Physics 228– Exam II
March 27, 2008
Profs. Coleman and Andrei

Your name sticker ⇒ with exam code

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TURN OFF CELLPHONES NOW!!!

1. The exam will last from 9:40 p.m. to 11:20 p.m. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.

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4. Enter 228 under COURSE, and your section number (see label above) under SEC.

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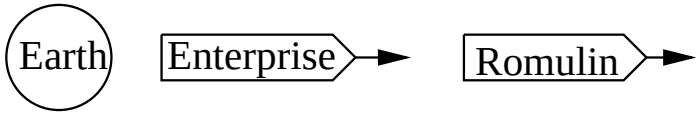
Possibly Useful Information

speed of light, c	3.00×10^{8} m/s
Planck's constant, h	6.626×10^{-34} J·s
hc	1240 eV-nm
Boltzmann's constant	1.380×10^{-23} J/K
Rydberg constant R_H	1.097×10^{7} m^{-1}
Bohr radius a_0	0.0529 nm
hydrogen ground state energy	-13.6 eV
elementary charge e	1.602×10^{-19} C
electron mass	9.11×10^{-31} kg
proton mass	1.673×10^{-27} kg
	1.007276 u
neutron mass	1.675×10^{-27} kg
	1.008665 u
atomic mass unit u	1.66×10^{-27} kg
	931.49 MeV/c^2
r_0 (nuclear radii $\sim r_0 A^{1/3}$)	1.2×10^{-15} m
visible light wavelengths	approx. 400-700 nm
1 meter	= 100 cm = 1000 mm
	$= 10^6$ μm $= 10^9$ nm
	$= 10^{12}$ pm $= 10^{15}$ fm
1 eV	1.602×10^{-19} J
1 keV	1000 eV

1. A pendulum inside a spaceship has a period of 4.0 s according to observers inside the ship. According to observers on earth, the pendulum has a period of 5.0 s. What is the speed v of the spaceship relative to earth?

   a) $0.30c \leq v < 0.50c$
   b) $v \geq 0.90c$
   c) $v < 0.30c$
   d) $0.70c \leq v < 0.90c$
   e) $0.50c \leq v < 0.70c$

2. The starship Enterprise travels at a speed of $0.9c$ relative to the Earth as it chases a Romulin vessel away from the Earth. ¿From the bridge of the Enterprise, Captain Picard sees the Romulin ship moving away at a velocity of $0.7c$. What is the velocity of the Romulin ship as measured by an observer on Earth?



   a) $1.6c$ b) $0.995c$ c) $0.63c$ d) $0.98c$
   e) $0.20c$

3. A navigational beacon in deep space broadcasts at a radio frequency of 50 MHz. A spaceship approaches the beacon with a relative velocity of 0.40c. The frequency of the beacon radio signal that is detected on the ship is closest to:

   a) 76
   b) 66
   c) 60
   d) 55
   e) 40

4. The total energy of an electron (rest mass = m) is three times its rest energy. What is the electron's momentum?

   a) $2mc$
   b) $3mc$
   c) $\sqrt{3}mc$
   d) $9mc$
   e) $\sqrt{8}mc$

5. When a photon undergoes Compton scattering off an electron initially at rest, it will emerge with the longest wavelength if it scatters though an angle of:

   a) $180°$
   b) $0°$
   c) $90°$
   d) $45°$
   e) $360°$

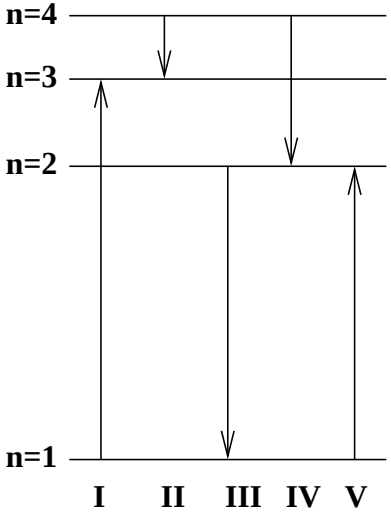
6. A photoelectric effect experiment is done using light of some wavelength λ_1. The photoelectrons are observed to have a maximum kinetic energy of 7.0 eV. If the experiment is repeated using light of twice that wavelength, i.e. $\lambda_2 = 2\lambda_1$, on the same metal, it is found that the maximum electron kinetic energy is 2.0 eV. What is the work function of the metal?

