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A4_11 Power Generation by Cycling

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Abstract

This paper considers the possibility of power generation, using a bicycle dynamo, in order to recharge a mobile phone. The results showed that a cyclist would need to be travelling at approximately 1 mph in order to provide enough electrical power to charge a typical mobile phone.

Introduction

Bicycle dynamos are commonly used to generate power for electrical lights. The aim of this paper is to examine how the dynamo provides this power, and whether this power could be used to recharge a mobile phone.

Power generated by the dynamo

Dynamos operate by converting rotational kinetic energy to electrical energy using a magnet and solenoid. A simplified set up of the dynamo is shown below in figure 1. For a dynamo attached to the centre of one wheel, the permanent magnet will rotate within the solenoid at an angular velocity, ω. This angular velocity is the same as the angular velocity of the bicycle wheel. The rotating magnet will result in a sinusoidally varying emf output, as the relative angle of the magnetic field lines and the coil varies sinusoidally. Therefore, the dynamo will produce an alternating current.

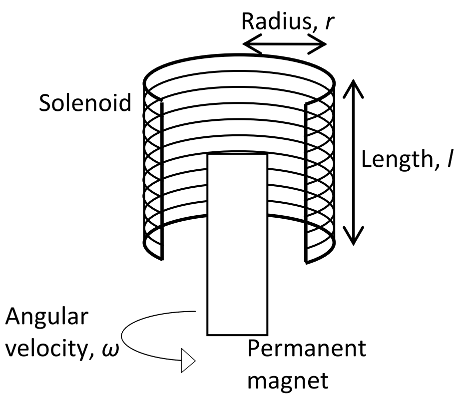

Figure 1. A diagram showing the setup for a dynamo, where the permanent magnet rotates within a stationary solenoid.

Faraday's law states that the emf produced by the dynamo is related to the rate of change of the magnetic flux in the solenoid. The magnetic flux, Φ_m, in the solenoid with radius r and N number of turns is [1]:

$$\Phi_m = \pi N B r^2 \cos(\omega t), \qquad (1)$$

where B is the magnetic field strength of the permanent magnet and t is the time.

By using Faraday's law, it can be shown that the peak emf output, ε_{peak}, for the magnet is [1]:

$$\varepsilon_{peak} = \pi \omega N B r^2. \qquad (2)$$

The peak emf produced is the peak emf amplitude for the alternating current.

The corresponding peak current, I_{peak} produced by the dynamo can be found from the magnetic flux, Φ_m, and the self-induced inductance, L, of the solenoid, by the relationship shown in equation (3), where I is the varying current [1].

$$I = \frac{\Phi_m}{L}. \qquad (3)$$

By substituting for the magnetic flux with equation (1), and using $L = \frac{\mu_0 N^2 A}{l}$ for a long solenoid [1], where l is the length of the solenoid and μ_0 is the permeability of free space, the peak current produced is:

$$I_{peak} = \frac{Bl}{\mu_0 N}. \qquad (4)$$

Equations (2) and (4), which correspondingly define the peak emf and current produced by the dynamo, can be used to determine the average power produced, P_{av}. This can be shown to be [1]:

$$P_{av} = \frac{1}{2}\varepsilon_{peak} I_{peak} = \frac{\pi \omega B^2 r^2 l}{2\mu_0}. \qquad (5)$$

Recharging a mobile phone

The power needed to charge a mobile phone can be up to approximately 15 W [2]. However, the dynamo produces alternating current (ac), whereas the mobile phone will need to be charged using a direct current (dc) source [3]. The current can be converted using a full wave rectifier, which typically has a maximum possible efficiency, ε, of 0.812 [4]. It will be assumed that a typical bicycle dynamo, usually used to power electric lights, will be used in this system. A typical dynamo has a neodymium magnet with a magnetic field strength of approximately 1.2T [5]. For the solenoid, it will be assumed that the radius, r, is 0.015m and the length, l, is 0.04m.

By rearranging equation (5) for the angular velocity, ω, and accounting for the dynamo efficiency, ε, the following relationship is found:

$$\omega = \frac{2\mu_0 P_{av}}{\pi \varepsilon B^2 r^2 l}. \qquad (6)$$

The relevant values, previously stated, can now be substituted into equation (6), which gives an angular velocity of 1.1 rads^{-1}. This represents the angular speed of the wheels for enough power generation to charge the mobile phone.

Using this angular velocity, the speed that the cyclist must be travelling at, $v_{cyclist}$, can be found from [1]:

$$v_{cyclist} = \omega r_{wheel}, \qquad (7)$$

where r_{wheel} is the radius of the bicycle wheel. For an average adult bike, r_{wheel} can be approximated as 0.325m [6]. Therefore, by using equation (7), it can be shown that the speed of the cyclist would need to be approximately 0.4 ms^{-1}, or equivalently 1 mph, in order to provide a high enough power to charge a mobile phone.

Discussion

This speed seems reasonably achievable for an average cyclist [7], and should be sustainable for a prolonged period of time. Therefore, it would be possible for a mobile phone to be charged, should the cyclist wish to cycle for an extended period.

The analysis showed that the speed that the cyclist must travel at depends on a range of variables. From equation (6), it can be seen that by increasing the magnetic strength of the permanent magnet and increasing the dimensions of the solenoid in the dynamo, the speed can be reduced. However, these changes must be reasonable, so that the dynamo can be easily attached to the wheel.

It is important to note that there are a variety of issues, which have not been considered, that would affect the validity of the results. For example, it has been assumed that the speed of the cyclist will be constant. However, in reality the speed would change with terrain and various other factors. It was also assumed that no energy is lost through slipping or heating in the system.

Conclusion

This paper has shown that it would be feasible to charge a mobile phone using a dynamo attached to the bicycle wheel. Although mobile phones were considered, this analysis could be extended for many other applications, such as providing enough power for a portable radio.

References

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