1. (a) (i) points plotted correctly **(1)** **(1)** (deduct one for each incorrect)
sensible scales chosen **(1)**
line of best fit **(1)**

(ii) change in momentum [or impulse] **(1)** (accept 0.8) max 4

(b) area under graph = 0.80±0.05 **(1)** ($kgms^{-1}$)

$\upsilon = \frac{\Delta m\upsilon}{m}$ **(1)** = 1.6 ms^{-1}

alternative:
state average force = 0.10(N) **(1)**
leading to correct derivation of 1.6ms^{-1} **(1)** 2

(c) (i) $\Delta m\upsilon = 0$ [or statement] **(1)** $\upsilon = 0.40ms^{-1}$ **(1)**

(ii) kinetic energy = 0.16 J **(1)**

(iii) initial kinetic energy = 0.64 (J) **(1)**
kinetic energy lost so inelastic **(1)** 5

[11]

2. (a) (i) $Q = 1.0 \times 10^{-3}$ C **(1)**

(ii) $E = 5.0 \times 10^{-2}$ J **(1)** 2

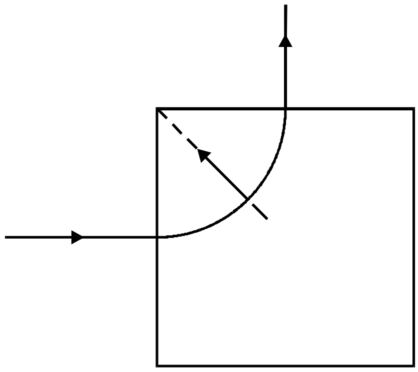
(b) (i) V = 50 V **(1)**

(ii) ($E_1 = \frac{1}{2} QV = 1.25 \times 10^{-2}$ J) $E_2 = 2.5 \times 10^{-2}$ J **(1)**

(iii) current flows (when capacitors connected together) **(1)**
(energy lost due to) heat in wires **(1)** 4

[6]

3. (a)



(uniformly) curved path continuous with linear paths at entry and exit points **(1)**
arrow marked F towards top left-hand corner **(1)** 2

(b) into (the plane of) the diagram **(1)** (not accept "downwards") 1

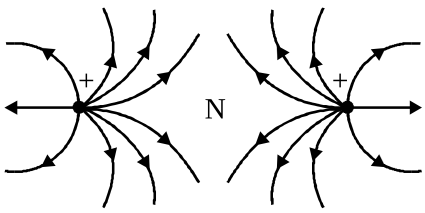
(c) $F(= BQ\upsilon) = 0.50 \times 1.60 \times 10^{-19} \times 5.0 \times 10^{6}$ **(1)**
$= 4.0 \times 10^{-13}$ N **(1)** 2

(d) B must be in opposite direction **(1)**
(much) smaller magnitude $\left(\approx \frac{1}{2000}\right)$ **(1)** 2

[7]

4. (a) (i) force per unit positive charge **(1)(1)**
[force on a unit charge **(1)** only]
vector **(1)**

(ii)

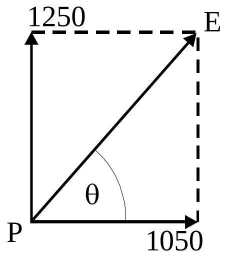


overall correct symmetrical shape **(1)**
outward directions of lines **(1)**
spacing of lines on appropriate diagram **(1)**
neutral point, N, shown midway between charges **(1)** max 6

(b) (i) $E_{AP}\left(=\dfrac{Q}{4\pi\varepsilon_0 r^2}\right) = \dfrac{2\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(0.12)^2}$ **(1)**

$= 1250 \text{ V m}^{-1}$ **(1)**

(ii) $E_{PB} = \dfrac{3\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(0.16)^2} = 1050\text{Vm}^{-1}$ **(1)**

(iii) 

(1)

allow e.c.f. from wrong numbers in (i) and (ii)

$E = \sqrt{1250^2 + 1050^2}$ **(1)** 1630Vm^{-1} **(1)**

$\theta = \tan^{-1}\left(\dfrac{1250}{1050}\right) = 50.0°$ to line PB and in correct direction **(1)** max 6

(c) (i) potential due to A is positive, potential due to B is negative **(1)**
at X sum of potentials is zero **(1)**

(ii) $\dfrac{2\times10^{-9}}{4\pi\varepsilon_0(x)} + \dfrac{-3\times10^{-9}}{4\pi\varepsilon_0(0.20-x)} = 0$ **(1)**

gives AX (= x) = 0.080m **(1)** (only from satisfactory use of potentials) 4

[16]

5. (a) attractive force between two particles (or point masses) **(1)**
proportional to product of masses and inversely proportional to square of separation [or distance] **(1)** 2

(b) (for mass, m, at Earth's surface) $mg = \dfrac{GMm}{R^2}$ **(1)**

rearrangement gives result **(1)** 2

(c) $M_{\text{moon}}\left(=\frac{gR^2}{G}\right) = \frac{1.62\times(1.74\times10^6)^2}{6.67\times10^{-11}}$ **(1)**

$= 7.35 \times 10^{22}$ kg **(1)**

$\frac{M_{\text{moon}}}{M_{\text{earth}}} = \frac{7.35\times10^{22}}{6.00\times10^{24}}$ (= 0.0123) $\therefore$ 1.23% 3

[7]

6. (a) (i) $\varepsilon_r = 6.3$ **(1)**

$\varepsilon_0 = 8.9\times10^{-12}$ (Fm^{-1}) **(1)**

$C = \frac{\varepsilon A}{d} = 4.6\times10^{-8}$ (F) **(1)**

$Q = CV = 5.5 \times 10^{-5}$ C **(1)**

(ii) $\rho = 10^{14}$(Ωm)

$R = \frac{\rho l}{A} = 1.2 \times 10^{11}\ \Omega$ **(1)** 6

(b) $I = \frac{Q}{t}$ **(1)**

$= \frac{5.5\times10^{-5}}{10800} = 5\times10^{-9}$ A **(1)** 2

(c) (as potential difference between plates increases)
electric field strength inside dielectric increases **(1)**
limit when breakdown occurs **(1)**
rapid discharge of capacitor **(1)** 3

[11]

7. (a) (i) $Q = 0.42(3)$C **(1)**

(ii) $E = 19$ J **(1)**

(iii) $I = 14$A **(1)** 3

(b) $E = \frac{1}{2}C\,(90^2 - 80^2)$ [or $E_{80} = 15$(J)] **(1)**
leading to 4.0 J 2

[5]

8. (a) (i) equation showing momentum before = momentum after **(1)**
correct use of sign **(1)**

(ii) no <u>external</u> forces (on any system of colliding bodies) **(1)** 3

(b) (i) (by conservation of momentum $m_1\upsilon_1 + m_2\upsilon_2 = 0$)

$0.25 \times 2.2 = (–)0.50\upsilon_2$ **(1)**
$\upsilon_2 = (–)1.1(0)\text{ms}^{-1}$ **(1)**

(ii) = total k.e. = $\frac{1}{2} \times 0.25 \times 2.2^2 + \frac{1}{2} \times 0.5 \times 1.1^2$ **(1)**
= 0.91J **(1)** 4

(c) (i) mass of air per second = $\rho A\upsilon$ **(1)**
correct justification, incl ref to time **(1)**

(ii) momentum per second (= $M\upsilon = \upsilon^2 A\rho$) = $\upsilon^2 A\rho$ **(1)**

(iii) force = rate of change of momentum (hence given result) **(1)**
upward force on helicopter equals (from Newton third law)
downward force on air **(1)** 5

(d) $\upsilon^2 A\rho = \frac{mg}{2}$ (for 50% support) **(1)**

$\upsilon^2 \times 180 \times 1.3 = \frac{2500 \times 9.81}{2}$ **(1)**

gives $\upsilon = 7.2\text{ms}^{-1}$ **(1)** (or 7.3, g taken as 10)
if not 50% of weight, max 1/3 provided all correct otherwise (gives 10.2) 3

[15]

9. (i) kinetic energy = mgh **(1)** = 0.37 J **(1)**

(ii) $\upsilon = \sqrt{\frac{2E}{m}}$ **(1)** = 2.22 ms^{-1} **(1)**

(iii) F_c = 2.9 N [or 3.0 N if g = 10 used] **(1)**

(iv) $T = F_c + W = 4.4$ N **(1)**

[6]

10. (a) (i) remains constant since connected to constant p.d. **(1)**

(ii) decreases because $C \propto \frac{1}{d}$ **(1)**

(iii) decreases because $Q = CV$ and C has decreased **(1)**

(iv) decreases because $E = \frac{1}{2} CV^2$ and C has decreased **(1)** 4

(b) (i) $C\left(=\frac{\varepsilon_0 A}{d}\right) = \frac{8.85\times10^{-12}\times8.0\times10^{6}}{0.75\times10^{3}}$ **(1)** ($= 9.44 \times 10^{-8}$ F)

E $\left(=\frac{1}{2}\mathrm{CV}^2\right) = \frac{1}{2} \times 9.44 \times 10^{-8} \times (200 \times 10^3)^2$ **(1)**

= 1890J **(1)**

(ii) $I\left(=\frac{Q}{t}\right) = \frac{9.44\times10^{-8}\times200\times10^{3}}{120\times10^{-6}}$ use of $Q = CV$ **(1)** use of $I = \frac{Q}{t}$ **(1)**

= 157 A **(1)** 6

[10]

11. (a) (i) $\left(g = -\frac{\Delta V}{\Delta x}\right) 19 = (-)\frac{\Delta V}{10}$ gives $\Delta V = 190$ **(1)** J kg^{-1} **(1)**

(ii) $W(= m\Delta V) = 9.0 \times 190 = 1710$J [or $mgh = 9.0 \times 19 \times 10 = 1710$J] **(1)**

(iii) on mountain, required energy would be less
because gravitational field strength is less **(1)** max 3

(b) $g \propto \frac{1}{r^2}$ (or F $\propto \frac{1}{r^2}$ or correct use of $F = \frac{GMm}{r^2}$) **(1)**

$\therefore g' = \frac{19}{2^2} = 4.75$(Nkg^{-1}) **(1)** 2

[5]

12. (i) $B\left(=\frac{\mu_0 NI}{l}\right) = \frac{4\pi\times10^{-7}\times500\times0.50}{0.10} = 3.14 \times 10^{-3}$T **(1)**

