InkPhysics

ANSWER BOOK

Magnetic flux and flux linkage

Magnetic fields · Year 13

AQA 3.7.5.3 · CIE 20.5.1, 20.5.2, 20.5.3 · OCR A 6.3.3(a), 6.3.3(b), 6.3.3(d)(ii)

18 questions · 49 marks

NAVY EDITION

inkphysics.co.uk/physics/ · youtube.com/@InkPhysics

SECTION A · Warm-up

A1 $\Phi = BA$, where B is the flux density and A the area perpendicular to the field (1); unit: weber (Wb) (1). [2]

A2 $\Phi = BA = 0.20 \times 0.05$ (1)
$\Phi = 0.01$ Wb (1) [2]

A3 The product of the magnetic flux through the coil and the number of turns, $N\Phi$ (1); unit: weber-turns (1). [2]

A4 $A = \pi r^2 = \pi \times 0.040^2 = 5.0 \times 10^{-3}$ m^2 (1)
$\Phi = BA = 0.15 \times 5.0 \times 10^{-3} = 7.5 \times 10^{-4}$ Wb (1) [2]

A5 Flux linkage is proportional to $\cos\theta$, and $\cos\theta = 0.5$ at $\theta = 60°$ (1). [1]

A6 Flux linkage $N\Phi = BAN\cos\theta$ is proportional to B, A and N (1); the factor is $2 \times ½ \times 2 = 2$, so the flux linkage doubles (1). [2]

SECTION B · Standard

B1 $N\Phi = BAN = 0.15 \times 0.02 \times 200$ (1)
$N\Phi = 0.60$ Wb-turns (1) [2]

B2 $N\Phi = BAN\cos\theta = 0.30 \times 0.01 \times 100 \times \cos 60°$ (1)
$N\Phi = 0.15$ Wb-turns (1) [2]

B3 $B = \Phi/A = (8.0 \times 10^{-3})/0.04$ (1)
$B = 0.20$ T (1) [2]

B4 $N\Phi = BAN\cos\theta$, where θ is the angle between the normal to the coil and the field (1). Maximum when $\theta = 0$, with the plane of the coil perpendicular to the field (1); zero when $\theta = 90°$, with the plane of the coil parallel to the field (1). [3]

B5 $\cos\theta = N\Phi/(BAN)$ (1)
$= 0.060/(0.25 \times 1.2 \times 10^{-3} \times 400) = 0.060/0.12 = 0.50$ (1)
$\theta = 60°$ (1) [3]

B6 [3]

The normal to the coil is vertical, so the angle between the field and the normal is 90° - 66° = 24° (1)
$N\Phi = BAN\cos\theta = 49 \times 10^{-6} \times 0.030 \times 2000 \times \cos 24°$ (1)
$N\Phi = 2.7 \times 10^{-3}$ Wb-turns (1)

B7 [4]

The normal to the coil is at 90° - 35° = 55° to the field (1)
$N\Phi = BAN \cos 55° = 0.32 \times 6.0 \times 10^{-4} \times 250 \times \cos 55° = 0.028$ Wb-turns (1)
Face-on: $N\Phi = BAN = 0.048$ Wb-turns (1)
Change = 0.048 - 0.028 = 0.020 Wb-turns (1)

SECTION C · Stretch

C1 [3]

Normal parallel: $N\Phi = BAN = 0.40 \times 0.02 \times 50$ (1)
$N\Phi = 0.40$ Wb-turns (1)
Normal at 90°: $N\Phi = BAN \cos 90° = 0$ (1)

C2 [3]

$\Delta(N\Phi) = NA\Delta B$ (1)
$= 500 \times 0.008 \times (0.30 - 0.10)$ (1)
$\Delta(N\Phi) = 0.80$ Wb-turns (1)

C3 [3]

A small coil of known area and number of turns is connected to an oscilloscope (or data logger) and placed with its plane perpendicular to the field (1). The flux through it is changed, for example by pulling it out of the field quickly or by using an alternating field, inducing an emf (1). The induced emf equals the rate of change of flux linkage, so B can be calculated from the measured emf, N and A (1).

C4 [4]

For a given field the flux linkage is $BAN\cos\theta$, so the trace amplitude is proportional to NA (1)
P: $NA = 500 \times 1.5 \times 10^{-4} = 0.075$ m²-turns (1)
Q: $NA = 2000 \times 0.80 \times 10^{-4} = 0.16$ m²-turns (1)
Q gives a trace about twice as tall as P, so the student should choose Q (1)

C5 [6]

Place the search coil in the alternating field, connected to the oscilloscope, starting face-on to the field (1). The trace amplitude is proportional to the peak flux linkage only while the field's angular frequency and amplitude are unchanged, since the peak induced emf scales with both, so the supply settings must be left alone throughout (1). Rotate the coil in measured steps, recording the angle θ between the normal and the field, for example every 15° from 0 to 90° (1). Read the trace amplitude at each angle, keeping the coil at the same position in the field so it samples the same field amplitude (1). Plot the amplitude against $\cos\theta$ (1). A straight line through the origin confirms that the flux linkage is proportional to $\cos\theta$ (1).