Phys 4C Practice Final Exam

(1) $\lambda = 410\,nm = 4.1\times10^{-7}m$ $\qquad d\sin\theta = m\lambda$

$d = 0.093\,mm = 9.3\times10^{-5}m$ $\qquad \frac{dy}{L} \simeq m\lambda$

$L = 2.8\,m$

$$y = \frac{m\lambda L}{d}$$

$$\Rightarrow \Delta y = y_4 - y_1 = (4-1)\frac{\lambda L}{d} = \frac{3\lambda L}{d} = \frac{3(4.1\times10^{-7}m)(2.8m)}{(9.3\times10^{-5}m)}$$

$\therefore \boxed{\Delta y = 0.037m} \boxed{\Rightarrow \text{choice (d)}}$

(2) $K = qV = 1000eV = \frac{1}{2}mv^2$

$2Km = (mv)^2$

$\sqrt{2Km} = mv$

$$\lambda = \frac{h}{\sqrt{2Km}} = \frac{6.626\times10^{-34}\,J.s}{\sqrt{2(1000eV)\left(\frac{1.609\times10^{-19}J}{1eV}\right)(9.11\times10^{-31}kg)}}$$

$\lambda = 3.8\times10^{-11}\,m \Rightarrow$ $\boxed{\text{Choice (e), none of the above.}}$

(3) A doped semiconductor with effective positive charge carriers has too few electrons (or in other words, too many holes) in its crystal structure. This makes it a p-type semiconductor, with an acceptor level close to a filled energy band (see Figure 43.28).

(4) $a\sin\theta = m\lambda, \quad m = \pm1, \pm2, \pm3\ldots$

$a_1\sin\theta_1 = a_2\sin\theta_2$

since since $\theta \simeq \sin\theta$ for small θ,

$a_1\theta_1 \simeq a_2\theta_2$ $\Rightarrow$ Doubling a will cause the separation of the minima to decrease by $\frac{1}{2}$ $\Rightarrow$ $\boxed{\text{Choice (d)}}$

(5) A concave mirror has $f > 0$ and $R > 0$, here, with $f = +35.0\,cm$.

The image is upright, so $M > 0$.
The image is 5 times the size of the object, so $M = 5 = -\frac{q}{p}$ and so $q = -5p$.

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{p} - \frac{1}{5p} = \frac{1}{35.0\,cm}$$

$$\frac{5-1}{5p} = \frac{4}{5p} = \frac{1}{35.0\,cm} \quad \therefore \boxed{p = +28.0\,cm} \quad \boxed{\Rightarrow \text{Choice (d)}}$$

(6) $m_1 = 3.0 \times 10^{-28}\,kg$
$v_1 = 0.793c$

$m_2 = 1.67 \times 10^{-27}\,kg$
Find: v_2

For this, we need relativistic momentum,

$$p \equiv \gamma m v.$$

(For classical physics, for speeds $v \ll c$, $p = mv$ is OK – it isn't here.)

By conservation of momentum,

$$\gamma_1 m_1 v_1 = \gamma_2 m_2 v_2$$

$$\frac{m_1 v_1}{\sqrt{1-(v_1/c)^2}} = \frac{m_2 v_2}{\sqrt{1-(v_2/c)^2}}$$

$$\frac{m_1^2 v_1^2}{1-(v_1/c)^2} = \frac{m_2^2 v_2^2}{1-(v_2/c)^2}$$

$$\left(\frac{m_1}{m_2}\right)^2 \left[\frac{1}{(c/v_1)^2 - 1}\right] = \left[\frac{1}{(c/v_2)^2 - 1}\right]$$

$$\Rightarrow \boxed{v_2 = 0.228c \Rightarrow \text{choice (a)}}$$

Check units:
$1\,J = kg\,\frac{m^2}{s^2}$
$1\,\frac{Js}{m} = 1\,kg\,\frac{m}{s}$ ✓