   a) 5.5 eV
   b) 3.0 eV
   c) 2.0 eV
   d) 4.3 eV
   e) 9.0 eV

7. The Balmer series corresponds to transitions to the n = 2 state of hydrogen. What is the ratio of the longest wavelength in the Balmer series to the shortest?

   a) 4
   b) 9
   c) 9/4
   d) 3/2
   e) 9/5

8. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the shortest wavelength?



a) I.
b) II.
c) III.
d) IV.
e) V.

9. A nonrelativistic electron and a nonrelativistic proton have the same de Broglie wavelength. Which of the following statements about these particles are accurate?

a) Both particles have the same momentum
b) The electron has less kinetic energy than the proton
c) The electron has more momentum than the proton
d) Both particles have the same kinetic energy.
e) Both particles have the same speed.

10. A laser pulse has a total energy of 1.2 J. If the wavelength of this radiation is 463 nm, how many photons are emitted in one pulse?

a) 2.2×10^{17}
b) 6.9×10^{19}
c) 1.1×10^{17}
d) 3.4×10^{19}
e) 2.8×10^{18}

11. A hydrogen atom makes a transition from a state of quantum number n = 2 to a state of quantum number n = 1. *According to the Bohr model*, which of the following statements are true?

- I: The energy of the atom decreases by a factor of 2
- II: The radius of the electron's orbit decreases by a factor of 2
- III: The orbital angular momentum decreases by a factor of 2

a) III is true; I and II are false
b) II and III are true; I is false
c) All three statements are false
d) II is true; I and III are false
e) I and III are true; II is false

12. The ground state energy of an electron in a one-dimensional infinite square well with zero potential energy in the interior and infinite potential energy at the walls is 2.0 eV. If the width of the well is doubled, the ground state energy will be:

a) 0.5 eV b) 1.0 eV c) 2.0 eV d) 4.0 eV
e) 8.0 eV

13. The atomic spacing in a single crystal of a typical metal is 0.3 nm. For an electron to be diffracted by such a crystal it should have a deBroglie wavelength comparable to this spacing. The kinetic energy of an electron that would best diffract from such a crystal is:

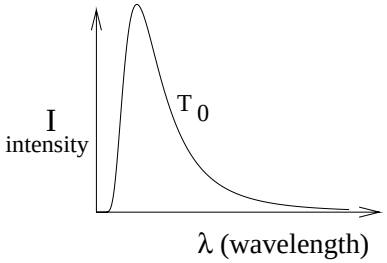
a) 5×10^{-5} eV
b) 0.1 eV
c) 17 eV
d) 1.22 MeV
e) 511 keV

14. Excited iron nuclei emit X-rays with 14.4 keV energy. The excited state of iron has a mean lifetime of 1×10^{-7}s. What is the approximate uncertainty in the energy of the emitted X-ray photon?

a) 8×10^{-11} eV
b) 4×10^{-10} eV
c) 2×10^{-14} eV
d) 7×10^{-9} eV
e) 7×10^{-3} eV

15. The figure shows a schematic plot of intensity I of blackbody radiation versus wavelength λ at temperature T_0. When the temperature increases above T_0 the wavelength corresponding to the maximum intensity will:

a) increase
b) decrease
c) increase initially, and eventually decrease
d) decrease initially and eventually increase
e) remains the same



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1. When a photon undergoes Compton scattering off an electron initially at rest, it will emerge with the longest wavelength if it scatters though an angle of:

   a) 360°
   b) 90°
   c) 180°
   d) 45°
   e) 0°

2. The Balmer series corresponds to transitions to the n = 2 state of hydrogen. What is the ratio of the longest wavelength in the Balmer series to the shortest?

   a) 4
   b) 9/4
   c) 9/5
   d) 3/2
   e) 9

3. A laser pulse has a total energy of 1.2 J. If the wavelength of this radiation is 463 nm, how many photons are emitted in one pulse?

