LEPH1AN

# ANSWERS

## Chapter 1

**1.1** $6 \times 10^{-3}$ N (repulsive)

**1.2** (a) 12 cm
(b) 0.2 N (attractive)

**1.3** $2.4 \times 10^{39}$. This is the ratio of electric force to the gravitational force (at the same distance) between an electron and a proton.

**1.5** Charge is not created or destroyed. It is merely transferred from one body to another.

**1.6** Zero N

**1.8** (a) $5.4 \times 10^{6}$ N $C^{-1}$ along OB
(b) $8.1 \times 10^{-3}$ N along OA

**1.9** Total charge is zero. Dipole moment = $7.5 \times 10^{-8}$ C m along *z*-axis.

**1.10** $10^{-4}$ N m

**1.11** (a) $2 \times 10^{12}$, from wool to polythene.
(b) Yes, but of a negligible amount ( = $2 \times 10^{-18}$ kg in the example).

**1.12** (a) $1.5 \times 10^{-2}$ N
(b) 0.24 N

**1.13** Charges 1 and 2 are negative, charge 3 is positive. Particle 3 has the highest charge to mass ratio.

**1.14** (a) 30Nm$^2$/C, (b) 15 Nm$^2$/C

**1.15** Zero. The number of lines entering the cube is the same as the number of lines leaving the cube.

**1.16** (a) 0.07 μC
(b) No, only that the net charge inside is zero.

**1.17** $2.2 \times 10^{5}$ N m$^2$/C

**1.18** $1.9 \times 10^{5}$ N m$^2$/C

**1.19** (a) $-10^{3}$ N m$^2$/C; because the charge enclosed is the same in the two cases.
(b) –8.8 nC

**1.20** –6.67 nC

**1.21** (a) $1.45 \times 10^{-3}$ C
(b) $1.6 \times 10^{8}$ Nm$^2$/C

**1.22** 10 μC/m

**1.23** (a) Zero, (b) Zero, (c) 1.9 N/C

## Chapter 2

**2.1** 10 cm, 40 cm away from the positive charge on the side of the negative charge.

**2.2** $2.7 \times 10^{6}$ V

**2.3** (a) The plane normal to AB and passing through its mid-point has zero potential everywhere.

(b) Normal to the plane in the direction AB.

**2.4** (a) Zero

(b) $10^{5}$ N $C^{-1}$

(c) $4.4 \times 10^{4}$ N $C^{-1}$

**2.5** 96 pF

**2.6** (a) 3 pF

(b) 40 V

**2.7** (a) 9 pF

(b) $2 \times 10^{-10}$ C, $3 \times 10^{-10}$ C, $4 \times 10^{-10}$ C

**2.8** 18 pF, $1.8 \times 10^{-9}$ C

**2.9** (a) $V = 100$ V, $C = 108$ pF, $Q = 1.08 \times 10^{-8}$ C

(b) $Q = 1.8 \times 10^{-9}$ C, $C = 108$ pF, $V = 16.6$ V

**2.10** $1.5 \times 10^{-8}$ J

**2.11** $6 \times 10^{-6}$ J

## Chapter 3

**3.1** 30 A

**3.2** 17 Ω, 8.5 V

**3.3** 1027 °C

**3.4** $2.0 \times 10^{-7}$ Ωm

**3.5** 0.0039 $°C^{-1}$

**3.6** 867 °C

**3.7** Current in branch AB = (4/17) A,
in BC = (6/17) A, in CD = (–4/17) A,
in AD = (6/17) A, in BD. = (–2/17) A, total current = (10/17) A.

**3.8** 11.5 V; the series resistor limits the current drawn from the external source. In its absence, the current will be dangerously high.