(7) $\Delta x = 0.5\times 10^{-9}\,m$.
Since $\Delta x\,\Delta p_x \geq \hbar/2$,
$$\Delta p_x \geq \frac{\hbar}{2(\Delta x)} = \frac{(1.055\times 10^{-34}\,J\cdot s)}{2(0.5\times 10^{-9}\,m)} \boxed{= 1.1\times 10^{-25}\,kg\,\frac{m}{s}}$$
$\boxed{\Rightarrow \text{Choice (a)}}$

(8) Both forbidden transitions and selection rules are because $\Delta \ell = \pm 1$ for electrons making transitions in atoms, which radiate (or absorb) photons. Since, during a transition, the electron changes its angular momentum (since $\Delta \ell = \pm 1$), since angular momentum is conserved, this implies $\boxed{\text{Choice (c)}}$ $\Rightarrow$ a photon must have angular momentum.

(9) $T_{1/2} = 8.04\,d$
$t = 3\,d$
$R = 0.5\,\mu Ci$
$$R = R_0 e^{-\lambda t}$$
$$\Rightarrow R_0 = R e^{\lambda t} = R \exp\left[\left(\frac{0.693}{T_{1/2}}\right)t\right]$$
$$= (0.5\,\mu Ci)\exp\left[\left(\frac{0.693}{8.04\,d}\right)3\,d\right]$$
$\boxed{R_0 = 0.65\,\mu Ci}$ $\boxed{\Rightarrow \text{Choice (d)}}$

(10) $I = 1340\,\frac{W}{m^2} = S_{av} = \frac{E_{max}B_{max}}{2\mu_0} = \frac{E_{max}^2}{2\mu_0 c}$, since $\frac{E_{max}}{B_{max}} = c$.
$$\Rightarrow E_{max} = \sqrt{2\mu_0 c I}$$
$$= \left[(2)\left(4\pi\times 10^{-7}\,\frac{Tm}{A}\right)\left(3\times 10^{8}\,\frac{m}{s}\right)\left(1340\,\frac{W}{m^2}\right)\right]^{1/2}$$
$\boxed{E_{max} = 1000\,\frac{V}{m}}$ $\boxed{\Rightarrow \text{Choice (b)}}$

Check units: $\left(\frac{T\cancel{m}}{A}\right)\left(\frac{\cancel{m}}{s}\right)\left(\frac{W}{\cancel{m^2}}\right) = \frac{TW}{As} = \left(\frac{V}{m^2}\right)\left(\frac{\cancel{s}}{C}\right)\left(\frac{J}{\cancel{s}}\right) = \frac{V^2}{m^2}$ ✓

(B) For $n=3$,

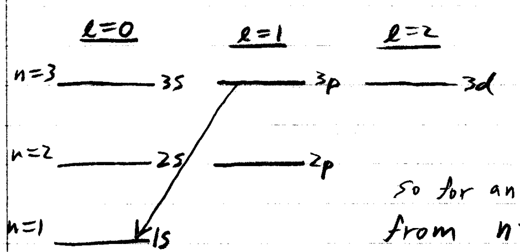
(i) ℓ can have values of $\ell = 0, 1, 2, \ldots, n-1$,
so $\boxed{\ell = 0, 1, \text{ or } 2}$.

m_ℓ can have values of $m_\ell = 0, \pm 1, \pm 2, \ldots, \pm \ell$,
so $\boxed{m_\ell = -2, -1, 0, 1, \text{ or } 2}$.