   a) 2.2×10^{17}
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   a) 9.0 eV
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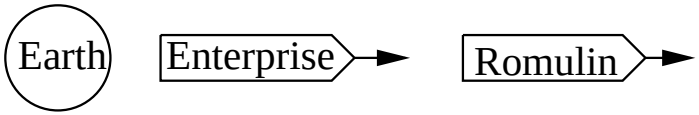
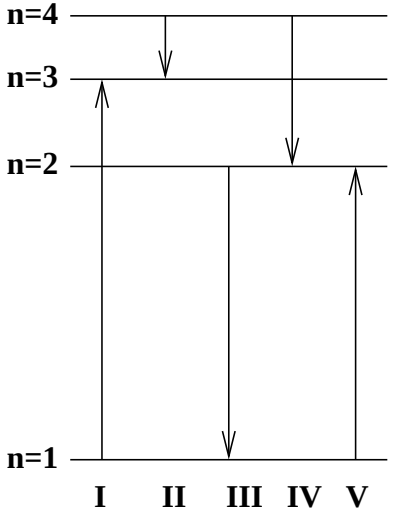
   c) 2.0 eV
   d) 5.5 eV
   e) 4.3 eV

5. The starship Enterprise travels at a speed of $0.9c$ relative to the Earth as it chases a Romulin vessel away from the Earth. ¿From the bridge of the Enterprise, Captain Picard sees the Romulin ship moving away at a velocity of $0.7c$. What is the velocity of the Romulin ship as measured by an observer on Earth?



   a) 0.63c b) $0.98c$ c) $0.20c$ d) $1.6c$
   e) $0.995c$

6. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the <u>emission</u> of a photon with the shortest wavelength?



   a) V.
   b) I.
   c) III.
   d) IV.
   e) II.

7. Excited iron nuclei emit X-rays with 14.4 keV energy. The excited state of iron has a mean lifetime of 1×10^{-7}s. What is the approximate uncertainty in the energy of the emitted X-ray photon?

a) 7×10^{-9} eV
b) 7×10^{-3} eV
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e) 2×10^{-14} eV

8. The figure shows a schematic plot of intensity I of blackbody radiation versus wavelength λ at temperature T_0. When the temperature increases above T_0 the wavelength corresponding to the maximum intensity will:

a) increase initially, and eventually decrease
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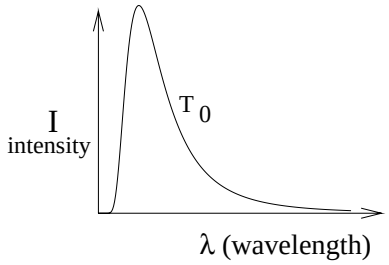

9. The total energy of an electron (rest mass = m) is three times its rest energy. What is the electron's momentum?

a) $9mc$
b) $\sqrt{3}mc$
c) $\sqrt{8}mc$
d) $2mc$
e) $3mc$

10. The ground state energy of an electron in a one-dimensional infinite square well with zero potential energy in the interior and infinite potential energy at the walls is 2.0 eV. If the width of the well is doubled, the ground state energy will be:

a) 4.0 eV b) 1.0 eV c) 2.0 eV d) 0.5 eV
e) 8.0 eV

11. A navigational beacon in deep space broadcasts at a radio frequency of 50 MHz. A spaceship approaches the beacon with a relative velocity of 0.40c. The frequency of the beacon radio signal that is detected on the ship is closest to:

a) 60
b) 55
c) 76
d) 40
e) 66

12. The atomic spacing in a single crystal of a typical metal is 0.3 nm. For an electron to be diffracted by such a crystal it should have a deBroglie wavelength comparable to this spacing. The kinetic energy of an electron that would best diffract from such a crystal is:

a) 511 keV
b) 17 eV
c) 1.22 MeV
d) 5×10^{-5} eV
e) 0.1 eV

13. A nonrelativistic electron and a nonrelativistic proton have the same de Broglie wavelength. Which of the following statements about these particles are accurate?

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b) Both particles have the same momentum
c) Both particles have the same speed.
d) The electron has more momentum than the proton
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14. A hydrogen atom makes a transition from a state of quantum number n = 2 to a state of quantum number n = 1. *According to the Bohr model*, which of the following statements are true?

