

Solutions

Original-task marks: M1 = method, A1 = accuracy, B1 = stated reasoning point.

2.1 Use the angle between wire current and field.

$$F = BIl \sin \theta = 0.25 \text{ T} \times 3.0 \text{ A} \times 0.080 \text{ m} \times \sin 30^\circ = 0.030 \text{ N}$$

Magnitude. Parallel gives $\sin 0 = 0$, hence zero force.

2.2 Perpendicular particle force.

$$F = qvB = 1.60 \times 10^{-19} \text{ C} \times 2.0 \times 10^6 \text{ m s}^{-1} \times 0.10 \text{ T} = 3.20 \times 10^{-14} \text{ N}$$

Magnitude. Proton force is upwards. Electron force is downwards with equal magnitude. Force is perpendicular to instantaneous velocity, doing no work and leaving speed unchanged.

2.3 Multiply flux per turn by turn count.

$$N\phi = NBA \cos \alpha = 60 \times 0.20 \text{ T} \times 3.0 \times 10^{-4} \text{ m}^2 \times \cos 40^\circ = 2.76 \times 10^{-3} \text{ Wb}$$

Linkage. Cosine takes the angle to the normal; the angle to the plane is its complement and would require sine.

3.1 Convert reading change to weight change.

$$F = \Delta mg = 1.2 \times 10^{-3} \text{ kg} \times 9.81 \text{ m s}^{-2} = 1.18 \times 10^{-2} \text{ N}$$

Use equal and opposite wire/magnet forces with $F = BIl$.

$$B = \frac{F}{Il} = \frac{1.1772 \times 10^{-2} \text{ N}}{4.0 \text{ A} \times 0.060 \text{ m}} = 0.0491 \text{ T}$$

Field. Increased balance reading means force on magnets downwards, so force on wire upwards. The balance change is a mass in grams; 1.2 alone is neither converted mass nor force in newtons.

3.2 Area leaves at rate Lv , so linkage changes at $NBLv$.

$$|\mathcal{E}| = NBLv = 80 \times 0.30 \text{ T} \times 0.040 \text{ m} \times 0.15 \text{ m s}^{-1} = 0.144 \text{ V}$$

Magnitude. Linked external flux decreases; induced current, if the circuit is closed, produces field in the original field direction to oppose that decrease. Outside, linkage no longer changes, so induced e.m.f. is zero.

3.3 Alternating current produces changing magnetic field in the transmitting coil. Changing flux links the receiving coil and induces e.m.f. by Faraday's law. Steady d.c. gives constant linkage after the switching transient, so no sustained e.m.f.. Some flux misses the receiver because of separation/alignment or lack of a shared core; equal turns do not imply equal linkage rates. Use change in linkage per time, not flux alone.

$$|\mathcal{E}| = \frac{N|\phi_2 - \phi_1|}{\Delta t} = \frac{120 \times |1.0 - 5.0| \times 10^{-5} \text{ Wb}}{0.0080 \text{ s}} = 0.60 \text{ V}$$

Value. Lenz direction opposes the flux change, consistent with energy conservation rather than creating energy from nothing.