2000.

1 (a) escape velocity – velocity required by object to move from surface of planet to infinity.

(b) Energy required to move from surface to ∞

$$E = \frac{GMm}{r}.$$

$$\frac{\cancel{m}v^2}{2} = \frac{GM\cancel{m}}{r} \Rightarrow v = \sqrt{\frac{2GM}{r}}$$

(c) $$v = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^{6}}} = 11.1 \text{ km/s}.$$

2. (a) $$\frac{\cancel{m}v^2}{r} = \frac{G\cancel{m}M}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

$$= 1\,000 \text{ m/s}.$$

(b) The radii of planets is small compared to dist of sep.

3. (a) $$eV = \frac{mv^2}{2} \Rightarrow v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9.11 \times 10^{-31}}} = 2.6 \times 10^{7} \text{ m/s}.$$

(b) $$m_0c^2 + qV = mc^2$$

$$(9.11 \times 10^{-31} \times 9 \times 10^{16}) + (1.6 \times 10^{-19} \times 6 \times 10^{5}) = mc^2$$

$$1.78 \times 10^{-13} = mc^2$$

$$m = 1.98 \times 10^{-30} \text{ kg}$$

$$\frac{m_0}{m} = \sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$\frac{9.11 \times 10^{-31}}{1.98 \times 10^{-30}} = \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$$

$$0.46 = \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$$

$$0.21 = 1 - \frac{v^2}{c^2}$$

$$\frac{v^2}{c^2} = 0.79$$

$$\frac{v}{c} = 0.88$$

$$v = 0.88c = 2.64 \times 10^{8} \text{ m/s}.$$

4(a) potential due to Q at r_c $= \frac{Q}{4\pi\varepsilon_0 r_c}$

Energy of q initially is $E_K = \frac{mv^2}{2}$

at r_c all E_K to potential

$$\frac{mv^2}{2} = \frac{Qq}{4\pi\varepsilon_0 r_c} \Rightarrow r_c = \frac{2Qq}{4\pi\varepsilon_0 m v^2}.$$

(b) $$r_c = \frac{2 \times 79 \times (1.6 \times 10^{-19})^2 \times 9 \times 10^9}{6.7 \times 10^{-27} \times (10^7)^2}$$

$$= 5.4 \times 10^{-14}\ \text{m}.$$

5. Y straight line - does not cross any field lines so experiences no force.

6. (a)(i) when switch is closed current changes, this change in current produces a back emf in inductor which opposes the change.

(ii) Initial change $\Delta t = 6\,\text{ms}$ $\Delta I = 4\,\text{mA}$

$$\text{rate} = \frac{\Delta I}{\Delta t} = \frac{4}{6} = 0.66\ \text{A/s}$$

(iii) $$e = -L\frac{dI}{dt}$$

$$L = -\frac{e}{\frac{dI}{dt}} = -\frac{-12}{0.66} = 18.2\ \text{H}.$$

(b) (i) Max rate of change reduced since L increased.

(ii) When field in inductor collapses a very large emf is induced. could damage computer / interface.

7(a)(i) A node is a point where the amplitude is always zero.

(ii) node 0 at $\cos\frac{2\pi x}{\lambda} = 0 \Rightarrow \quad x_0 = \frac{\lambda}{4}$

Node 1 at $\cos\frac{2\pi x}{\lambda} = 0 \Rightarrow \frac{2\pi x}{\lambda} = \frac{3\pi}{2} \quad x_1 = \frac{3\lambda}{4}$

separation $= \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$

(b) (i) Separation of minima $= 800 \div 8 = 100\,mm = 0.1\,m$.
$\Rightarrow \lambda = 0.2\,m$.

(ii) Increase frequency of sound wave.

8. (a) not required.

(b) Paschen $4 \rightarrow 3$.

9. (a) (i) $v = \omega r$

(ii) $p = m\omega r$

(iii) $L = m\omega r^2$

(iv) $E_K = \frac{m\omega^2 r^2}{2}$

(b) Moment of inertia is resistance of object to rotation.

(c) (i) not required.

(ii) The mass is distributed about the axis of rotation in exactly the same way as the disc.

(d) (i) Mgh – change in E_p of cylinder.

$\frac{1}{2}I\omega^2$ – gain in rotational E_K.

$\frac{1}{2}m\omega^2 r^2$ – gain in linear E_K.

(ii) Mean $= \frac{\Sigma}{n} = 3.92$. random Unc $= \frac{Max - Min}{n} = 0.02$

$3.92 \pm 0.02\,s$.