(ii) $\Phi(= BA) = 3.14 \times 10^{-3} \times 1.6 \times 10^{-4}$ **(1)** $= 5.02 \times 10^{-7}$ Wb **(1)**

[3]

13. A

[1]

14. D

[1]

15. B

[1]

16. (a) (i) equation showing momentum before = momentum after **(1)**
correct use of sign **(1)**

(ii) no <u>external</u> forces (on any system of colliding bodies) **(1)** 3

(b) (i) (by conservation of momentum $m_1\upsilon_1 + m_2\upsilon_2 = 0$)

$0.25 \times 2.2 = (-)0.50\upsilon_2$ **(1)**

$\upsilon_2 = (-)1.1(0)\text{ms}^{-1}$ **(1)**

(ii) allow e.c.f from (i)

min. stored energy = total k.e. = $\frac{1}{2} \times 0.25 \times 2.2^2 + \frac{1}{2} \times 0.5 \times 1.1^2$ **(1)**

= 0.91J **(1)** 4

(c) (i) mass of air per second = $\rho A\upsilon$ **(1)**
correct justification, incl ref to time **(1)**

(ii) momentum per second ($= M\upsilon = \upsilon^2 A\rho$) $= \upsilon^2 A\rho$ **(1)**

(iii) force = rate of change of momentum (hence given result) **(1)**
upward force on helicopter equals (from Newton third law)
downward force on air **(1)** 5

(d) $\upsilon^2 A\rho = \dfrac{mg}{2}$ (for 50% support) **(1)**

$\upsilon^2 \times 180 \times 1.3 = \dfrac{2500 \times 9.81}{2}$

gives $\upsilon = 7.2\text{ms}^{-1}$ **(1)** (or 7.3, g taken as 10)
if not 50% of weight, max 1/3 provided all correct otherwise (gives 10.2) 3

[15]

17. (a) (i) *free:* system displaced and left to oscillate **(1)**

(ii) *forced:* oscillation due to (external) periodic driving force
[or oscillation at the frequency of another vibrating system] **(1)** 2

(b) (i) $k = \dfrac{3000}{5.0 \times 10^{-2}} = 6.0 \times 10^4\ \text{Nm}^{-1}$ **(1)**

(ii) $T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{9000}{g \times 6.0 \times 10^4}}$
giving 0.78 s **(1)** 3

(c) (i) $t = \dfrac{s}{\upsilon} = \dfrac{16}{20} = 0.80$ s **(1)**

(ii) time ≅ period of free oscillations, resonance **(1)**
i.e. large amplitude oscillations **(1)** 3

[8]

18. (i) $1000\ \text{km hr}^{-1} = \dfrac{1000 \times 10^3}{3600}\ \text{ms}^{-1}$

flux cut per second = B × area swept out per second

$\left[\text{or } 4.5 \times 10^{-5} \times 42 \times \dfrac{10^4}{36}\right]$ **(1)**

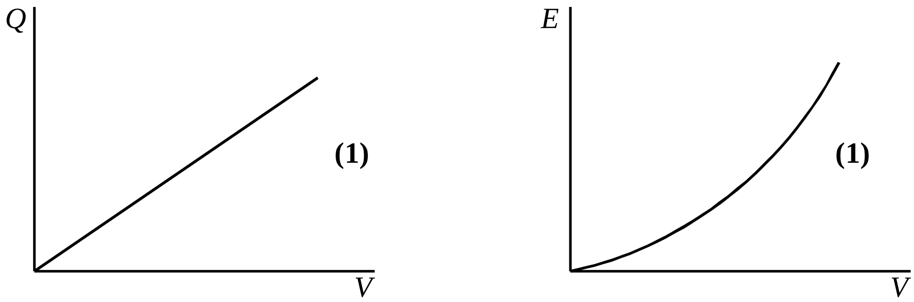
= 0.52Wb **(1)**

(ii) induced e.m.f. equals flux cut per second [or equation and symbols defined] **(1)**
$\therefore E = 0.52\text{V}$ **(1)**

(iii) direction of p.d. reversed **(1)**

[6]

19. (a)



capacitance [or charge per volt or Q/V] **(1)** 3

(b) (i) $Q = CV$ (=0.68 × 6.0)=4.1C **(1)**

(ii) $E\left(= \frac{1}{2}QV = \frac{1}{2} \times 4.1 \times 6.0\right) = 12\text{J}$ **(1)** 2

[5]

20. (i) $f = \frac{3000}{60} = 50$ (Hz) **(1)**
$\omega\ (= 2\pi f) = 314\ (\text{rad s}^{-1})$ **(1)**

(ii) $\alpha = (r\omega^2) = 95 \times 10^{-3} \times 314^2 = 9.4 \times 10^3\ \text{ms}^{-2}$ **(1)**

(iii) (inwards) towards axis of rotation **(1)** 5

[5]

ð**21.** (a) vibrations are forced when periodic force is applied **(1)**
frequency determined by frequency of driving force **(1)**
resonance when frequency of applied force = natural frequency **(1)**
when vibrations of large amplitude produced
[or maximum energy transferred at resonance] **(1)** max 3

(b) (i) damping when force opposes motion [or damping removes energy] **(1)**

(ii) damping reduces sharpness of resonance

[or reduces amplitude at resonant frequency] **(1)** 2

[5]

22. (a)

________	N kg^{-1}	electric field strength	N C^{-1} or V m^{-1}	**(1)**
gravitational constant	N m^2 kg^{-2}	________	________	**(1)**
mass	kg	charge	C	**(1)**
distance (from mass to point)	m	distance (from charge to point)	m	**(1)**

4

(b) (i) none **(1)**

both F_E and $F_G \propto \frac{1}{r^2}$ (hence both reduced to $\frac{1}{4}$ [affected equally] **(1)**

(ii) charge on B must be doubled **(1)** 3

[7]

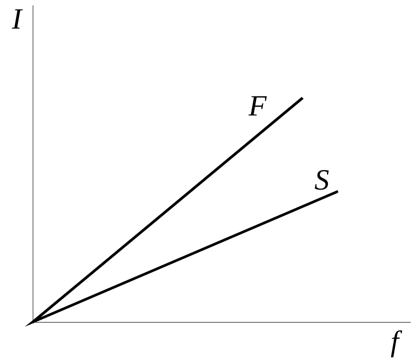
23. (a) arrow towards left **(1)** 1

(b) $I\left(=\frac{E}{R}\right) = \frac{2.0}{0.40} = 5$ (A) **(1)**

$F(= BIl) = 0.080 \times 5 \times 0.060 = 0.024$ N**(1)** 2

[3]

24. (a)



(i) *F* is straight line through 0 **(1)**

(ii) *S* is straight line through 0 with smaller (half) gradient **(1)**

(iii) $I = \dfrac{V}{X_c}$ **(1) =** $\dfrac{V}{\left(\frac{1}{2}\pi fC\right)} = 2\pi fCV$ **(1)**

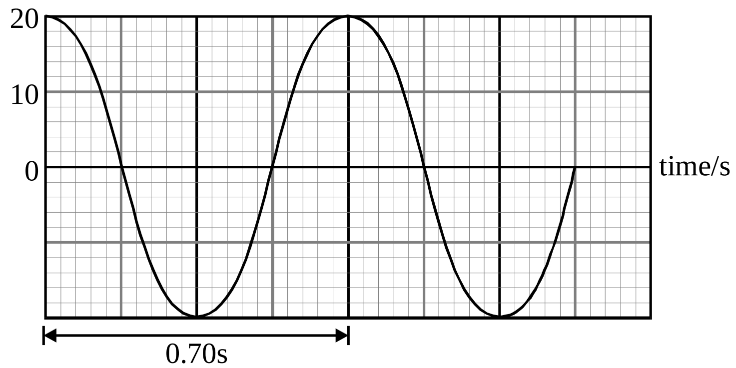
$\therefore$ gradient is $2\pi CV$ and $C = \dfrac{\text{gradient}}{2\pi V}$ **(1)** 5

(b) $X_C = \dfrac{V_{\text{r.m.s.}}}{I_{\text{r.m.s.}}} = \dfrac{7.8}{90 \times 10^{-3}}$ **(1)** 87Ω **(1)** 2

[7]

25. (a) (i) $k = \dfrac{2.0}{50 \times 10^{-3}}$ **(1)** $T = 2\pi\sqrt{\dfrac{0.5}{40}}$ **(1)** = 0.70 s

(ii)



a correct (= 20mm) **(1)**

$x = \pm 20$ mm at $t = 0$ **(1)**

T correct (= 0.70 s)**(1)** 5

(b) (i) vibrates at 0.5 Hz with low amplitude **(1)**

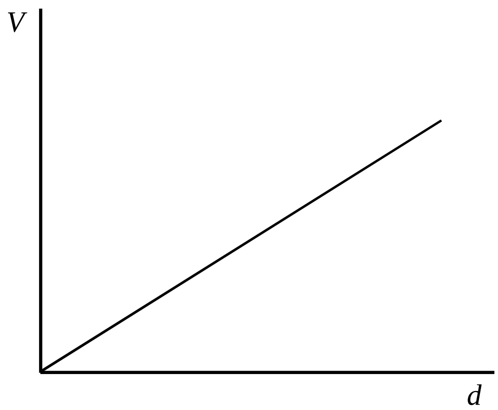
(ii) vibrates with high amplitude **(1)**
at natural frequency **(1)**
resonates **(1)** max 3

[8]

26. (a) (i) parallel (near centre), perpendicular to and touching plates **(1)**
arrows away from positive plate **(1)**

$E\left(=\frac{V}{d}\right) = \frac{1500}{0.020}$ **(1)** = 75 × 10^4 V m^{-1} [or N C^{-1}]

(ii)



straight line from origin **(1)** 5

(b) (i) $F(=Ee) = 7.5 \times 10^4 \times 3 \times 10^{-9}$ **(1)**
$= 2.25 \times 10^{-4}$ (N) **(1)**

$\alpha\left(=\frac{F}{m}\right) = \frac{2.25\times10^{-4}}{5.0\times10^{-4}}$ = 0.45 (m s^{-2}) **(1)**

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2\times10\times10^{-3}}{0.45}}$ (= 0.20s) **(1)**

ball towards positive plate **(1)**

(ii) on contact, acquires same charge as plate **(1)**
hence repelled away [or attracted to other plate] **(1)**
at other plate, charge change again, process repeats **(1)** max 6

