MODEL ANSWER
A2 PHYSICS
MAGNETIC FIELD & EM INDUCTION

14 JUNE 2007 PHY5

4. (i) When the switch is closed the wire is seen to continually "kick" out of the mercury and then return to it. When the switch of the circuit is closed, the current in the circuit produce a magnetic field around it. The interaction between the magnetic field due to the current and the magnetic field directed into the page produces a resultant magnetic field. This is called a catapult field. Using Fleming's left hand rule, the direction of the force is towards the right direction. This leads to the anticlockwise moment acting on the wire pivoting at P, pushing the wire out of the mercury. However, once the wire is out of the mercury, the current flow is disconnected and the electrical circuit is cut off, resulting in zero force and moment. The weight of the wire produces a corresponding moment at a distance from pivot, falling into the mercury and reconnect the electrical circuit.

(ii) Given the moment of the force about P produced when the switch is closed is 5.0×10^{-4} N m.
Moment = Force X Perpendicular distance
Force = Moment / Perpendicular Distance
We take midpoint of the 9.0 cm wire and a distance of 1.5 cm from the edge of the field to the pivot. The perpendicular distance is therefore
4.5 cm + 1.5 cm = 6.0 cm
Force = Moment / Perpendicular Distance
= $5.0 \times 10^{-4} / 0.06$
= $\underline{8.33 \times 10^{-3}\text{ N}}$
The force is shown to be about 8×10^{-3} N

(iii) When the switch is closed, the current in the circuit can be found by using the rearrangement of the expression $F = B I l$
Current, $I = F / B l$
$= 8.33 \times 10^{-3} / [4.0 \times 10^{-2}][0.09]$
= $\underline{2.31\text{ A}}$

5. (i) Using Fleming's right hand rule, the induced emf is in outward direction from the hub. The hub is labeled with negative sign, and the rim is labeled with positive sign. The wheel rotated clockwise and B was into the paper. This gives the current pointing out towards the rim, however the electrons move in the opposite direction to conventional current making the hub negative

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(ii) Faraday's Law states that an e.m.f. is induced in a conductor when there's a rate of change of magnetic flux linkage. The bicycle wheel is rotating at constant rate and the each spoke is moving at right angles to the magnetic field, this leads to the constant rate of flux cutting. Therefore a constant e.m.f. is induced.

(iii) Given the magnitude of the e.m.f. is **25 μV** and the Earth's magnetic flux density is **2.8×10^{-5} T**, along with the area of the circle, assuming the area of the hub is negligible, we can find the time for the wheel to complete one revolution by using the following rearrangement of the expression from Faraday's Law,

e.m.f. , E = - change of flux / time

= - dΦ/dt

E = - BA/t

t = - B A/ E

= [- 2.8 X 10^{-5} X π X 0.30^2]/ [-25 X 10^{-6}]

= 0.317 s

(b) (i) If the student turns the bicycle so that the wheel is still spinning in a vertical plane but the plane is now at 45° to the Earth's field, the magnitude of the e.m.f will be reduced by an amount of $\frac{1}{(\sqrt{2})}$. This is due to the rate of flux cutting being reduced from maximum. The change of flux is maximum when both the magnetic flux and the motion of the spoke components are perpendicular with each other.

(ii) When the student causes the wheel to accelerate, the rate of cutting of flux between the spoke and the magnetic field is increasing, resulting in the increased value of induced e.m.f.

(iii) The student rearranges the bicycle so that the wheel spins in a horizontal plane. In such arrangement, the spoke is now spinning in parallel direction with the Earth's magnetic field. Therefore there's no cutting of flux and no e.m.f. is induced. Starting from original setting to new arrangement, the induced e.m.f. reduces to zero.

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