**3.9** $2.7 \times 10^{4}$ s (7.5 h)

## Chapter 4

**4.1** $\pi \times 10^{-4}$ T $\simeq 3.1 \times 10^{-4}$ T

**4.2** $3.5 \times 10^{-5}$ T

**4.3** $4 \times 10^{-6}$ T, vertical up

**4.4** $1.2 \times 10^{-5}$ T, towards south

**4.5** 0.6 N $m^{-1}$

**4.6** $8.1 \times 10^{-2}$ N; direction of force given by Fleming's left-hand rule

**4.7** $2 \times 10^{-5}$ N; attractive force normal to A towards B

**4.8** $8\pi \times 10^{-3}$ T $\simeq 2.5 \times 10^{-2}$ T

**4.9** 0.96 N m

**4.10** (a) 1.4, (b) 1

**4.11** 4.2 cm

**4.12** 18 MHz

**4.13** (a) 3.1 Nm, (b) No, the answer is unchanged because the formula $\boldsymbol{\tau} = N\, I\, \mathbf{A} \times \mathbf{B}$ is true for a planar loop of any shape.

## Chapter 5

**5.1** 0.36 $JT^{-1}$

**5.2** (a) **m** parallel to **B**; $U = -mB = -4.8 \times 10^{-2}$ J: stable.

(b) **m** anti-parallel to **B**; $U = +mB = +4.8 \times 10^{-2}$ J; unstable.

**5.3** 0.60 $JT^{-1}$ along the axis of the solenoid determined by the sense of flow of the current.

**5.4** $7.5 \times 10^{-2}$ J

**5.5** (a) (i) 0.33 J (ii) 0.66 J

(b) (i) Torque of magnitude 0.33 J in a direction that tends to align the magnitude moment vector along **B**. (ii) Zero.

**5.6** (a) 1.28 A $m^2$ along the axis in the direction related to the sense of current via the right-handed screw rule.

(b) Force is zero in uniform field; torque = 0.048 Nm in a direction that tends to align the axis of the solenoid (i.e., its magnetic moment vector) along **B**.

**5.7** (a) 0.96 g along S-N direction.

(b) 0.48 G along N-S direction.

## Chapter 6

**6.1** (a) Along qrpq

(b) Along prq, along yzx

(c) Along yzx

(d) Along zyx

(e) Along xry

(f) No induced current since field lines lie in the plane of the loop.

**6.2** (a) Along adcd (flux through the surface increases during shape change, so induced current produces opposing flux).

(b) Along a′d′c′b′ (flux decreases during the process)

**6.3** $7.5 \times 10^{-6}$ V

**6.4** (1) $2.4 \times 10^{-4}$ V, lasting 2 s

(2) $0.6 \times 10^{-4}$ V, lasting 8 s

**6.5** 100 V

**6.6** (a) $1.5 \times 10^{-3}$ V, (b) West to East, (c) Eastern end.

**6.7** 4H

**6.8** 30 Wb

## Chapter 7

**7.1** (a) 2.20 A

(b) 484 W

**7.2** (a) $\frac{300}{\sqrt{2}} = 212.1\,\text{V}$

(b) $10\sqrt{2} = 14.1\,\text{A}$

**7.3** 15.9 A

**7.4** 2.49 A

**7.5** Zero in each case.

**7.6** 125 $s^{-1}$; 25

**7.7** $1.1 \times 10^3\ s^{-1}$

**7.8** 0.6 J, same at later times.

**7.9** 2,000 W

**7.10** $\nu = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$, i.e., $C = \frac{1}{4\pi^2 \nu^2 L}$

For $L$ = 200 μH, ν = 1200 kHz, $C$ = 87.9 pF.

For $L$ = 200 μH, ν = 800 kHz, $C$ = 197.8 pF.

The variable capacitor should have a range of about 88 pF to 198 pF.

