Midterm: Monday Feb 9, 2026 **Name:_______________**

Allowed: Formula sheet (given), calculator, 1 hour 50 minutes

PART 1 – answer questions **1-8** in pencil/pen here or in your exam booklet **then** use your scratch card:
One scratch = **100%**; two scratches **33%**; three scratches **25%** (part 1 total is 50%)
PART 2 – answer questions **9** & **10** in the exam booklet provided (each question here is worth 25%)

Qu's 1 & 2) Magnesium has a work function of 3.70 eV.

1) What is the approximate cut-off wavelength, $\lambda_{\text{cut-off}}$, of the incident light for electrons to be released, and do wavelengths λ greater or less than this value cause electron release?

A. $\lambda_{\text{cut-off}} \approx 590$ nm, if $\lambda < \lambda_{\text{cut-off}} \Rightarrow$ release electrons

B. $\lambda_{\text{cut-off}} \approx 520$ nm, if $\lambda < \lambda_{\text{cut-off}} \Rightarrow$ release electrons

C. $\lambda_{\text{cut-off}} \approx 420$ nm, if $\lambda > \lambda_{\text{cut-off}} \Rightarrow$ release electrons

D. $\lambda_{\text{cut-off}} \approx 340$ nm, if $\lambda < \lambda_{\text{cut-off}} \Rightarrow$ release electrons

E. $\lambda_{\text{cut-off}} \approx 295$ nm, if $\lambda > \lambda_{\text{cut-off}} \Rightarrow$ release electrons

2) With what maximum speed will electrons be emitted if the incident light has $\lambda = 280$ nm?

A. $510\ \text{kms}^{-1}$ **B.** $470\ \text{kms}^{-1}$ **C.** $370\ \text{kms}^{-1}$ **D.** $320\ \text{kms}^{-1}$ **E.** $280\ \text{kms}^{-1}$

3) Which of the following statements best describes what was discovered by correctly explaining *blackbody radiation*?

A. The formula for the spectral energy density inside a cavity can only be correctly derived if each electromagnetic wave of frequency *f* can have any energy, depending only on the amplitude of the electric field.
B. The formula for the spectral energy density inside a cavity can only be correctly derived if the total electromagnetic field inside the cavity has only one frequency, *f*.
C. The formula for the spectral energy density inside a cavity can only be correctly derived if each electromagnetic wave of frequency *f* has an energy given by $E = hf$.
D. The correct formula for the spectral energy density inside a cavity can only be derived if each electromagnetic wave of frequency *f* has *one* of a discrete set of energies, with values $0, hf, 2hf, \ldots$
E. The formula for the spectral energy density inside a cavity can only be correctly derived if the total electromagnetic field inside the cavity has one of a discrete number of frequencies, with value $0, f, 2f, \ldots$.

4) Light of wavelength 102 nm is observed from a hydrogen atom discharge lamp in the lab. What transition might produce this emission?

A. $n=4$ to $n=3$ **B.** $n=3$ to $n=1$ **C.** $n=1.13$ to $n=1$ **D.** $n=6$ to $n=1$ **E.** $n=5$ to $n=2$

Qu's 5 & 6) Suppose a particle with total energy of $1.5\ \text{eV}$ moves along the positive *x*-axis, experiencing a potential energy *U* given in eV and distance *x* given in nanometres, according to:

$$U(x)=\frac{1}{x^2}-\frac{2}{x}+2$$

5) By sketching this function, which of the following is the kinetic energy of the particle at $x=1\ \text{nm}$?

A. 0.1 eV **B.** 0.2 eV **C.** 0.3 eV **D.** 0.4 eV **E.** 0.5 eV

6) Which of the following statements about the particle experiencing this potential energy is most accurate?

A. The particle is *bound* and has turning points at $x=2\pm\sqrt{2}\ \text{nm}$.
B. The particle is *unbound* and has turning points at $x=2\pm\sqrt{2}\ \text{nm}$.
C. The particle is *unbound* and can travel to $x\rightarrow+\infty$.
D. The particle is *bound*, and a particle with double the total energy would also be bound.
E. The particle experiences a finite (non-zero) force at all locations of *x* where it is located.

7) Which of the following best represents the **three** lowest allowed energies of a proton in an infinite well, with the potential energy set to zero only between $x = 0$ and $x = 0.1\text{ nm}$?

A. 0.02 eV, 0.08 eV, 0.19 eV **B.** 0.06 eV, 0.24 eV, 0.52 eV **C.** 0.04 eV, 0.17 eV, 0.37 eV

D. 0.02 eV, 0.04 eV, 0.06 eV **E.** 0.0 eV, 0.08 eV, 0.19 eV

8) What are the S.I. units of the *probability density* for a single particle, $|\psi(x)|^2$?

A. kg^{-1} **B.** dimensionless **C.** m^{-1} **D.** $\text{m}^{-1/2}$ **E.** kgms^{-1}

PART II – answer <u>both</u> questions in exam booklet provided

9. We shall explore one solution to the *time dependent Schrödinger equation* (TDSE) for a free particle of mass m.

a) Carefully describe what is meant by the term *free particle*. Give an example of a particle that is *not* free.
b) Given the trial wave function $\Psi(x,t) = Ae^{i(kx-\omega t)}$, show that this satisfies the free particle TDSE provided that a particular relationship between ω and k is satisfied. What is this relationship between ω and k, and sketch ω on the vertical axis vs. k on the horizontal axis.
c) If the wave function for the free particle is in fact $\Psi(x,t) = A\exp\left(i\left(9.12\times10^{11}x - 2.64\times10^{16}t\right)\right)$, where the values and variables are in SI units, then what is the particle's momentum, total energy, and mass?

10. An electron is confined in an infinite well, in the ground state, with an energy of 0.15 eV.

a) What is the well's length?

b) If the wave function of the particle in this state is given by $\psi(x) = \sqrt{\frac{2}{L}}\sin\frac{\pi x}{L}$ inside the well (and zero outside of the well), then carefully sketch, on two labelled graphs with units directly above each other, both $\psi(x)$ and $|\psi(x)|^2$.
c) Find the probability that the electron is found within the *middle third* of the well (so between $x = L/3$ and $x = 2L/3$.
d) How does your answer in part (c) compare to the value if the particle behaved strictly according to classical mechanics?
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