(iii) $\bar{v} = \frac{s}{t} = \frac{1.0}{3.92} = 0.255 m/s$

final $v = 0.51 m/s$

$\omega = \frac{v}{r} = 20.4$ rad/s

$$M_c gh = \frac{I\omega^2}{2} + \frac{M_c v^2}{2}$$

$$2 \times 9.8 \times 0.02 = I\left(\frac{20.4^2}{2}\right) + \frac{2 \times 0.51^2}{2}$$

$$0.392 = 208I + 0.26$$

$$208I = 0.132$$

$$I = 6.34 \times 10^{-4} \text{ kg m}^2$$

(iv) Time will increase, I cylinder increased so v and ω will be reduced since change in E_p same.

10. (a) (i) $F = mg = 2.4 \times 10^{-3} \times 9.8$

$= 2.35 \times 10^{-2}$ N

$= 0.0235$ N.

(ii) $F = BIL$

$B = \frac{F}{IL} = \frac{0.0235}{2 \times 0.04} = 0.29$T.

(iii) reading on balance 102.4 g.

(b)

(i) F at I_2 due to B_1 from I_1 $= B_1 I_2 l$

$= \frac{\mu_0 I_1 I_2 l}{2\pi r}$

F per unit length $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$

(ii)

$F_A = \frac{4\pi \times 10^{-7} \times 2.5 \times 2.5}{2\pi \times 0.06} = 2.08 \times 10^{-5}$ N towards B.

(c) (i) Force is upwards.

(ii) $F = BIL$ $\qquad I = q/t$

$= \frac{BqL}{t}$ $\qquad L/t = v$

$= Bqv$.

10 (d) $\frac{mv^2}{r} = Bqv$

$$r = \frac{mv^2}{Bqv} = \frac{mv}{Bq} = \frac{3 \cdot 49 \times 10^{-26} \times 2 \times 10^5}{0 \cdot 6 \times 1 \cdot 6 \times 10^{-19}} = 0 \cdot 073\,m$$

11. (a) (i) $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} = \frac{9 \times 10^9 \times (1 \cdot 6 \times 10^{-19})^2}{(5 \cdot 3 \times 10^{-11})^2} = 8 \cdot 2 \times 10^{-8}\,N$

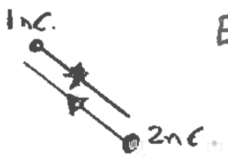
(ii) $F = \frac{GMm}{r^2} = \frac{6 \cdot 67 \times 10^{-11} \times 1 \cdot 673 \times 10^{-27} \times 9 \cdot 11 \times 10^{-31}}{(5 \cdot 3 \times 10^{-11})^2} \sim 10^{-48}$

(iii) Strong nuclear, weak nuclear.

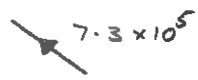
(b) (i) not required.

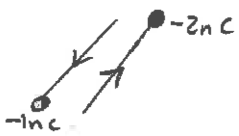
(ii) all equidistant take dist = r. $r = 35\,mm$. $35 \times 10^{-3}\,m$.

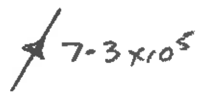
$E = \frac{9 \times 10^9}{(3 \cdot 5 \times 10^{-3})^2} \times q = 7 \cdot 3 \times 10^{14}\,q$

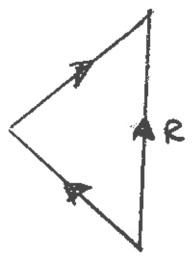


$E = (7 \cdot 3 \times 10^{14} \times 10^{-9}) - (7 \cdot 3 \times 10^{14} \times 2 \times 10^{-9})$
$= -7 \cdot 3 \times 10^5\,N/C$.









$R = \sqrt{(7 \cdot 3 \times 10^5)^2 + (7 \cdot 3 \times 10^5)^2}$
$= 1 \cdot 03 \times 10^6\,N/C$ vertically upward

(c)

$$V = -\frac{Q_1}{4\pi\varepsilon_0 r} + -\frac{Q_2}{4\pi\varepsilon_0 r} = -\frac{9 \times 10^9}{25 \times 10^{-3}} \times ((5+3) \times 10^{-9})$$

$= -2\,880\,V$

(d) $F = eE = 1 \cdot 6 \times 10^{-19} \times 2 \times 10^4 = 3 \cdot 2 \times 10^{-15}\,N$

$a = \frac{F}{m} = \frac{3 \cdot 2 \times 10^{-15}}{9 \cdot 11 \times 10^{-31}} = 3 \cdot 5 \times 10^{15}\,m/s^2$

$t = \frac{s_H}{v_H} = \frac{40 \times 10^{-3}}{2 \times 10^7} = 20 \times 10^{-10}\,s$.

