



## 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<sup>-1</sup> 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)  $30 \text{ Nm}^2/\text{C}$ , (b)  $15 \text{ Nm}^2/\text{C}$
- 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  $\mu\text{C}$   
(b) No, only that the net charge inside is zero.
- 1.17**  $2.2 \times 10^5$  N m<sup>2</sup>/C
- 1.18**  $1.9 \times 10^5$  N m<sup>2</sup>/C
- 1.19** (a)  $-10^3$  N m<sup>2</sup>/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<sup>2</sup>/C
- 1.22** 10  $\mu\text{C}/\text{m}$
- 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<sup>-1</sup>  
(c)  $4.4 \times 10^4$  N C<sup>-1</sup>
- 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  $\Omega$ , 8.5 V
- 3.3 1027  $^{\circ}\text{C}$
- 3.4  $2.0 \times 10^{-7}$   $\Omega\text{m}$
- 3.5 0.0039  $^{\circ}\text{C}^{-1}$
- 3.6 867  $^{\circ}\text{C}$
- 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  $\pi \cdot 10^{-4}$  T  $\simeq$  3.1  $\cdot 10^{-4}$  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  $0.6 \text{ N m}^{-1}$   
 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  $8\pi \times 10^{-3} \text{ T} \approx 2.5 \times 10^{-2} \text{ T}$   
 4.9  $0.96 \text{ N m}$   
 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  $\tau = N I \mathbf{A} \times \mathbf{B}$  is true for a planar loop of any shape.

## CHAPTER 5

- 5.1  $0.36 \text{ JT}^{-1}$   
 5.2 (a)  $\mathbf{m}$  parallel to  $\mathbf{B}$ ;  $U = -mB = -4.8 \times 10^{-2} \text{ J}$ ; stable.  
 (b)  $\mathbf{m}$  anti-parallel to  $\mathbf{B}$ ;  $U = +mB = +4.8 \times 10^{-2} \text{ J}$ ; unstable.  
 5.3  $0.60 \text{ JT}^{-1}$  along the axis of the solenoid determined by the sense of flow of the current.  
 5.4  $7.5 \times 10^{-2} \text{ J}$   
 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 magnetic moment vector along  $\mathbf{B}$ . (ii) Zero.  
 5.6 (a)  $1.28 \text{ A m}^2$  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  $\mathbf{B}$ .  
 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  $7.5 \times 10^{-6} \text{ V}$
- 6.4 (1)  $2.4 \times 10^{-4} \text{ V}$ , lasting 2 s  
 (2)  $0.6 \times 10^{-4} \text{ V}$ , lasting 8 s
- 6.5 100 V
- 6.6 (a)  $1.5 \times 10^{-3} \text{ V}$ , (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  $1.1 \times 10^3 \text{ s}^{-1}$
- 7.7 2,000 W
- 7.8 (a)  $50 \text{ rad s}^{-1}$   
 (b)  $40 \Omega$ , 8.1 A  
 (c)  $V_{Lrms} = 1437.5 \text{ V}$ ,  $V_{Crms} = 1437.5 \text{ V}$ ,  $V_{Rrms} = 230 \text{ V}$

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

## CHAPTER 8

- 8.1 (a)  $C = \epsilon_0 A / d = 8.00 \text{ pF}$

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

$$\frac{dV}{dt} = \frac{0.15}{8 \times 10^{-12}} = 1.87 \times 10^{10} \text{ V s}^{-1}$$

- (b)  $i_d = \epsilon_0 \frac{d}{dt} \Phi_E$ . Now across the capacitor  $\Phi_E = EA$ , ignoring end corrections.

$$\text{Therefore, } i_d = \epsilon_0 A \frac{dE}{dt}$$

$$\text{Now, } E = \frac{Q}{\epsilon_0 A}. \text{ Therefore, } \frac{dE}{dt} = \frac{i}{\epsilon_0 A}, \text{ which implies } i_d = i = 0.15 \text{ A.}$$

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

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

- (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

$$B_0 = \frac{\mu_0}{2\pi} \frac{r}{R^2} i_0, \text{ where } B_0 \text{ and } i_0 \text{ are the amplitudes of the oscillating magnetic field and current, respectively. } i_0 = \sqrt{2} I_{\text{rms}} = 9.76 \mu\text{A. For } r = 3 \text{ cm, } R = 6 \text{ cm, } B_0 = 1.63 \times 10^{-11} \text{ T.}$$

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

8.4  $\mathbf{E}$  and  $\mathbf{B}$  in  $x$ - $y$  plane and are mutually perpendicular, 10 m.

8.5 Wavelength band: 40 m – 25 m.

8.6  $10^9 \text{ Hz}$

8.7 153 N/C

8.8 (a) 400 nT,  $3.14 \times 10^8 \text{ rad/s}$ , 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  $\lambda = 1 \text{ m}$ )

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

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,  $\lambda = 10^{-12} \text{ m}$  corresponds to photon energy =  $1.24 \times 10^6 \text{ eV} = 1.24 \text{ MeV}$ . 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:  $u_E = (1/2)\epsilon_0 E^2$   
 Energy density in **B** field:  $u_B = (1/2\mu_0)B^2$

Using  $E = cB$ , and  $c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$ ,  $u_E = u_B$