(ii) The maximum values from (i) are $\ell = 2$ and $m_\ell = 2$.

$$L = \hbar\sqrt{\ell(\ell+1)} = \hbar\sqrt{2(2+1)} = \hbar\sqrt{6}$$
$$L_z = m_\ell \hbar = 2\hbar$$

$L_z = L\cos\theta$, so
$$\theta = \arccos(L_z/L) = \arccos(2\cancel{\hbar}/[\sqrt{6}\,\cancel{\hbar}]) = \arccos(0.8165)$$
$$\therefore \boxed{\theta = 35.3^\circ}.$$

(iii)


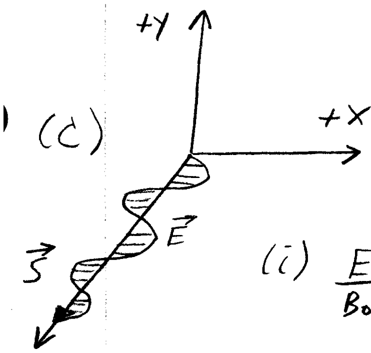
Because the atom emits a photon during an electron transition, $\Delta\ell = \pm 1$, so for an electron making a transition from $n=3$ to $n=1$, the only way it can do so is to go from $\ell=1$ to $\ell=0$, as shown at left.

Also, for $n=1$, $\ell=0$ only, so $m_\ell = 0$ only when $n=1$.

Since $\Delta m_\ell = 0, \pm 1$ only, the only allowed transitions for an electron going from $n=3$ to $n=1$ have:

$$\boxed{\begin{array}{lll} \ell=1 & \text{and} & m_\ell = 0 \\ \ell=1 & \text{and} & m_\ell = -1 \\ \ell=1 & \text{and} & m_\ell = +1 \end{array}}.$$

(c)



$\lambda = 3.50\,cm = 3.5\times10^{-2}\,m$

$E_0 = 275\,V/m$

$B = B_0 \sin(kx-\omega t)$

(i) $\dfrac{E_0}{B_0} = c \Rightarrow B_0 = \dfrac{E_0}{c} = \dfrac{275\,(V/m)}{3.0\times10^{8}\,m/S}$

$= 9.2\times10^{-7}\,\dfrac{V\cdot s}{m^2}$

$\therefore \boxed{B_0 = 9.2\times10^{-7}\,T}$.

Check units: $\dfrac{V}{m} = \dfrac{T\,m}{s}$ ✓

$k = \dfrac{2\pi}{\lambda} = \dfrac{2\pi}{3.5\times10^{-2}\,m} = \boxed{k = 180\,m^{-1}}$.

$\omega = 2\pi f = \dfrac{2\pi c}{\lambda} = kc = \boxed{\omega = 5.39\times10^{10}\,s^{-1}}$.

(ii) $\vec{S} = \dfrac{1}{\mu_0}\,\vec{E}\times\vec{B} = \dfrac{1}{\mu_0}\left[E_0 \sin(kx-\omega t)\,\hat{x}\right]\times\left[B_0 \sin(kx-\omega t)\,\hat{y}\right]$

$= \left(\dfrac{E_0 B_0}{\mu_0}\right)\left[\sin^2(kx-\omega t)\right]\hat{x}\times\hat{y}$

$= \left(\dfrac{275\,\frac{V}{m}\times 9.2\times10^{-7}\,T}{4\pi\times10^{-7}\,\frac{Tm}{A}}\right)\sin^2(kx-\omega t)\,\hat{z}$

$\boxed{\vec{S} = \left(200\,\dfrac{W}{m^2}\right)\left[\sin^2(kx-\omega t)\right]\hat{z}}$

Check units:
$W = Fd$
$J = Nm$
$W = \dfrac{Nm}{S}$
$\dfrac{V}{m} \neq \dfrac{A}{m} =$
$\dfrac{N}{\cancel{C}}\,\dfrac{\cancel{C}}{s\,m} = \dfrac{W}{m^2}$ ✓

$\dfrac{W}{m^2}\,\dfrac{s}{m} = \dfrac{Ws}{m} = \dfrac{N}{m^2}$

Averaged over one cycle, this is:

$I = S_{av} = \dfrac{E_0 B_0}{2\mu_0} = 100\,\dfrac{W}{m^2}$,

$\boxed{\text{in the } +\hat{z} \text{ direction}}$

(iii) For complete reflection,

$\boxed{P = \dfrac{2I}{c} = 6.67\times10^{-7}\,\dfrac{N}{m^2}}$.