Solutions to the Physics II mock exam FS 2021

1 Optical lens (8 Points)

(a) For the focal length of a lens, the following applies:

$$\frac{1}{f} = (\frac{n}{n_{\text{air}}} - 1) \cdot (\frac{1}{r_1} - \frac{1}{r_2}) \quad \textbf{(1 Point)}$$
$$= (\frac{1.45}{1} - 1) \cdot (\frac{1}{-30\text{ cm}} - \frac{1}{25\text{ cm}})$$
$$\Rightarrow f = -30.3\,\text{cm} \quad \textbf{(1 Point)}$$

(total 2 Points)

(b) From the lens equation $1/g + 1/b = 1/f$ we have:

$$b = \frac{gf}{g-f} \quad \textbf{(1 Point)}$$
$$= \frac{(80\,\text{cm}) \cdot (-30.3\,\text{cm})}{(80\,\text{cm}) - (-30.3\,\text{cm})}$$
$$= -22.0\,\text{cm} \quad \textbf{(1 Point)}$$

(total 2 Points)

(c) The magnification is:

$$V = -\frac{b}{g} \quad \textbf{(1 Point)}$$
$$= -\frac{-22\,\text{cm}}{80\,\text{cm}}$$
$$= 0.3 \quad \textbf{(1 Point)}$$

(total 2 Points)

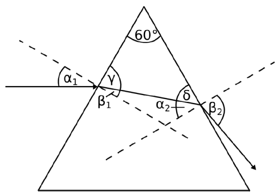
(d)
- Since $b < 0$, the image is virtual. **(1 Point)**
- Since $V > 0$, the image is upright. **(1 Point)**

(total 2 Points)

2 Prism (6 Points)

Calculating of the first refraction angle β_1 with $\alpha_1 = 30°$:

$$\frac{n_{\text{glass}}}{n_{\text{air}}} = \frac{\sin\alpha_1}{\sin\beta_1} \quad \textbf{(1 Point)}$$
$$\Rightarrow \beta_1 = \arcsin\left(\frac{\sin\alpha_1}{n_{\text{glass}}}\right)$$
$$= \beta_1 = 19.3° \quad \textbf{(1 Point)}$$



Knowing this angle, the incidence angle on the other side can be determined. **(1 Point)** for the correct drawing.

$$90° = \beta_1 + \gamma$$
$$\Rightarrow \gamma = 70.7° \quad \textbf{(0.5 Point)}$$
$$180° = \gamma + 60° + \delta$$
$$\Rightarrow \delta = 49.3°$$
$$90° = \alpha_2 + \delta$$
$$\Rightarrow \alpha_2 = 40.7° \quad \textbf{(0.5 Point)}$$

This incidence angle is now used to calculate the second refraction angle.

$$\frac{\sin\alpha_2}{\sin\beta_2} = \frac{n_{\text{air}}}{n_{\text{glass}}} \quad \textbf{(1 Point)}$$
$$\Rightarrow \beta_2 = \arcsin\left(n_{\text{glass}}\sin\alpha_2\right)$$
$$= \beta_2 = 79.9° \quad \textbf{(1 Point)}$$

(total 6 Points)

3 Photoelectric effect (8 Points)

(a) For the energy of an incident photon the following holds:

$$\begin{aligned} E_{Ph} &= hf = \frac{hc}{\lambda} \quad \textbf{(1 Point)} \\ &= \frac{6.626 \cdot 10^{-34}\ \text{Js} \cdot 2.9979 \cdot 10^{8}\ \text{m/s}}{300\ \text{nm}} \\ &= 4.13\ \text{eV} \quad \textbf{(1 Point)} \end{aligned}$$

(total 2 Points)

(b) The work of detachment of potassium can be calculated from the kinetic energies of photons and electrons:

$$\begin{aligned} W_{\text{detach}} &= E_{Ph} - E_{kin,e} \quad \textbf{(1 Point)} \\ &= 4.13\ \text{eV} - 2.03\ \text{eV} \\ &= 2.10\ \text{eV} \quad \textbf{(1 Point)} \end{aligned}$$

(total 2 Points)

(c) It is valid for the kinetic energy of the electrons:

$$\begin{aligned} E_{kin,e} &= hf - W_{\text{detach}} = \frac{hc}{\lambda} - W_{Abl} \quad \textbf{(1 Point)} \\ &= \frac{6.626 \cdot 10^{-34}\ \text{Js} \cdot 2.9979 \cdot 10^{8}\ \text{m/s}}{430\ \text{nm}} - 2.10\ \text{eV} \\ &= 0.78\ \text{eV} \quad \textbf{(1 Point)} \end{aligned}$$

(total 2 Points)

(d) For the cutoff wavelength:

$$\begin{aligned} \lambda_{\text{cutoff}} &= \frac{hc}{W_{\text{detach}}} \quad \textbf{(1 Point)} \\ &= \frac{6.626 \cdot 10^{-34}\ \text{Js} \cdot 2.9979 \cdot 10^{8}\ \text{m/s}}{2.1\ \text{eV}} \\ &= 590\ \text{nm} \quad \textbf{(1 Point)} \end{aligned}$$

(total 2 Points)

4 Radioactive decay (7 Points)

(a) The decay law applies

$$N(t) = N_0 e^{-\lambda t} \quad \textbf{(1 Point)}$$

where N_0 is initial quantity, N is the quantity that still remains after time t. In the half-life $t = T_{1/2}$, half of the nuclei decay, i.e. $N = N_0/2$, so that for the decay constant we have

$$\lambda = \frac{\ln 2}{T_{1/2}} \quad \textbf{(1 Point)}$$

For Po-210:

$$T_{1/2} = 138\,\mathrm{d} \approx 1.19 \cdot 10^7\,\mathrm{s} \quad \text{and} \quad \lambda = 5.82 \cdot 10^{-8}\,\mathrm{s}^{-1}$$

For $N_0 = 10^6$ nuclei and $t = 24\,\mathrm{h} = 86400\,\mathrm{s}$ one obtains the following according to the decay law

$$N(86400\text{ s}) \approx 995000$$

So in 24 h the decay:

$$\Delta N = N_0 - N \approx 5000 \text{ Kerne} \quad \textbf{(1 Point)}$$

The decay rate for $t = 1$ s is:

$$A = \frac{\Delta N}{t} \approx 0.06\,\mathrm{Bq} \quad \textbf{(1 Point)}$$

(Alternative calculation with $A = \lambda \cdot N(t)$ is possible).

(total 4 Points)

(b) From the decay law follows, with $\lambda = \ln 2/T_{1/2}$, for the activity as the number of nuclear decays per second:

$$A = -\frac{\mathrm{d}N}{\mathrm{d}t} = \lambda N_0 e^{-\lambda t} = \lambda N$$

thus the decay law is obtained in the form

$$A = A_0 e^{-\lambda t} = A_0 e^{-(\ln 2)t/T_{1/2}} \quad \textbf{(1 Point)}$$

With $A = A_F = 50\,\mathrm{kBq}$, $A_0 = 185\,\mathrm{kBq}$ and $t = nT_{1/2}$ (decay time), it follows that

$$A_0/A_F = e^{n \ln 2}$$
$$\rightarrow n = \frac{\ln(A_0/A_F)}{\ln 2} = 1.89 \quad \textbf{(1 Point)}$$

For Co-60 $T_{1/2} = 5.3\,\mathrm{a}$, therefore:

$$t = n \cdot T_{1/2} = 10.0 \text{ a} \quad \textbf{(1 point)}$$

(total 3 Points)