8 The popularity of electric vehicles (EVs) is rapidly increasing, driven by advances in battery technology and growing environmental awareness. EVs rely on electricity stored in batteries for propulsion. However, challenges such as high electricity consumption and inadequate charging infrastructure can limit their range and practical usability.

Regenerative braking is an energy recovery system that slows a vehicle by converting kinetic energy into a form that can be stored or used later, unlike conventional brakes that waste energy as heat through friction. It uses electromagnetic induction, where a motor acts as a generator during braking as shown in Fig. 8.1

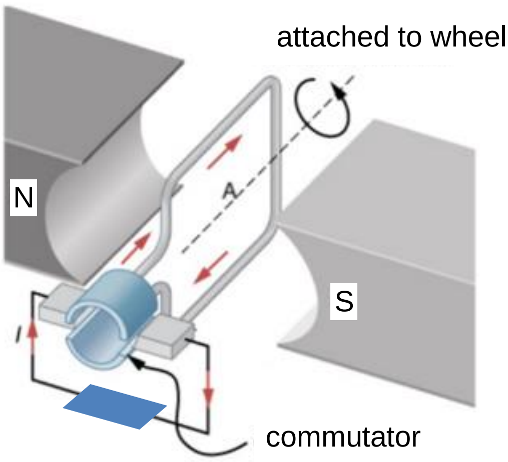

Fig. 8.1

In EVs, this technology improves efficiency and can potentially extend the driving range by up to 30%. It is especially effective during downhill driving or deceleration, capturing energy that would otherwise be wasted. Fig. 8.2 shows the percentage of electrical energy savings by vehicle type. It can be seen that heavier vehicles tend to have a greater percentage of their energy saved.

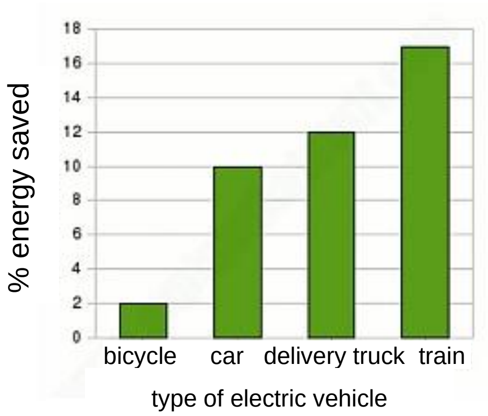

Fig. 8.2

While regenerative braking provides significant benefits, it still has its limitations. The system's effectiveness decreases at lower speeds, where a substantial amount of kinetic energy is dissipated through friction braking. Additionally, the system's overall efficiency and the need for comprehensive charging infrastructure are important challenges. The most efficient driving approach involves minimizing the use of both the motor and brakes by anticipating traffic conditions, thereby optimizing energy use and improving the practicality of electric vehicles.

(a) **(i)** With reference to Fig. 8.1 and using Faraday's law of electromagnetic induction, explain how regenerative braking improves fuel efficiency.

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(ii) Hence, explain why the efficiency of the regenerative system decreases at lower speeds.

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(iii) Define magnetic flux

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(iv) Hence, derive an expression for the magnetic flux linkage through a coil with N turns, area A when its normal makes an angle of θ with the uniform magnetic field of flux density B as shown in Fig. 8.3.

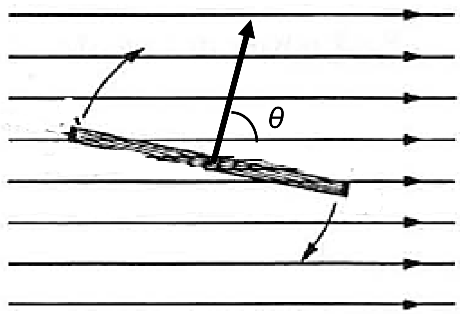

Fig. 8.3

[1]

(v) Hence, if the coil shown in Fig. 8.3 has 75 turns, an area of 200 cm^2 and that the magnetic flux density of the field is 0.70 T, calculate the maximum induced e.m.f. E if the coil is rotating at a rate of 30 turns per second.

E = …………………. V [4]

(vi) Fig. 8.4 shows the variation of induced e.m.f. E with time t.

Sketch on the same axis how the graph will look like if the speed of rotation of the coil were halved.

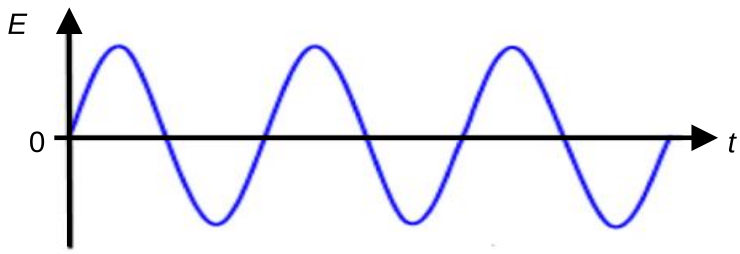

Fig. 8.4

[2]

(b) The passage mentions that regenerative braking improves fuel efficiency and extends the vehicle's range, state one more advantage of the regenerative braking system.

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.... [1]

(c) Fig. 8.2 shows that heavier vehicles recover a greater percentage of their energy via regenerative braking, suggest why this is the case.

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.... [1]

END OF PAPER

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