(c) no (resultant) force **(1)**
charge must be moving for magnetic force
[or weight balanced by tension] **(1)** 2

[13]

27. (a) (i) –31 MJ kg^{-1} **(1)**

(ii) increase in potential energy = $m\Delta V$ **(1)**
$= 1200 \times (62 - 21) \times 10^6$ **(1)**
$= 4.9 \times 10^{10}$ J **(1)** 4

(b) (i) $g = -\dfrac{\Delta V}{\Delta x}$ **(1)**

(ii) g is the gradient of the graph = $\dfrac{62.5\times10^6}{4\times6.4\times10^6}$ **(1)**
$= 2.44$ N kg^{-1} **(1)**

(iii) $g \propto \dfrac{1}{R^2}$ and R is doubled **(1)**

expect g to be $\dfrac{9.81}{4}$ = 2.45 N kg–^{1} **(1)**

[*alternative (iii)*

$g \propto \dfrac{1}{R^2}$ and R is halved **(1)**

expect g to be $2.44 \times 4 = 9.76$ N kg^{-1} **(1)**] 5

[9]

28. (a) output voltage proportional to current in circuit (*)
resistance of resistor is independent of frequency (*)
reactance of capacitor falls as frequency rises (*)
at low frequencies, little current so output voltage small (*)
at high frequencies, max current flows so output voltage high (*)
limited only by resistance (*)
(*) **(1) (1) (1)** 3

(b) $R\left(=\dfrac{V_{\text{out}}}{I_{\text{r.m.s.}}}\right) = \dfrac{5.0}{0.5\times10^{-3}}$ = 10 kΩ **(1)** 1

(c) V = 2.5 V from graph **(1)** $I = \dfrac{2.5}{10 \times 10^3}$ = 0.25 mA **(1)**

$Z\left(= \dfrac{V}{I_{\text{r.m.s.}}}\right) = \dfrac{5.0}{2.5 \times 10^{-4}}$ = 20 kΩ **(1)**

$Z\left(= \sqrt{R^2 + X^2}\right) = \sqrt{\left(10^4\right)^2 + \left(\dfrac{1}{2\pi \times 900 \times C}\right)^2}$ **(1)** = 2.0 × 10^4 **(1)**

(gives C =1.0 × 10^{-8} F) max 3

(d) $P = \dfrac{V^2}{R}$ **(1)** so $\dfrac{P}{2} = \dfrac{\left(\dfrac{V_{\text{out}}}{\sqrt{2}}\right)^2}{R}$ **(1)**

$\dfrac{5}{\sqrt{2}}$ = 3.54 V which corresponds to a frequency of 1.6kHz

(± 0.2 kHz) **(1)** max 2

[9]

29. B

[1]

30. C

[1]

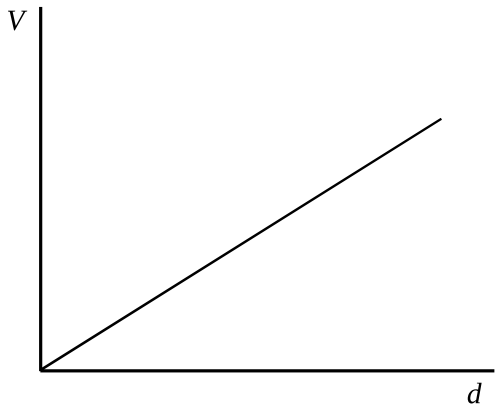
31. C

[1]

32. (a) (i) parallel (near centre), perpendicular to and touching plates **(1)**
arrows away from positive plate **(1)**

$E\left(= \dfrac{V}{d}\right) = \dfrac{1500}{0.020}$ **(1)** = 7.5 × 10^4 V m^{-1} [or N C^{-1}] **(1)**

(ii)



straight line from origin **(1)** 5

(b) (i) $F(= Ee) = 7.5 \times 10^4 \times 3 \times 10^{-9}$ **(1)**

$= 2.25 \times 10^{-4}$ (N) **(1)**

$a\left(=\frac{F}{m}\right) = \frac{2.25 \times 10^{-4}}{5.0 \times 10^{-4}} = 0.45(\text{m s}^{-2})$ **(1)**

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 10 \times 10^{-3}}{0.45}}$ (= 0.20 s) **(1)**

ball towards positive plate **(1)**

(ii) on contact, acquires same charge as plate **(1)**
hence repelled away [or attracted to other plate] **(1)**
at other plate, charge change again, process repeats **(1)**
not SHM, valid explanation **(1)** 8

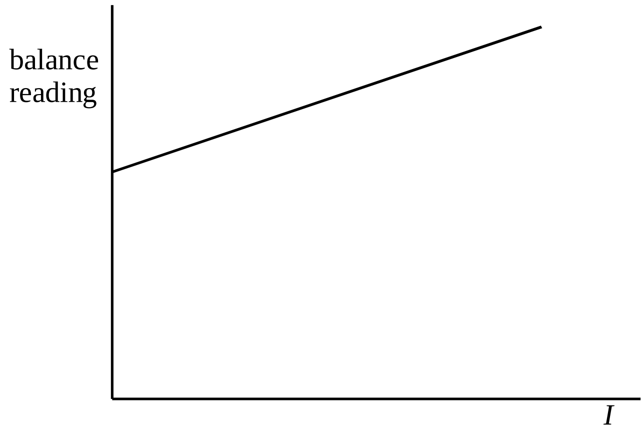
(c) no (resultant) force **(1)**
charge must be moving for magnetic force
[or weight balanced by tension] **(1)** 2

[15]

33. (a) (i) interaction between current and *B*-field gives force on wire **(1)**
equal and opposite force on magnet (down) **(1)**

(ii) force on wire must be up **(1)**
$\therefore$ current right to left **(1)**
by left hand rule **(1)**

(iii) (force = $BIl = mg$ = change in mass × 9.8)
$B \times 5.0 \times 0.060 = 1.54 \times 10^{-3} \times 9.8$ **(1)**
$B = 0.050$ T [50.3 mT] **(1)** max 6

(b) 

straight line **(1)**
intercept, upward slope **(1)** 2

[8]

34. (a) momentum before collision = momentum after collision **(1)**
provided no external force acts **(1)** 2

(b) (i) $p = m\upsilon$ **(1)**

$10 \times 10^{-3} \times 200 = 2.(0)$ **(1)** kg ms^{-1} (Ns) **(1)**

(ii) total mass after collision = 0.40 kg **(1)**
$0.40\ \upsilon = 2.0$ gives $\upsilon = 5.(0)\ ms^{-1}$ **(1)** (allow e.c.f. from (i)) 4

(c) (i) kinetic energy = $\frac{1}{2} mv^2$

$$= \frac{10 \times 10^{-3} \times 200^2}{2}$$ **(1)** (= 200 J)

(ii) kinetic energy = $\frac{0.40 \times 5.0^2}{2}$ **(1)** (= 5.0 J)

(iii) $\Delta Q = 200 - 5 = 195$ (J) = $mc\Delta\theta$ **(1)**

$$\Delta\theta = \frac{195}{10 \times 10^{-3} \times 250} = 78 \text{ K}$$ **(1)** (allow e.c.f. for incorrect ΔQ) 5

(d) kinetic energy lost (= potential energy gained) = mgh **(1)**

$h = \frac{5}{0.40 \times 9.8}$ 1.3 m **(1)** 2

[13]

35. (a) kinetic energy is not conserved **(1)** 1

(b) (i) ($p = mv$ gives) $p = 0.12 \times 18 = 2.2$ N s **(1)** (2.16 N s)

(ii) $p = 0.12 \times (–15) = –1.8$ N s **(1)**

(iii) $\Delta p = 2.2 – (–1.8) = 4.0$ N s (3.96 N s) **(1)**
(allow e.c.f. from(i) and(ii))

(iv) ($F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{3.96}{0.14}$ **(1)**
= 28 N **(1)** (28.3 N)
(allow e.c.f from(iii))

(v) ($E_k = ½mv^2$ gives) $E_k = 0.5 \times 0.12 \times (18^2 – 15^2) = 5.9$ J **(1)** 6

[7]

36. (a) 360 N **(1)** 1

(b) (i) ($E_p = mgh$ gives) $E_p = 720 \times 0.6 = 4.3 \times 10^2$ J **(1)**

(ii) $T \cos 20°$ **(1)** = 360(N)
T = 380 N **(1)**
(allow e.c.f from(a)) 3

(c) (potential energy) changes **(1)**
centre of mass/gravity moves upwards **(1)** 2
QWC

[6]

37. D

[2]

38. C

[2]

39. B

[2]

40. A

[2]

41. D

[2]

42. C

[2]

43. B

[2]

44. B

[2]

45. A

[2]

46. (a) use of $mg = ke$ gives $k = \dfrac{0.20 \times 9.81}{3.5 \times 10^{-2}}$ **(1)**

$= 56$ N m^{-1} **(1)** [or kg s^{-2}] 2

(b) (i) 28 (N m^{-1}) **(1)** (unit to be given in either (a) or (b))
(allow C.E. from (a))

(ii) (use of $T = 2\pi\sqrt{\dfrac{m}{k}}$ gives) $T = 2\pi\sqrt{\dfrac{0.50}{28}}$ = 0.84 (s) **(1)**
(allow C.E. for value of k from (b)(i))

number of oscillations per minute = $\dfrac{60}{0.84}$ = 71 **(1)**
(allow C.E. from (b)(ii)) 3

[5]

47. (a) graph to show:
straight line from origin **(1)**
<u>end point</u> at 4.5 (V), 9.0 (μF) **(1)** 2

(b) (i) $\Delta W = V\,\Delta Q$ explained **(1)**
energy stored or total work done in charging = area under graph or charge × average voltage **(1)**

energy stored = work done (= ½QV) **(1)**

(ii) Q = 2.0 ×1.5 = 3.0 (μC) **(1)**
E (=½ QV) = ½ × 3.0 × 10^{-6} × 1.5 = 2.25 × 10^{-6}J **(1)**
[or E = (½CV^2 = ½ × 2.0 × 10^{-6} × 1.5^2 = 2.25 × 10^{-6} J] 5

[7]

48. (a) (i) (force) to the right **(1)**

(ii) electrons accelerate or speed increases **(1)** 2

(b) (i) sketch to show path <u>curving</u> upwards in the field
(must not become vertical) **(1)**