**7.11** (a) 50 rad $s^{-1}$

(b) 40 Ω, 8.1 A

(c) $V_{Lrms} = 1437.5$ V, $V_{Crms} = 1437.5\,\text{V}$, $V_{Rrms} = 230\,\text{V}$

$$V_{LCrms} = I_{rms}\left(\omega_0 L - \frac{1}{\omega_0 C}\right) = 0$$

## Chapter 8

**8.1** (a) $C = \varepsilon_0 A / d = 8.00$ pF

$$\frac{dQ}{dt} = C\frac{dV}{dt}$$

$$\frac{dV}{dt} = \frac{0.15}{80.1 \times 10^{-12}} = 1.87 \times 10^{9}\ \text{V s}^{-1}$$

(b) $i_d = \varepsilon_0 \frac{\mathrm{d}}{\mathrm{d}t}\Phi_E$. Now across the capacitor $\Phi_E = EA$, ignoring end corrections.

Therefore, $i_d = \varepsilon_0 A \frac{\mathrm{d}\Phi_E}{\mathrm{d}t}$

Now, $E = \frac{Q}{\varepsilon_0 A}$. Therefore, $\frac{\mathrm{d}E}{\mathrm{d}t} = \frac{i}{\varepsilon_0 A}$, which implies $i_d = i = 0.15$ A.

(c) Yes, provided by 'current' we mean the sum of conduction and displacement currents.

**8.2** (a) $I_{rms} = V_{rms}\, \omega C = 6.9 \mu A$

(b) Yes. The derivation in Exercise 8.1(b) is true even if $i$ is oscillating in time.

(c) The formula $B = \frac{\mu_0}{2\pi}\frac{r}{R^2} i_d$

goes through even if $i_d$ (and therefore $B$) oscillates in time. The formula shows they oscillate in phase. Since $i_d = i$, we have $B_0 = \frac{\mu_0}{2\pi}\frac{r}{R^2} i_0$, where $B_0$ and $i_0$ are the amplitudes of the oscillating magnetic field and current, respectively. $i_0 = \sqrt{2} I_{rms} = 9.76$ μA. For $r = 3$ cm, $R = 6$ cm, $B_0 = 1.63 \times 10^{-11}$ T.

**8.3** The speed in vacuum is the same for all: $c = 3 \times 10^8$ m s$^{-1}$.

**8.4** **E** and **B** in $x$-$y$ plane and are mutually perpendicular, 10 m.

**8.5** Wavelength band: 40 m – 25 m.

**8.6** $10^9$ Hz

**8.7** 153 N/C

**8.8** (a) 400 nT, $3.14 \times 10^8$ rad/s, 1.05 rad/m, 6.00 m.

(b) $\mathbf{E} = \{ (120 \text{ N/C}) \sin[(1.05 \text{ rad/m})]x - (3.14 \times 10^8 \text{ rad/s})t]\} \, \hat{\mathbf{j}}$

$\mathbf{B} = \{ (400 \text{ nT}) \sin[(1.05 \text{ rad/m})]x - (3.14 \times 10^8 \text{ rad/s})t]\} \, \hat{\mathbf{k}}$

**8.9** Photon energy (for $\lambda = 1$ m)

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19}} \text{ eV} = 1.24 \times 10^{-6} \text{ eV}$$

Photon energy for other wavelengths in the figure for electromagnetic spectrum can be obtained by multiplying approximate powers of ten. Energy of a photon that a source produces indicates the spacings of the relevant energy levels of the source. For example, $\lambda = 10^{-12}$ m corresponds to photon energy = $1.24 \times 10^6$ eV = 1.24 MeV. This indicates that nuclear energy levels (transition between which causes $\gamma$-ray emission) are typically spaced by 1 MeV or so. Similarly, a visible wavelength $\lambda = 5 \times 10^{-7}$ m, corresponds to photon energy = 2.5 eV. This implies that energy levels (transition between which gives visible radiation) are typically spaced by a few eV.

**8.10** (a) $\lambda = (c/\nu) = 1.5 \times 10^{-2}$ m

(b) $B_0 = (E_0/c) = 1.6 \times 10^{-7}$ T

(c) Energy density in **E** field: $u_E = (1/2)\varepsilon_0 E^2$

Energy density in **B** field: $u_B = (1/2\mu_0)B^2$

Using $E = cB$, and $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$, $u_E = u_B$