with an external device such as a card reader. However, there is no internal power source in the card. The area of the EZ-Link card is 4.00×10^{-3} m^2.

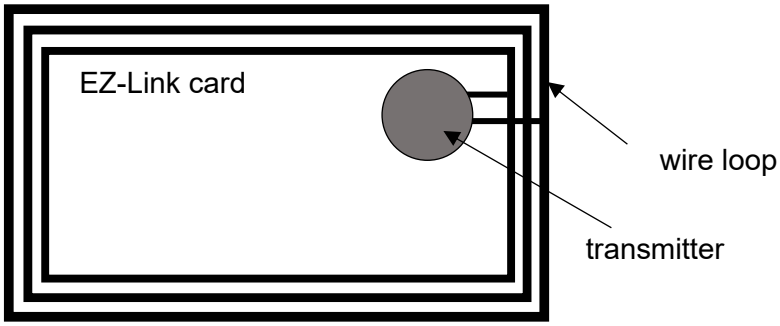

Fig. 5.1

Fig. 5.2 shows a card reader which produces a sinusoidal magnetic field of frequency, *f*, 13.6×10^6 Hz.

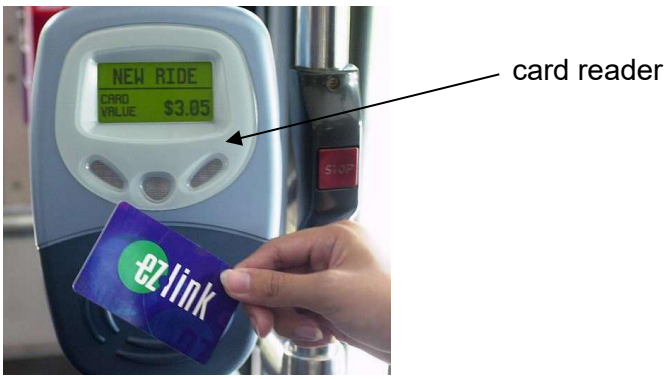

Fig. 5.2

(a) State Faraday’s law of electromagnetic induction.

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..... [1]

(b) Using Faraday's law, explain how electrical energy is generated to power the transmitter of the EZ-Link card when it is tapped onto the card reader.

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..... [3]

(c) The card reader generates a magnetic field, B given by the equation $B = B_0 \sin(2\pi ft)$.

(i) Show clearly that the magnitude of the peak e.m.f. generated in the card is given by $1.02 \times 10^6 B_0$.

[3]

(ii) Calculate the peak magnetic flux density B_0 if the card needs a r.m.s. voltage of 10.0 mV to operate.

B_0 = ... T [2]

(d) The system is designed such that it can work if the card is tapped with either face. Explain briefly why this is possible.

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..... [1]