(ii) horizontal component of velocity is unchanged **(1)**
vertical or upwards acceleration (or force) **(1)**
parabolic path described (or named) **(1)** max 3
QWC

[5]

× 1.5 = 2.25 × 10^{-6}J **(1)**
[or E = (½CV^2 = ½ × 2.0 × 10^{-6} × 1.5^2 = 2.25 × 10^{-6} J] 5

[7]

49. (a) (i) length of card
[or distance travelled by trolley A] **(1)**
time at which first light gate is obscured
[or time taken to travel the distance] **(1)**

(ii) time at which second light gate is obscured
[or distance travelled after collision <u>and</u> time taken] **(1)** 3

(b) momentum = mass × velocity **(1)**
mass of each trolley **(1)**
(check whether) $p_{\text{initial}} = p_{\text{final}}$ **(1)** max 2

(c) incline the ramps **(1)**
until component of weight balances friction **(1)**
[or identify where the friction occurs **(1)**
sensible method of reducing **(1)**] 2

[7]

50. B

[2]

51. B

[2]

52. D

[2]

53. B

[2]

54. D

[2]

55. A

[2]

56. C

[2]

57. C

[2]

58. D

[2]

59. A

[2]

60. (a) forced vibrations or resonance **(1)** 1

(b) reference to natural frequency (or frequencies) of structure **(1)**
driving force is at same frequency as natural frequency of structure **(1)**
resonance **(1)**
large <u>amplitude</u> vibrations produced or large energy transfer to structure **(1)**
could cause damage to structure [or bridge to fail] **(1)** max 4

(c) stiffen the structure (by reinforcement) **(1)**
install dampers or shock absorbers **(1)**
[or other acceptable measure e.g. redesign to change natural frequency
or increase mass of bridge or restrict number of pedestrians] 2

[7]

61. (a) $Q = CV$ **(1)**
$(= 4.7 \times 10^{-6} \times 6.0) = 28 \times 10^{-6}$ C or 28 μC **(1)** 2

(b) $E = \frac{1}{2}CV^2$ **(1)**
$= \frac{1}{2} \times 4.7 \times 10^{-6} \times 2.0^2$ **(1)**
$= 9.4 \times 10^{-6}$ J **(1)**
[or $E = \frac{1}{2}QV$ **(1)**
$= \frac{1}{2} \times 9.4 \times 10^{-6} \times 2.0$ **(1)**
$= 9.4 \times 10^{-6}$ J **(1)**] 3

(c) time constant is time taken for V to fall to $\frac{V_o}{e}$ **(1)**
$\therefore V$ must fall to 2.2 V **(1)**
time constant = 32 ms **(1)**
[or draw tangent at t = 0 **(1)**
intercept of tangent on t axis is time constant **(1)**
accept value 30 - 35 ms **(1)**]
[or $V = V_0 \exp(-t/RC)$ or $Q = Q_0 \exp(-t/RC)$ **(1)**
correct substitution **(1)**
time constant = 32 ms **(1)**] 3

(d) time constant = RC **(1)**
$R = \frac{32 \times 10^{-3}}{4.7 \times 10^{-6}}$ = 6800 Ω **(1)**
(allow C.E. for value of time constant from (c)) 2

[10]

62. (a) θ = 90° (or 270° or $\frac{\pi}{2}$ or $\frac{3\pi}{2}$) **(1)** 1

(b) $\Phi = BA \cos\theta$ **(1)**
$= 2.5 \times 10^{-3} \times 35 \times 10^{-3} \times 20 \times 10^{-3} \times \cos 30° = 1.5 \times 10^{-6}$ Wb **(1)** 2

(c) $\Phi_{max} = 2.5 \times 10^{-3} \times 35 \times 10^{-3} \times 20 \times 10^{-3}$ (Wb) **(1)** $(= 1.75 \times 10^{-6})$
flux linkage = $650 \times 1.75 \times 10^{-6} = 1.1(4) \times 10^{-3}$ (Wb turns) **(1)** 2

[5]

63. (a) $^{212}_{83}\text{Bi} \rightarrow {}^{4}_{2}\alpha + {}^{208}_{81}\text{Tl}$
either **(1)** (for both atomic mass numbers, 4 and 208)
and **(1)** (for both atomic numbers, 2 and 81)
[or **(1)** for $^{208}_{81}\text{Tl}$ and incorrect α] 2

(b) (i) $E_k = (\frac{1}{2}mv^2) = 6.1 \times 10^6 \times 1.6 \times 10^{-19}$ (J) **(1)**
substitution for $m = 4.0 \times 1.66 \times 10^{-27}$ (kg) **(1)**
$v = \left(\frac{2 \times 6.1 \times 10^6 \times 1.6 \times 10^{-19}}{4.0 \times 1.66 \times 10^{-27}}\right)^{1/2}$ **(1)** $(= 1.7 \times 10^7 \text{ m s}^{-1})$

(ii) correct use of conservation of momentum $m_{Tl}\, v_{recoil} = m_\alpha\, v$ **(1)**
substitution of m_{Tl} = 208u **(1)**
(allow C.E. for mass = 208)
$v_{recoil} = \dfrac{4\times1.7\times10^7}{208} = 3.3\times10^5$ m s^{-1} **(1)**
(allow C.E. for value of *v*) 6

[8]

64. (a) (i) uud **(1)**

(ii) $u\bar{d}$ **(1)** 2

(b) (i) $\dfrac{mv^2}{r} = Bev$ [or $r = \dfrac{mv}{Be}$] **(1)**
$m = 1.67\times10^{-27}$ **(1)**
$r\left(=\dfrac{mv}{Be}\right) = \dfrac{1.67\times10^{-27}\times1.5\times10^7}{0.16\times1.6\times10^{-19}}$ **(1)**
= 0.98 m **(1)**

(ii) pion path more curved than proton path **(1)**

(iii) path more curved
[or radius (of path) smaller] **(1)**
for both paths **(1)** 7

[9]

65. (a) gravity or force acts towards centre **(1)**
force acts at right angles to velocity or direction of motion
[or velocity is tangential] **(1)**
no movement in direction of force **(1)**
no work done so no change of kinetic energy so no change in speed **(1)** 3

(b) (i) $B = (56^2 + 17^2)^{½} = 59$ μT **(1)**

(ii) $\tan\theta = \frac{17}{56}$ **(1)**

$\theta = 17°$ **(1)** (± 1°)

(iii) rod sweeps out or cuts (magnetic) flux
[or rod cuts field] **(1)** 4

[7]

66. (a) kinetic energy changes to potential energy **(1)**
potential energy calculated by measuring *h* **(1)**
equate kinetic energy to potential energy to find speed **(1)**
[or use *h* to find *s* **(1)**
use $g \sin\theta$ for *a* **(1)**
use $v^2 = u^2 + 2as$ **(1)**]
[or use *h* to find *s* **(1)**
time to travel *s* and calculate v_{av} **(1)**
$v = 2v_{av}$ **(1)**] 3

(b) (i) $p(= mv) = 0.5(0) \times 0.4(0) = 0.2(0)$ **(1)** N s(or kg m s^{-1}) **(1)**

(ii) (use of $m_p v_p = m_t v_t$ gives) $0.002(0)\ v = 0.2(0)$ **(1)**
$v = 100$ m s^{-1} **(1)** 4

(c) (i) kinetic energy is not conserved **(1)**

(ii) initial kinetic energy = $\frac{1}{2} \times 0.002 \times 100^2 = 10$ (J) **(1)**
final kinetic energy = $\frac{1}{2} \times 0.5 \times 0.4^2 = 0.040$ (J) **(1)**
hence change in kinetic energy **(1)**
(allow C.E. for value of *v* from (b)) 4

[11]

67. (a) displacement is a vector **(1)**
ball travels in opposite directions **(1)** max 1

(b) velocity is rate of change of displacement
average speed is rate of change of distance
velocity is a vector [or speed is a scalar)
velocity changes direction any two **(1) (1)** 2

(c) (i) $a = \dfrac{(-6.0-8.0)}{0.10}$ **(1)**

$= (-)140.\text{m s}^{-1}$ **(1)**

(allow C.E. for incorrect values of Δv)

(ii) $F = 0.45 \times (-)\ 140 = (-)\ 63\text{N}$ **(1)**

(allow C.E for value of *a)*

(iii) away from wall **(1)**
at right angles to wall **(1)**
[or back to girl **(1) (1)**]
[or opposite to direction of velocity at impact **(1) (1)**] 5

[8]

68. B

[2]

69. A

[2]

70. B

[2]

71. C

[2]

72. A

[2]

73. B

[2]

74. A

[2]

75. B

[2]

76. (a) (use of $T = 2\pi\sqrt{\frac{l}{g}}$ gives) $T = 2\pi\sqrt{\frac{0.80}{9.81}}$ **(1)**

$= 1.8$ s **(1)** 2

(b) $mgh = ½\, mv^2$ **(1)**

$v = \sqrt{(2 \times 9.81 \times 20 \times 10^{-3})}$ **(1)** (= 0.63 m s^{-1})

$v_{\text{max}} = 2\pi fA = \frac{2\pi A}{T}$ **(1)**

$A = \frac{0.63 \times 1.8}{2\pi}$ **(1)** (= 0.18m)

[or by Pythagoras $A^2 + 780^2 = 800^2$

gives $A = \sqrt{(800^2 \text{-} 780^2)}$ **(1)** (= 180 mm)

(or equivalent solution by trigonometry **(1)** **(1)**)

$v_{max} = 2\pi fA$ or $= \frac{2\pi A}{T}$ **(1)**

$= \frac{2\pi \times 0.18}{1.8}$ **(1)** (= 0.63 m s^{-1}) 4

(c) tension given by F, where $F - mg = \frac{mv^2}{l}$ **(1)**

$F = 25 \times 10^{-3} \left(9.81 + \frac{0.63^2}{0.8}\right) = 0.26$ N **(1)** 2

[8]

77. (a) (i) $E\ (= \frac{Q}{4\pi\varepsilon_0 r^2}) = \frac{29 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times (1.15 \times 10^{-10})^2}$ **(1)**

$= 3.15 \times 10^{12}$Vm^{-1} (or (NC^{-1}) **(1)**

(ii) $V(= -\frac{GM}{r}) = (-)\frac{6.67 \times 10^{-11} \times 63 \times 1.66 \times 10^{-27}}{1.15 \times 10^{-10}}$ **(1)**

