

## EE 362 Electronic, Magnetic, & Opt. Prop. of Mat'ls Quiz 2 (Spring 2026)

Name KEY A

Instructions: Open book & notes. Place answers in indicated spaces and show all work for credit.

In free space, determine the frequency (Hz), kinetic energy (J & eV), and momentum (kg-m/s) of a photon of yellow light of wavelength 580 nm. If the photon encounters a resting electron, transferring all energy, find the velocity (m/s) of the electron afterward.

$$c = f\lambda \Rightarrow f = c/\lambda = 2.99792458 \times 10^8 / 580 \times 10^{-9} \\ \Rightarrow \underline{f = \nu = 5.1688355 \times 10^{14} \text{ Hz} = 516.884 \text{ THz}}$$

From section 2.1,

$$E = h\nu = 6.62607015 \times 10^{-34} (5.1688355 \times 10^{14}) \Rightarrow \underline{E = 3.424907 \times 10^{-19} \text{ J}}$$

$$E = 3.424907 \times 10^{-19} \text{ J} (1 \text{ eV} / 1.6021766 \times 10^{-19} \text{ J}) \Rightarrow \underline{E = 2.13766 \text{ eV}}$$

Per (2.2), the momentum of the photon is

$$p = \frac{h}{\lambda} = \frac{6.62607015 \times 10^{-34}}{580 \times 10^{-9}} \Rightarrow \underline{p = 1.142426 \times 10^{-27} \text{ kg-m/s}}$$

### Method 1

Problem statement said the photon transferred all its kinetic energy to the electron. That implies the photon would cease to exist, cannot have a photon with zero energy.

From classical physics, kinetic energy is  $E = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E}{m}}$ . Using the rest mass  $m_0$  of an electron, we get

$$v = \sqrt{\frac{2(3.424907 \times 10^{-19})}{9.1093837015 \times 10^{-31}}} \Rightarrow \underline{v = 867,151.3 \text{ m/s} = 8.67151 \times 10^5 \text{ m/s}}$$

### Method 2

What if the photon transferred all its momentum to the electron? Again, this implies the photon ceases to exist.

From classical physics, momentum is  $p = mv \Rightarrow v = p/m$ . Using the rest mass  $m_0$  of an electron, we get

$$v_1 = p/m_0 = 1.142426 \times 10^{-27} / 9.1093837015 \times 10^{-31} \Rightarrow \underline{v_1 = 1,254.12 \text{ m/s (different!?)}}$$

**Reality- It's NOT possible for a photon to transfer all its momentum and/or energy to a free electron as we cannot conserve both energy and momentum, only partial transfers are possible.**

$$\text{frequency} = \underline{5.16884 \times 10^{14} \text{ Hz} = 516.884 \text{ THz}} \quad \text{K.E.} = \underline{3.424907 \times 10^{-19} \text{ J} = 2.13766 \text{ eV}}$$

$$\text{momentum} = \underline{p = 1.142426 \times 10^{-27} \text{ kg-m/s}} \quad \text{velocity} = \underline{v = 867,151 \text{ m/s} = 8.67151 \times 10^5 \text{ m/s}}$$

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Name KEY B

Instructions: Open book & notes. Place answers in indicated spaces and show all work for credit.

In free space, determine the frequency (Hz), kinetic energy (J & eV), and momentum (kg-m/s) of a photon of blue light of wavelength 480 nm. If the photon encounters a resting electron, transferring all energy, find the velocity (m/s) of the electron afterward.

$$c = f\lambda \Rightarrow f = c/\lambda = 2.99792458 \times 10^8 / 480 \times 10^{-9} \\ \Rightarrow \underline{f = \nu = 6.245676 \times 10^{14} \text{ Hz} = 624.568 \text{ THz}}$$

From section 2.1,

$$E = h\nu = 6.62607015 \times 10^{-34} (6.245676 \times 10^{14}) \Rightarrow \underline{E = 4.13843 \times 10^{-19} \text{ J}}$$

$$E = 4.13843 \times 10^{-19} \text{ J} (1 \text{ eV} / 1.6021766 \times 10^{-19} \text{ J}) \Rightarrow \underline{E = 2.58300 \text{ eV}}$$

Per (2.2), the momentum of the photon is

$$p = \frac{h}{\lambda} = \frac{6.62607015 \times 10^{-34}}{480 \times 10^{-9}} \Rightarrow \underline{p = 1.38043 \times 10^{-27} \text{ kg-m/s}}$$

### Method 1

Problem statement said the photon transferred all its kinetic energy to the electron. That implies the photon would cease to exist, cannot have a photon with zero energy.

From classical physics, kinetic energy is  $E = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E}{m}}$ . Using the rest mass  $m_0$  of an electron, we get

$$v = \sqrt{\frac{2(4.13843 \times 10^{-19})}{9.1093837015 \times 10^{-31}}} \Rightarrow \underline{v = 953,209.4 \text{ m/s} = 9.53209 \times 10^5 \text{ m/s}}$$

### Method 2

What if the photon transferred all its momentum to the electron? Again, this implies the photon ceases to exist.

From classical physics, momentum is  $p = mv \Rightarrow v = p/m$ . Using the rest mass  $m_0$  of an electron, we get

$$v_2 = p/m_0 = 1.38043 \times 10^{-27} / 9.1093837015 \times 10^{-31} \Rightarrow v_2 = 1,515.39 \text{ m/s (different!?)}$$

**Reality- It's NOT possible for a photon to transfer all its momentum and/or energy to a free electron as we cannot conserve both energy and momentum, only partial transfers are possible.**

$$\text{frequency} = \underline{6.245676 \times 10^{14} \text{ Hz} = 624.568 \text{ THz}} \quad K.E. = \underline{4.13843 \times 10^{-19} \text{ J} = 2.58300 \text{ eV}}$$

$$\text{momentum} = \underline{p = 1.38043 \times 10^{-27} \text{ kg-m/s}} \quad \text{velocity} = \underline{v = 953,209.4 \text{ m/s} = 9.53209 \times 10^5 \text{ m/s}}$$