$S = \frac{1}{2} a t^2 = \frac{1}{2} \times 3 \cdot 5 \times 10^{15} \times (20 \times 10^{-10})^2 = 7 \times 10^{-3}\,m$
$= \underline{7mm}$.

48

12. (a) (i) $y = a\sin\omega t$; $\frac{dy}{dt} = +a\omega\cos\omega t$; $\frac{d^2y}{dt^2} = -a\omega^2\sin\omega t = -\omega^2 y$

$\Rightarrow \frac{d^2y}{dt^2} + \omega^2 y = 0$.

(ii) $y = a\sin\omega t$ $\quad v = a\omega\cos\omega t$

$y^2 = a^2\sin^2\omega t$ $\quad v^2 = a^2\omega^2\cos^2\omega t$

$\frac{y^2}{a^2} = \sin^2\omega t$ $\quad \frac{v^2}{a^2\omega^2} = \cos^2\omega t$.

$\frac{y^2}{a^2} + \frac{v^2}{a^2\omega^2} = \sin^2\omega t + \cos^2\omega t$.

$\frac{y^2}{a^2} + \frac{v^2}{a^2\omega^2} = 1$

$y^2\omega^2 + v^2 = a^2\omega^2$

$v^2 = a^2\omega^2 - y^2\omega^2$

$v = \pm\omega\sqrt{a^2-y^2}$.

(b)

(i) The restoring force is directly proportional to the displacement of the mass.

(ii) $\omega = \frac{\theta}{t} = \frac{20\pi}{6} = 10\cdot5$ rad/s

$v = \pm\, 10\cdot5\sqrt{a^2}$

$= \pm\, 0\cdot525$ m/s

(iii) $v = \pm\, 10\cdot5\sqrt{0\cdot05^2 - 0\cdot025^2}$

$= \pm\, 0\cdot45$ m/s.

(iv) $E_K = \frac{1}{2}mv^2 = \underline{\underline{\frac{1}{2}m\omega^2(a^2-y^2)}}$

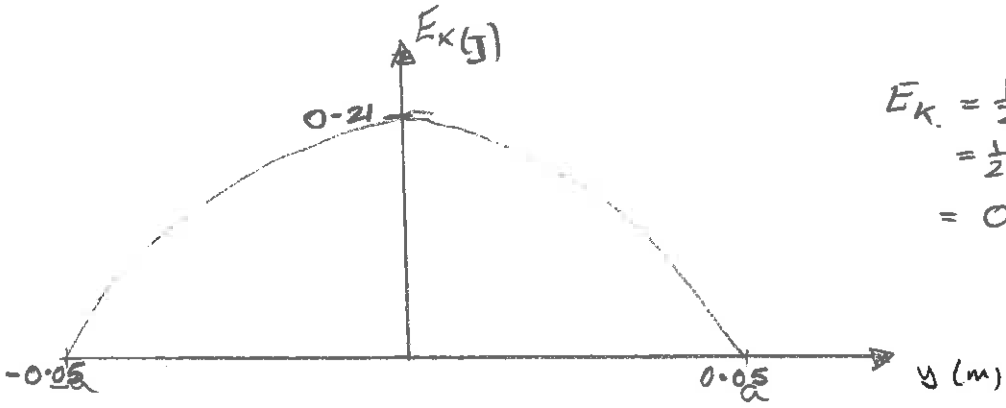
all energy is E_K when $v = \max$ $y = 0$. $\quad E = \frac{1}{2}m\omega^2a^2$

$E_{TOT} = E_K + E_P$

$\frac{1}{2}m\omega^2a^2 = \frac{1}{2}m\omega^2(a^2-y^2) + E_P$

$\Rightarrow E_P = \underline{\underline{\frac{1}{2}m\omega^2y^2}}$

(v.)



$$E_K = \frac{1}{2} m \omega^2 a^2$$
$$= \frac{1}{2} \times 0{\cdot}5 \times (10{\cdot}5)^2 (0{\cdot}05)$$
$$= 0{\cdot}21 \text{ J}$$