$= (-)\ 6.07 \times 10^{-26}$ **(1)** – sign and J kg^{-1} 5

(b) arrow pointing to the right **(1)** 1

[6]

78. (a) (i) acceleration **(1)**

(ii) both represent acceleration of free fall
[or same acceleration] **(1)**

(iii) height/distance ball is dropped from above the ground
[or displacement] **(1)**

(iv) moving in the opposite direction **(1)**

(v) kinetic energy is lost in the collision
[or inelastic collision] **(1)** 5

(b) (i) $v^2 = 2 \times 9.81 \times 1.2$ **(1)**
$v = 4.9$ m s^{-1} **(1)** (4.85 m s^{-1})

(ii) $u^2 = 2 \times 9.81 \times 0.75$ **(1)**
$u = 3.8$ m s^{-1} **(1)** (3.84 m s^{-1})

(iii) change in momentum = 0.15 × 3.84 – 0.15 × 4.85 **(1)**
= $^{-1}$.3 kg m s^{-1} **(1)** (1.25 kg m s^{-1})

(allow C.E. from (b) (i) and (b)(ii))

(iv) $F = \frac{1.3}{0.10}$ **(1)**

= 13 N **(1)**

(allow C.E. from (b)(iii)) 8

[13]

79. A

[2]

80. B

[2]

81. A

[2]

82. B

[2]

83. A

[2]

84. D

[2]

85. C

[2]

86. C

[2]

87. D

[2]

88. A

[2]

89. (a) period = 24 hours or equals period of Earth's rotation **(1)**
remains in fixed position relative to surface of Earth **(1)**
equatorial orbit same angular speed as Earth or equatorial surface **(1)** max 2

(b) (i) $\frac{GMm}{r^2} = m\omega^2 r$ **(1)**

$T = \frac{2\pi}{\omega}$ **(1)**

$r\left(=\frac{GMT^2}{4\pi^2}\right)^{1/3} = \left(\frac{6.67\times10^{-11}\times6\times10^{24}\times(24\times3600)^2}{4\pi^2}\right)^{1/3}$ **(1)**

(gives $r = 42.3 \times 10^3$ km)

(ii) $\Delta V = GM\frac{1}{R} - \frac{1}{r}$ **(1)**

$= 6.67 \times 10^{-11} \times 6 \times 10^{24} \times \left(\frac{1}{6.4\times10^6} - \frac{1}{4.23\times10^7}\right)$

$= 5.31 \times 10^7$ (J kg^{-1}) **(1)**

$\Delta E_p = m\Delta V$ (= $750 \times 5.31 \times 10^7$) = 3.98×10^{10} J **(1)**
(allow C.E. for value of ΔV)

[alternatives:
calculation of $\frac{GM}{R}$ (6.25×10^7) or $\frac{GM}{r}$ (9.46×10^6) **(1)**
or calculation of $\frac{GMm}{R}$ (4.69×10^{10}) or $\frac{GMm}{r}$ (7.10×10^9) **(1)**

calculation of both potential energy values **(1)**
subtraction of values or use of $m\Delta V$ with correct answer **(1)** 6

[8]

90. (a) units: F - newton (N), B - tesla (T) or weber metre^{-2} (Wb m^{-2}),
I - ampere (A), l - metre (m) **(1)**
condition: I must be perpendicular to B **(1)** 2

(b) (i) mass of bar, $m = (25 \times 10^{-3})^2 \times 8900 \times l$ **(1)** (= $5.56l$)
weight of bar (= mg) = $54.6l$ **(1)**
$mg = BIl$ or weight = magnetic force **(1)**
$54.6l = B \times 65 \times l$ gives $B = 0.840$ T **(1)**

(ii) arrow in correct direction (at right angles to I, in plane of bar) **(1)** 5

[7]

91. (a) (i) $r = 0.012$ (m)
(use of $v = 2\pi fr$ gives) $v = 2\pi 50 \times 0.012$ **(1)**
$= 3.8$ m s^{-1} **(1)** (3.77 m s^{-1})

(ii) correct use of $a = \dfrac{v^2}{r}$ or $a = \dfrac{3.8^2}{0.012}$ **(1)**

$= 1.2 \times 10^3$ m s^{-2} **(1)**

[or correct use of $\alpha = \omega^2 r$]
(allow C.E. for value of v from (i)) 5

(b) panel resonates **(1)**
(because) motor frequency = natural frequency of panel **(1)** 2
QWC 2

[7]

92. (a) $mg = T \cos 6$ **(1)**
$F = T \sin 6$ **(1)**
hence $F = mg \tan 6$ **(1)**
[or correct use of triangle:
(1) for sides correct, **(1)** for 6°, **(1)** for tan 6 = F/mg
or $F\Delta x = mg\,\Delta h$, $\tan\theta = \dfrac{\Delta h}{\Delta x}$ $\tan 6° = \dfrac{F}{mg}$ 3

(b) (i) (use of $E = \dfrac{V}{d}$ gives) $E = \dfrac{4200}{60 \times 10^{-3}} = 7.0 \times 10^4$ V m^{-1}

(ii) (use of $Q = \dfrac{F}{E}$ gives) $Q \left(= \dfrac{mg \tan 6}{E} \right) = \dfrac{21 \times 10^{-4} \times 9.8 \tan 6}{7 \times 10^4}$
$= 3.1 \times 10^{-9}$ C
(allow C.E. for value of E from (i)) 3

[6]

93. C

[2]

94. A

[2]

95. D

[2]

96. A

[2]

97. C

[2]

98. C

[2]

99. C

[2]

100. A

[2]

101. C

[2]

102. (a)

quantity	**SI unit**	
(gravitational potential)	J kg^{-1} or N m kg^{-1}	scalar
(electric field strength)	N C^{-1} or V m^{-1}	vector
(magnetic flux density	T or Wb m^{-2} or N A^{-1} m^{-1}	vector

6 entries correct **(1)** **(1)** **(1)**
4 or 5 entries correct **(1)** **(1)**
2 or 3 entries correct **(1)** 3

(b) (i) $mg = EQ$ **(1)**

$$E\left(\frac{mg}{Q} = \frac{4.3\times10^{-9}\times9.81}{3.2\times10^{-12}}\right) = 1.32 \times 10^4 \text{ (V m}^{-1}\text{)} \quad \textbf{(1)}$$

(ii) positive **(1)** 3

[6]

103. (a) deflects one way **(1)**
then the other way **(1)** 2

(b) (i) acceleration is less than g [or reduced] **(1)**
suitable argument **(1)** (e.g. correct use of Lenz's law)

(ii) acceleration is less than g [or reduced] **(1)**
suitable argument **(1)** (e.g. correct use of Lenz's law) 4

(c) magnet now falls at acceleration g **(1)**
emf induced **(1)**
but no current **(1)**
no energy lost from circuit **(1)**
[or no opposing force on magnet, or no force from magnetic field or no magnetic field produced] 3

QWC 2

[9]

104. (a) Q (= CV = 330 × 9.0) = 2970 (μC) **(1)**
E (= ½QV) = ½ _ 2.97 × 10^{-3} × 9.0 = 1.34 × 10^{-2}J **(1)**
[or E (= ½CV^2) = ½ × 300 × 10^{-6} × 9.0^2 **(1)** = 1.34 × 10^{-2}J **(1)**] 2

(b) time constant (= RC) = 470 × 103 × 330 × 10^{-6} = 155 s **(1)** 1

(c) $Q\left(= Q_0 e^{-t/RC}\right) = 2970 \times e^{-60/155}$
= 2020 (μC)
(allow C.E. for time constant from (b))

$$V\left(= \frac{Q}{C}\right) = \frac{2020}{330} = 6.11\text{V} \quad \textbf{(1)}$$

(allow C.E. for Q)
[or $V = V_0 e^{-t/\text{RC}}$ **(1)** = 9.0 $e^{-60/155}$ **(1)** = 6.11 V **(1)**] 3

[6]

105. (a) increased impact time **(1)**
same loss of momentum **(1)**
force = change of momentum/impact time **(1)**
$\therefore$ force is reduced **(1)**
[alternative for 2nd and 3rd : reduced deceleration of body **(1)**
force = mass × acceleration **(1)**]

[or area of contact increased **(1)**
force on driver 'spread out' over larger area **(1)**
pressure or force/unit area on driver reduced **(1)**]
[or air bag absorbs E_k of driver **(1)**
over a greater distance **(1)**

force = $\dfrac{\Delta E_k}{\text{distance}}$ **(1)**

force is reduced **(1)**] 4
QWC 2

(b) (use of $v^2 = u^2 + 2as$ gives) $a \left(= \dfrac{v^2 - u^2}{2s} \right) = \dfrac{(0) - 18^2}{2 \times 2.5}$ **(1)**

a = – 65 m s^{-2} **(1)** (– 64.8 m s^{-2}) (hence deceleration = 65 m s^{-2}) 2

[6]

106. (a) kinetic energy not conserved **(1)**
[or velocity of approach is equal to velocity of separation] 1

(b) (i) (use of $p = mv$ gives) $p = 4.5 \times 10^{-2} \times 60$ **(1)**
$= 2.7$ kg m s^{-1} **(1)**

(ii) (use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{2.7}{15 \times 10^{-3}}$ **(1)**

= 180 N **(1)**

[or $a = \dfrac{v - u}{t} = \dfrac{60}{15 \times 10^{-3}} = 4000$ (ms^{-1})

$F = (ma) = 4.5 \times 10^{-2} \times 4000 = 180$ N] 4

(c) (i) 180 N **(1)**
(allow C.E. for value of *F* from (b) (ii**)**
in opposite direction (to motion of the club) **(1)**

(ii) body A (or club) exerts a force on body B (or ball) **(1)**
(hence) body B (or ball) exerts an equal force on body A (or club) **(1)**
correct statement of Newton's third law **(1)** max 4
QWC 1

[9]

107. C

[2]

108. D

[2]

109. D

[2]

110. B

[2]

111. A

[2]

112. B

[2]

113. B

[2]

114. A

[2]

115. B

[2]

116. C

[2]

117. (a) (i) out of plane of diagram **(1)**

(ii) circular path **(1)**
in a horizontal plane [or out of the plane of the diagram] **(1)**

