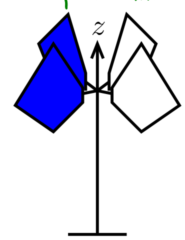
# tutorial #12 [particles and waves] .quiz

**1)** The radiometer shown in fig. 1 is made of four plates with one black side which absorbs light and one mirror side. These plates are connected to an axis which can rotate freely. We shine light from front to this radiometer.

mirror: i, p →; f, p ← ; each photon exchange 2p momentum

black: i, p →; f ; each photon exchange p momentum

**a)** Is there any force acting on each plate? Why?
**b)** If we look from above, this radiometer will rotate clockwise or counterclockwise? Why?
**c)** If the intensity of light is 1 kW/m$^2$, the area of each plate is 10 cm$^2$, and the lever arm for each plate is 3 cm, estimate the torque acting on this radiometer.



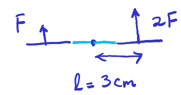




Figure 1: A radiometer.

a) Yes, photons are exchanging momentum.

b) Counterclockwise, mirror plates feel more force, almost double the black side.

c) $\tau = 2F\ell - F\ell = F\ell$, $\text{Power} = IA = 1\,\frac{kW}{m^2} \cdot 10\,cm^2 = 1\,W$,

$p = \frac{E}{c}$ for each photon $\rightarrow P_{tot} = \frac{E_{tot}}{c} \rightarrow F = \frac{\text{Power}}{c} = \frac{1\,W}{3\times10^8\,m/s} = 3\,nN \rightarrow \tau = 10^{-8}\,Nm.$

**2)** The interatomic spacing in a crystal of table salt is 0.282 nm. This crystal is being studied in a neutron diffraction experiment. How fast must a neutron, mass = $1.67 \times 10^{-27}$ kg, be moving to have a de Broglie wavelength of 0.282 nm?

$$\lambda = \frac{h}{p} \approx \frac{h}{mv} \rightarrow v = \frac{h}{\lambda m} = \frac{6.63\times10^{-34}\,J.s}{0.282\,nm \times 1.67\times10^{-27}\,kg} = 1.4\times10^{3}\,m/s .$$

$p \approx mv$ $(v \ll c)$.

**3)** Light with a wavelength of 95 nm shines on a selenium surface, which has a work function of 5.9 eV. The ejected electrons have some kinetic energy. Determine the maximum speed with which electrons are ejected. The mass of the electron is $m = 9.11 \times 10^{-31}$ kg.

$$K_{max} = hf - W = h\frac{c}{\lambda} - W \rightarrow v_{max} = \left[\frac{2}{m}\left(h\frac{c}{\lambda} - W\right)\right]^{1/2}$$

$$= 1.6\times10^{6}\,m/s .$$

$K \approx \frac{1}{2}mv^2$ as $v \ll c$.