$BQv = \frac{mv^2}{r}$ **(1)**

radius of path, $r \left(\frac{mv}{BQ}\right) = \frac{1.05 \times 10^{-25} \times 7.8 \times 10^5}{0.28 \times 2 \times 1.6 \times 10^{-19}}$ **(1)**

= 0.91(4) m **(1)** max 5

(b) (i) radius decreased **(1)**
halved **(1)**
[or radius is halved **(1)** **(1)**]

(ii) radius increased **(1)**
doubled **(1)**
[or radius is doubled **(1)** **(1)**] max 3

[8]

118. (a) work = force × distance moved in direction of force **(1)**
(in circular motion) force is perpendicular to displacement **(1)**
no movement in direction of force **(1)** (hence no work)
[or speed of body remains constant (although velocity changes) **(1)**
kinetic energy is constant **(1)**
potential energy is constant **(1)**]

[or gravitational force acts towards the Earth **(1)**
Moon remains at constant distance/radius from Earth **(1)**
since radius is unchanged, gravitational force does no work
or E_p of Moon is constant **(1)**] 3
QWC 1

(b) (i) any suitable example of circular motion **(1)**

(ii) any SHM example at maximum displacement **(1)**
[or any other suitable example, e.g. car starts from rest] 2

[5]

119. (a) (i) h (= ct) (= $3.0 \times 10^8 \times 68 \times 10^{-3}$) = $2.0(4) \times 10^7$ m **(1)**

(ii) $g = (-)\dfrac{GM}{r^2}$ **(1)**

r (= $6.4 \times 10^6 + 2.04 \times 10^7$) = 2.68×10^7 (m) **(1)**

(allow C.E. for value of h from (i) for first two marks, but not 3rd)

$g = \dfrac{6.67\times10^{-11}\times6.0\times10^{24}}{(2.68\times10^7)^2}$ **(1)** (= 0.56 N kg^{-1}) 4

(b) (i) $g = \dfrac{v^2}{r}$ **(1)**

$v = [0.56 \times (2.68 \times 10^7)]^{½}$ **(1)**

= 3.9×10^3m s^{-1} **(1)** (3.87×10^3 m s^{-1})

(allow C.E. for value of r from a(ii**)**

[or $v^2 = \dfrac{GM}{r} =$ **(1)**

$v = \left(\dfrac{6.67\times10^{-11}\times6\times10^{24}}{2.68\times10^7}\right)^{1/2}$ **(1)**

= 3.9×10^3 m s^{-1} **(1)**]

(ii) $T\left(=\dfrac{2\pi r}{v}\right) = \dfrac{2\pi\times2.68\times10^7}{3.87\times10^3}$ **(1)**

= $4.3(5) \times 10^4$s **(1)** (12.(1) hours)

(use of $v = 3.9 \times 10^3$ gives $T = 4.3(1) \times 10^4$ s = 12.0 hours)

(allow C.E. for value of v from (I)

[alternative for (b):

(ii) $T^2 = \left(\dfrac{4\pi^2}{GM}\right)r^3$ **(1)**

$\left(=\dfrac{4\pi^2}{6.67\times10^{-11}\times6.0\times10^{24}}\times(2.68\times10^7)^3\right)$ = (1.90×10^9 (s^2**)** **(1)**

$T = 4.3(6) \times 10^4$ s **(1)**

(i) $v\left(\dfrac{2\pi r}{T}\right) = \dfrac{2\pi\times2.68\times10^7}{4.36\times10^4}$ **(1)**

= $3.8(6) \times 10^3$ m s^{-1} **(1)**]

(allow C.E. for value of r from (a)(ii) and value of T) 5

[9]

120. B

[2]

121. C

[2]

122. D

[2]

123. D

[2]

124. D

[2]

125. C

[2]

126. (a) acceleration is proportional to displacement **(1)**
acceleration is in opposite direction to displacement, or
towards a fixed point, or towards the centre of oscillation **(1)** 2

(b) (i) $f = \dfrac{25}{23}$ = 1.1 Hz (or s^{-1}) **(1)** (1.09 Hz)

(ii) (use of $a = (2\pi f)^2 A$ gives) $a = (2\pi \times 1.09)^2 \times 76 \times 10^{-3}$ **(1)**
$= 3.6$ m s^{-2} **(1)** (3.56 m s^{-2})
(use of f = 1.1 Hz gives a = 3.63 m s^{-2})
(allow C.E. for incorrect value of f from (i))

(iii) (use of $x = A\cos(2\pi ft)$ gives) $x = 76 \times 10^{-3} \cos(2\pi \times 1.09 \times 0.60)$ **(1)**
$= (–)4.3(1) \times 10^{-2}$ m **(1)** (43 mm)
(use of f = 1.1 Hz gives $x = (–)4.0(7) \times 10^{-2}$ m (41 mm))
direction: above equilibrium position or upwards **(1)** 6

(c) (i) graph to show:

correct shape, i.e. cos curve **(1)**
correct phase i.e. –(cos) **(1)**

(ii) graph to show:

two cycles per oscillation **(1)**
correct shape (even if phase is wrong) **(1)**
correct starting point (i.e. full amplitude) **(1)** max 4

[12]

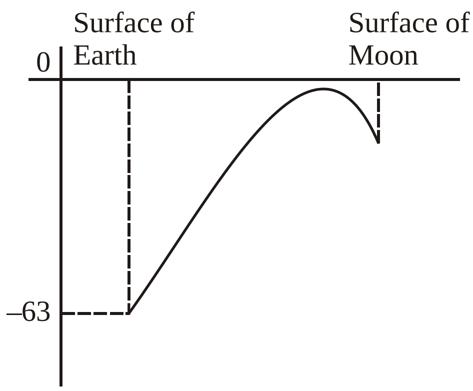
127. (a) work done/energy change (against the field) per unit mass **(1)**
when moved from infinity to the point **(1)** 2

(b) $V_E = -\dfrac{GM_E}{R_E}$ and $V_M = -\dfrac{GM_M}{R_M}$ **(1)**

$V_M = -G \times \dfrac{M_E}{81} \times \dfrac{3.7}{R_E} = \dfrac{3.7}{81} V_E$ **(1)**

$= 4.57 \times 10^{-2} \times (-63) = -2.9$ MJ kg^{-1} **(1)** (2.88 MJ kg^{-1}) 3

(c)



limiting values ($-63, -V_M$)
on correctly curving line **(1)**
rises to value close to but below zero **(1)**
falls to Moon **(1)**
from point much closer to M than E **(1)**

max 3

[8]

128. (a) Φ (= BA) = 45 × 10^{-3} × π × (70 × $10^{-3})^2$ **(1)**
= 6.9 × 10^{-4} Wb **(1)** (6.93 × 10^{-4} Wb) 2

(b) (i) $N\Delta\Phi$ (= NBA – 0) = 850 × 6.93 × 10^{-4} **(1)**
= 0.59 (Wb turns) **(1)** (0.589 (Wb turns))
(if Φ = 6.9 × 10^{-4}, then 0.587 (Wb turns))
(allow C.E. for value of Φ from (a))

(ii) induced emf (= $N \dfrac{\Delta\Phi}{\Delta t}$) = $\dfrac{0.589}{0.12}$ **(1)**
= 4.9 V **(1)** (4.91 V)
(allow C.E. for value of Wb turns from (ii) 4

[6]

129. (a) (i) change of momentum (= 0.44 × 32) = 14(.1) kg m s^1 **(1)**

(ii) (use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{14.1}{9.2 \times 10^{-3}}$ **(1)**
= 1.5(3) × 10^3N **(1)**
(allow C.E. for value of Δ(mv) from (i) 3

(b) (i) deceleration = $\dfrac{24 - 15}{9.2 \times 10^{-3}}$ = 9.8 × 10^2m s^{-2} **(1)** (9.78 × 10^2m s^{-2})

(ii) (use of $a = \dfrac{v^2}{r}$ gives)
centripetal acceleration = $\dfrac{24^2}{0.62}$ = 9.3 × 10^2m s^{-2} **(1)**
(9.29 × 10^2 m s^{-2})

(iii) before impact: radial pull on knee joint due to centripetal acceleration of boot **(1)**
during impact: radial pull reduced **(1)** 4

[7]

130. (a) (i) (change in momentum of A) = **– (1)** 25 × 10^3 **(1)** kg m s^{-1} (or N s) **(1)**

(ii) (change in momentum of B) = 25 × 10^3 kg m s^{-1} **(1)** 4

(b)

	initial vel/m s^{-1}	final vel/m s^{-1}	initial k.e./J	final k.e./J
truck A	2.5	1.25	62500	15600
truck B	0.67	1.5	6730	33750
	(1)	**(1)**	**(1)**	**(1)**

4

(c) not elastic **(1)**
because kinetic energy not conserved **(1)**
kinetic energy is greater before the collision (or less after) **(1)**
[or justified by correct calculation] 3

[11]

131. B

[2]

132. A

[2]

133. C

[2]

134. D

[2]

135. D

[2]

136. A

[2]

137. A

[2]

138. B

[2]

139. (a) reference to resonance **(1)**
air set into vibration at frequency of loudspeaker **(1)**
resonance when driving frequency = natural frequency of air column **(1)**
more than one mode of vibration **(1)**
stationary wave (in air column) **(1)** (or reference to nodes and antinodes)
maximum amplitude vibration (or max energy transfer) at resonance **(1)**

[alternative answer to (a):
first two marks as above, remaining four marks for
wave reflected from surface (of water) **(1)**
interference/superposition
(between transmitted and reflected waves) **(1)**
maximum intensity when path difference is $n\lambda$ **(1)**
maxima (or minima) observed when l changes by $\lambda/2$ **(1)**] Max 4

QWC 1

(b) (i) $\frac{\lambda}{2}$ = 523 – 168 **(1)** (= 355 mm)
λ = 710 mm **(1)**
[if $\frac{\lambda}{4}$ = 168, giving λ = 670 mm, **(1)** (1 max) (672 mm)]

(ii) $c(= f\lambda)$ = 480 × 0.71 **(1)**
= 341 m s^{-1} **(1)**
(allow C.E. for incorrect λ from (i))
[allow 480 × 0.67 = 320 m s^{-1} **(1)** (1max) (322 m s^{-1})] 4

[8]

140. (a) (i) straight line through origin **(1)**

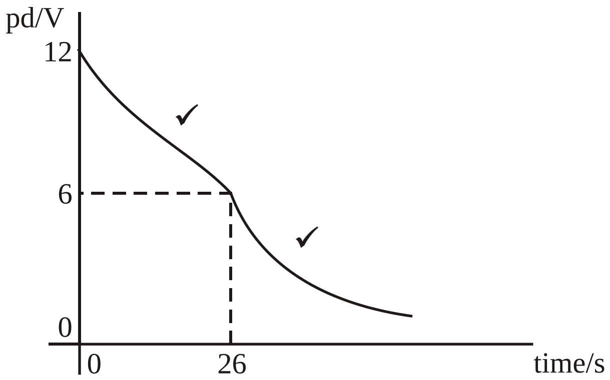
(ii) $\frac{1}{\text{capacitance}}$ **(1)**

(iii) energy (stored by capacitor) **(1)** (or work done (in charging capacitor)) 3

(b) (i) $RC = 5.6 \times 10^3 \times 6.8 \times 10^{-3}$ **(1)** (= 38.1 s)
$V(= V_0\, e^{-t/RC}) = 12\, e^{-26/38.1}$ **(1)**
= 6.1 V **(1)** (6.06 V)
[or equivalent using $Q = Q_0 e^{-t/RC}$ and $Q = CV$]

(ii) $(RC)' = 2.8 \times 10^3 \times 6.8 \times 10^{-3}$ **(1)** (= 19.0 s)
V (= 6.06 $e^{-14/19}$) = 2.9(0) V **(1)**
(use of V' = 6.1 V gives V = 2.9(2) V)

(iii)



7

[10]

141. (a) attractive **force** between point masses **(1)**
proportional to (product of) the masses **(1)** 3
inversely proportional to square of separation/distance apart **(1)**

(b) $m\omega^2 R = (-)\frac{GMm}{R^2}\left(\text{or} = \frac{mv^2}{R}\right)$ **(1)**

(use of $T = \frac{2\pi}{\omega}$ gives) $\frac{4\pi^2}{T^2} = \frac{GM}{R^3}$ **(1)** 3

G and M are constants, hence $T^2 \propto R^3$ **(1)**

(c) (i) (use of $T^2 \propto R^3$ gives) $\frac{365^2}{(1.50 \times 10^{11})^3} = \frac{T_m^2}{(5.79 \times 10^{10})^3}$ **(1)**

T_m = 87(.5) days **(1)**

(ii) $\frac{1^2}{(1.50 \times 10^{11})^3} = \frac{165^2}{R_N^3}$ **(1)** (gives $R_N = 4.52 \times 10^{12}$ m)

ratio = $\frac{4.51 \times 10^{12}}{1.50 \times 10^{11}}$ = 30(.1) **(1)** 4

[10]

142. C

[2]

143. C

[2]

144. D

[2]

145. B

[2]

146. B

[2]

147. A

[2]

148. C

[2]

149. A

[2]

150. B

[2]

151. (a) (i) $mg = ke$ **(1)**

$$k = \left(\frac{0.25 \times 9.81}{40 \times 10^{-3}}\right) = 61(.3) \text{ N m}^{-1}$$ **(1)**

$$T\left(= 2\pi\sqrt{\frac{m}{k}}\right) = 2\pi\sqrt{\frac{0.69}{61.3}}$$ **(1)** (= 0.667 s)

(ii) $f\left(= \frac{1}{T}\right) = \frac{1}{0.667}$ **(1)**(= 1.50 Hz) 4

(b) (i) forced vibrations (at 0.2 Hz) **(1)**
amplitude less than resonance (≈ 30 mm) **(1)**
(almost) in phase with driver **(1)**

(ii) resonance [or oscillates at 1.5 Hz] **(1)**
amplitude very large (> 30 mm) **(1)**
oscillations may appear violent **(1)**
phase difference is 90º **(1)**

(iii) forced vibrations (at 10 Hz) **(1)**
small amplitude **(1)**
out of phase with driver [or phase lag of (almost) π on driver] **(1)** Max 6

[10]

152. (a) $E \propto V^2$ (or $E = {}^1/_2CV^2$) **(1)**

pd after 25 s = 6 V **(1)** 2

(b) (i) use of $Q = Q_0\,e^{-t/RC}$ or $V = V_0\,e^{-t/RC}$ **(1)**

(e.g. $6 = 12e^{-25/RC}$) gives $e^{\frac{25}{RC}} = \frac{12}{6}$ and $\frac{25}{RC}$ = 1n 2 **(1)**

(RC = 36(.1) s)

[alternatives for (i):

$V = 12\,e^{-25/36}$ gives V = 6.0 V **(1)** (5.99 V)

or time for pd to halve is 0.69RC

$\therefore RC = \frac{25}{0.69}$ **(1)** = 36(.2) s]

(ii) $R = \frac{36.1}{680 \times 10^{-6}}$ **(1)** = 5.3(0) × 10^4 Ω**(1)** 4

[6]

153. (a) orbits (westwards) over Equator **(1)**
maintains a fixed position relative to surface of Earth **(1)**
period is 24 hrs (1 day) or same as for Earth's rotation **(1)** Max 3
offers uninterrupted communication between transmitter and receiver **(1)**
steerable dish not necessary **(1)**

(b) (i) $G\frac{Mm}{(R+h)^2} = mw^2(R+h)$ **(1)**

use of $w = \frac{2\pi}{T}$ **(1)**

(ii) gives $\frac{GM}{(R+h)^3} = \frac{4\pi^2}{T^2}$, hence result **(1)**

(iii) limiting case is orbit at zero height i.e. $h = 0$ **(1)**

$T^2 = \left(\frac{4\pi^2 R^3}{GM}\right) = \frac{4\pi^2 \times (6.4\times10^6)^3}{6.67\times10^{-11}\times6.0\times10^{24}}$ **(1)**

$T = 5090$ s **(1)** (= 85 min) 6

(c) speed increases **(1)**

loses potential energy but gains kinetic energy **(1)**

[or because $v^2 \propto \frac{1}{r}$ from $\frac{GMm}{r^2} = \frac{mv^2}{r}$]

[or because satellite must travel faster to stop it falling
inwards when gravitational force increases] 2

[11]

154. (a) (i) $E\left(=\frac{V}{d}\right) = \frac{1400}{15\times10^{-3}}$ **(1)** $(= 9.3\times10^4\ \mathrm{Vm^{-1}})$

(ii) $t\left(=\frac{l}{v}\right)=\frac{30\times10^{-3}}{3.2\times10^{7}}=9.38\times10^{-10}$ s **(1)**

(iii) $ma_y = Ee$ **(1)**

$ay = \frac{9.3\times10^{4}\times1.60\times10^{-19}}{9.11\times10^{31}}$ **(1)** (= 1.64×10^{16} m s^{-2})

acceleration is upwards [or towards + plate]**(1)** 5

(b) vy (= $a_y t$) = $1.64 \times 10^{16} \times 9.38 \times 10^{-10}$ **(1)** (= 1.54×10^{7} m s^{-1})

$v=\sqrt{(1.54\times10^{7})^2+(3.2\times10^{7})^2}$ =3.55×10^{7}m s^{-1}**(1)**

at $\tan^{-1}\left(\frac{1.54}{3.2}\right)=26^{\circ}$ above the horizontal **(1)** 3

[8]

155. (a) momentum **(1)**

kinetic energy **(1)** 2

(b) (i) 450ms^{-1} **(1)**

in the opposite direction **(1)**

$\Delta p = 8.0 \times 10^{-26} \times 900$ **(1)**

$= 7.2 \times 10^{-23}$Ns **(1)** 4

(c) force is exerted on molecule by wall **(1)**
to change its momentum **(1)**
molecule must exert an equal but opposite force on wall **(1)**
in accordance with Newton's second or third law **(1)** 4

[10]

156. B

[2]

157. C

[2]

158. B

[2]

159. C

[2]

160. D

[2]

161. D

[2]

162. B

[2]

163. C

[2]

164. D

[2]

165. (a) $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ **(1)** 2

Oscillations must be of small amplitude **(1)**

(b) (i) $f = \dfrac{25}{46.5} = 0.53(8)(s^{-1})$ **(1)**

[or $T = \dfrac{46.5}{25}$ = 1.8(6) (s)]

$l\left(= \dfrac{g}{4\pi^2 f^2}\right) = \dfrac{9.81}{4\pi^2 0.538^2}$ [or $l\left(\dfrac{T^2 g}{4\pi^2}\right) = \dfrac{1.86^2 \times 9.81}{4\pi^2}$] **(1)**

l = 0.85(9)m **(1)**

(allow C.E. for values of or T)

(ii) $a_{max}\{= (-)(2\pi f)^2 A\} = (2\pi \times 0.538)^2 \times 51 \times 10^{-3}$ **(1)**

(= 0.583 ms^{-2})

(allow C.E. for value of from (i))

$F_{max}(= ma_{max}) = 1.2 \times 10^{-2} \times 0.583$ **(1)**

$= 7.0 \times 10^{-3}$N **(1)**
(6.99×10^{-3}N)

[or $F_{max}(= mg \sin \theta_{max})$ where $\sin \theta_{max} = \dfrac{51}{859}$ **(1)**

$= 1.2 \times 10^{-2} \times 9.81 \times \dfrac{51}{859}$ **(1)**

$= 6.99 \times 10^{-3}$N **(1)**] 6

[8]

166. (a) vibrates or oscillates or moves in shm **(1)**
vibration/oscillation is vertical/perpendicular to wave propagation direction **(1)**
frequency *(=c/λ)* = 3.0(Hz) **(1)**

(or same as P)

amplitude = 90 (mm) **(1)**

(or same as P)

Q has a phase lag on P **(1)**

(or vice versa)

phase difference of $\left(\dfrac{0.4}{1.2} \times 2\pi\right) = \dfrac{2\pi}{3}$ (rad) or 120° **(1)** 5

(b) use of f =3.0(Hz) **(1)**

v_{max} (= $2\pi fA$) = $2n \times 3.0 \times 90 \times 10^{-3}$ **(1)**

= 1.7(0)ms^{-1} **(1)** 3

[8]

167. (a) (i) force per unit charge **(1)**
acting on a positive charge **(1)**

(ii) vector **(1)** 3

(b) (i) $F\left(=\dfrac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\dfrac{4.0\times10^{-9}\times8.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(80\times10^{-3})^2}$ **(1)**

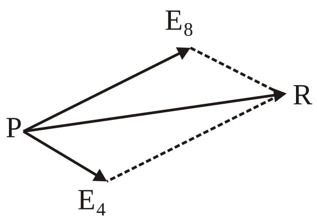
=4.5(0) × 10^{-5}N **(1)**

(ii) (use of $V=\dfrac{Q}{4\pi\varepsilon_0 x}$ gives) $0=\left(\dfrac{4.0\times10^{-9}}{4\pi\varepsilon_0 x}\right)-\left(\dfrac{8.0\times10^{-9}}{4\pi\varepsilon_0(80\times10^{-3}-x}\right)$

or $\dfrac{4}{x}=\dfrac{8}{80-x}$ **(1)**

x = 26.7mm **(1)** 4

(c) correct directions for E_4 and E_s **(1)**
E_8 approx twice as long as E_4 **(1)**
correct direction of resultant R
shown **(1)** 3



[10]

168. (a) greater flux (linkage) or more flux lines (at same distance)
[or stronger magnet produces flux lines closer together] **(1)**
greater rate of change of flux (linkage)
[or more flux lines cut per unit time] **(1)**
emf $\propto$ rate of change of flux (linkage) **(1)**

[or using $\in = N\dfrac{\Delta\phi}{\Delta t}$, where $\Delta\Phi = A\,\Delta B$, v and Δt are the same **(1)**

ΔB is larger since magnet is stronger **(1)**
N and A are constant, $\therefore \in$ is larger **(1)**] 3

(b) (i) area swept out, $\Delta A = lv\Delta t$ **(1)**

$\Delta\Phi\,(= \mathrm{B}\Delta A) = Blv\,\Delta t$ **(1)**

$\in\left(=(N)\dfrac{\Delta\phi}{\Delta t}\right) = \dfrac{Blv\Delta t}{\Delta t}$ gives result **(1)** 3

(c) (i) $w(=2\pi f) = 2\pi \times 16$ **(1)**
$= 101\ \mathrm{rads}^{-1}$ **(1)**

(ii) $v(=rw) = 32 \times 10^{-3} \times 101 = 3.2(3)\mathrm{ms}^{-1}$ **(1)**

(allow C.E. for value of w from (i))

(iii) $\in(= Blv) = 28 \times 10^{-3} \times 64 \times 10^{-3} \times 3.23$ **(1)**
$= 5.7(9) \times 10^{-3}\mathrm{V}$ **(1)** 5

(allow C.E. for values of v from (ii))

(solutions using $\in = Bfnr^2$ to give $5.7(6) \times 10^{-3}$ V acceptable)

[11]

169. D

[1]

170. B

[1]

171. C

[1]

172. A

[1]

173. A

[1]

174. B

[1]

175. B

[1]

176. C

[1]

177. A

[1]

178. B

[1]

179. C

[1]

180. D

[1]

181. B

[1]

182. A

[1]

183. D

[1]

184. B

[1]

185. D

[1]

186. A

[1]

187. C

[1]

188. D

[1]

189. C

[1]

190. D

[1]

191. C

[1]

192. B

[1]

193. C

[1]

194. (a) *kinetic* energy is not conserved **(1)**

(or velocity of approach equals velocity of separation) 1

(b) (i) (use of $p = mv$ gives) p $= 4.5 \times 10^{-2} \times 60$ **(1)**

$= 2.7\text{kg m s}^{-1}$ **(1)**

(ii) (use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{2.7}{15\times10^{-3}}$ **(1)**

$= 180$ N **(1)**

[or $a = \dfrac{v-u}{t} = \dfrac{60}{15\times10^{-3}} = 400\ (\text{m s}^{-1})$ **(1)**

$F = ma = 4.5 \times 10^{-2} \times 4000 = 180\text{N}$ **(1)** 4

[5]

195. (a) (i) $mg = ke$ **(1)**

$k = \left(\dfrac{0.25\times9.81}{40\times10^{-3}}\right) = 61(.3)\ \text{N m}^{-1}$ **(1)**

(ii) $T = \left(= 2\pi\sqrt{\dfrac{m}{k}}\right) = 2\pi\sqrt{\dfrac{0.69}{61.3}}$ **(1)** (= 0.667 s)

$f\left(= \dfrac{1}{T}\right) = \dfrac{1}{0.667}$ **(1)** (= 1.5(0) Hz) 4

(b) The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question.

Level	**Descriptor** an answer will be expected to meet most of the criteria in the level descriptor	**Mark range**
Good **3**	– answer supported by appropriate range of relevant points – good use of information or ideas about physics, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of spelling, punctuation and grammar	**5-6**
Modest **2**	– answer partially supported by relevant points – good use of information or ideas about physics given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of spelling, punctuation and grammar	**3-4**
Limited **1**	– valid points but not clearly linked to an argument structure – limited use of information or ideas about physics – unstructured – errors in spelling, punctuation and grammar or lack of fluency	**1-2**
0	– incorrect, inappropriate or no response	**0**

examples of the sort of information or idea that might be used to support an argument

- forced vibrations (at 0.2 Hz) **(1)**
- amplitude fairly large (≈ 30 mm) **(1)**
- in phase with driver **(1)**
- resonance (at 1.5 Hz) **(1)**
- amplitude very large (> 30 mm) **(1)**
- oscillations may appear violent **(1)**
- phase difference at 90º **(1)**
- forced vibrations (at 10 Hz) **(1)**
- small amplitude **(1)**
- out of phase with driver or phase lag of π on driver **(1)**

[10]

196. (a) period is 24 hours (or equal to period of Earth's rotation) **(1)**

remains in fixed position relative to surface of Earth **(1)**

equatorial orbit **(1)**

same *angular* speed as Earth (or equatorial surface) **(1)** max 2

(b) (i) $\frac{GMm}{r^2} = m\omega^2 r$ **(1)**

$T = \frac{2\pi}{\omega}$ **(1)**

$$r\left(= \frac{GMT^2}{4\pi^2}\right) = \left(\frac{6.7\times10^{-11}\times6.0\times10^{24}\times(24\times3600)^2}{4\pi^2}\right)^{1/3}$$ **(1)**

(gives r = 42.3 × 10^3 km)

(ii) $\Delta V = GM\left(\frac{1}{R} - \frac{1}{r}\right)$ **(1)**

$= 6.67 \times 10^{-11} \times 6 \times 10^{24} \times \left(\frac{1}{6.4\times10^6} - \frac{1}{4.23\times10^7}\right)$

$= 5.31 \times 10^7$ (J kg^{-1}) **(1)**

$\Delta E_P = m\Delta V$ (= 750 × 5.31 × 10^7) = 3.98 ×10^{10} J **(1)**

(allow ecf for value of ΔV) 6

(c) (i) signal would be too weak at large distance **(1)**

(or large aerial needed to detect/transmit signal, or any other acceptable reason)

the signal spreads out more the further it travels **(1)**

(ii) **for** road pricing would reduce congestion

stolen vehicles can be tracked and recovered

uninsured/unlicensed vehicles can be apprehended

against road pricing would increase cost of motoring

possibility of state surveillance/invasion of privacy

(1)(1) any 2 valid points (must be for both for **or** against) 4

[12]

197. (a) $T \cos 6° = mg$ **(1)**

$T \sin 6° = F$ **(1)**

hence $F = mg \tan 6°$ **(1)**

[or by use of triangle: sides correct **(1)** 6° correct **(1)** tan 6° = F/mg **(1)**] 3

(b) (use of $E = \frac{V}{d}$ gives) $E = \frac{4200}{60 \times 10^{-3}} = 7.0 \times 10^4$ V m^{-1} **(1)**

(use of $Q = \frac{F}{E}$ gives) $Q \left(\frac{mg \tan 6°}{E}\right) = \frac{2.1 \times 10^{-4} \times 9.81 \tan 6°}{7.0 \times 10^{-4}}$ **(1)**

$= 3.1 \times 10^{-9}$C **(1)** 3

(allow ecf for value of E from (i))

[6]

198. (a) (i) E (= ½ $CV^2 = 0.5 \times 180 \times 10^{-6} \times 100^2$) = 0.90J **(1)**

(ii) W (= $QV = CV^2 = 180 \times 10^{-6} \times 100^2$) = 1.8 J **(1)** 2

(b) (i) ($V = V_0 e^{-t/RC}$) gives $30 = 100\ e^{-t/RC}$ **(1)**

$\therefore t = (-RC \ln (30/100) = -1.5 \times 180 \times 10^{-6} \times -1.204$ s)
$= 3.3 \times 10^{-4}$ s **(1)**

(ii) image would be less sharp (or blurred) because the discharge would last longer and the image would be photographed as it is moving **(1)**

image would be brighter because the capacitor stores more energy and therefore produces more light **(1)** 4

[6]

199. (a) greater flux (linkage) or more flux lines (at same distance)

[or stronger magnet produces flux lines closer together] **(1)**

greater rate of change of flux (linkage)

[or more flux lines cut per unit time] **(1)**

induced emf °= [or =] rate of change of flux (linkage) **(1)**

[or using $\in = \text{NA}\dfrac{\Delta B}{\Delta t}$ **(1)** ΔB is larger since magnet is stronger **(1)**

N, A and Δt are the same at the same speed $\therefore \in$ is larger **(1)**] 3

(b) area swept out $\Delta A = lv\Delta t$ **(1)**

$\Delta\Phi$ (= $B\Delta A$) = $Blv\Delta t$ **(1)**

$\in \left(= (N)\dfrac{\Delta\Phi}{\Delta t} \right) = \dfrac{Blv\Delta t}{\Delta t}$ gives result **(1)** 3

(c) (i) ω (= $2\pi f$) = $2\pi \times 16$ **(1)**

$= 101$ rad s^{-1} **(1)**

(ii) v (= $r\omega$) = $32 \times 10^{-3} \times 101 = 3.2(3)$ m s^{-1} **(1)**

(allow ecf for value of ω from (i))

(iii) $\in$ (= Blv) $= 28 \times 10^{-3} \times 64 \times 10^{-3} \times 3.23$ **(1)**

$= 5.7(9) \times 10^{-3}$V **(1)**

(allow ecf for value of v from (ii))

[or accept solutions using $\in = Bf\pi r^2$ to give $5.7(9) \times 10^{-3}$ V] 5

[11]