- I: The energy of the atom decreases by a factor of 2
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15. A pendulum inside a spaceship has a period of 4.0 s according to observers inside the ship. According to observers on earth, the pendulum has a period of 5.0 s. What is the speed v of the spaceship relative to earth?

a) $0.70\text{c} \leq v < 0.90\text{c}$
b) $v \geq 0.90\text{c}$
c) $0.50\text{c} \leq v < 0.70\text{c}$
d) $0.30\text{c} \leq v < 0.50\text{c}$
e) $v < 0.30\text{c}$

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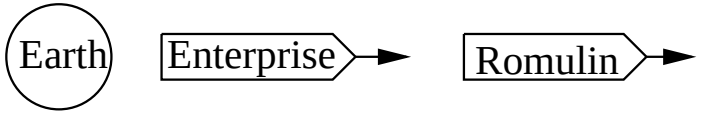

   a) $0.995c$ b) $0.98c$ c) 0.63c d) $0.20c$
   e) $1.6c$

3. A laser pulse has a total energy of 1.2 J. If the wavelength of this radiation is 463 nm, how many photons are emitted in one pulse?

   a) 2.8×10^{18}
   b) 6.9×10^{19}
   c) 2.2×10^{17}
   d) 1.1×10^{17}
   e) 3.4×10^{19}

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5. The Balmer series corresponds to transitions to the n = 2 state of hydrogen. What is the ratio of the longest wavelength in the Balmer series to the shortest?

   a) 9/5
   b) 9
   c) 3/2
   d) 4
   e) 9/4

6. The ground state energy of an electron in a one-dimensional infinite square well with zero potential energy in the interior and infinite potential energy at the walls is 2.0 eV. If the width of the well is doubled, the ground state energy will be:

   a) 4.0 eV b) 1.0 eV c) 2.0 eV d) 8.0 eV
   e) 0.5 eV

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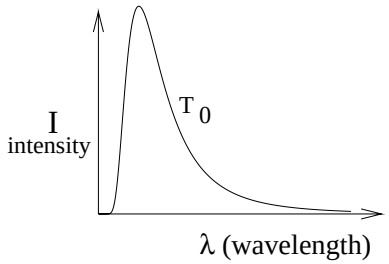

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b) $0.30\text{c} \leq v < 0.50\text{c}$
c) $v < 0.30\text{c}$
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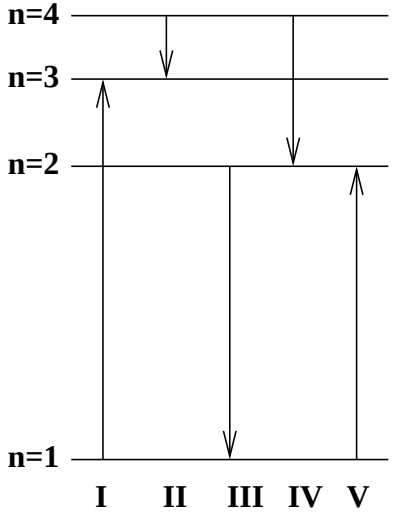

a) IV.
b) II.
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2. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.

3. Under STUDENT # enter your 9-digit Identification Number.

4. Enter 228 under COURSE, and your section number (see label above) under SEC.

5. Under CODE enter the exam code given above.

6. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.

7. There are 15 multiple-choice questions on the exam. For each question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. At the end of the exam, **hand in the answer sheet and the cover page**. Retain this question paper for future reference and study.

8. When you are asked to open the exam, make sure that your copy contains all 15 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.

9. Please **SIGN the cover sheet under your name sticker.** A proctor will check your name sticker and your student ID sometime during the exam. Please have them ready.

10. Good luck!

Possibly Useful Information

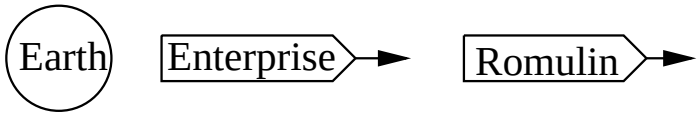
speed of light, c	3.00×10^{8} m/s
Planck's constant, h	6.626×10^{-34} J·s
hc	1240 eV-nm
Boltzmann's constant	1.380×10^{-23} J/K
Rydberg constant R_H	1.097×10^{7} m^{-1}
Bohr radius a_0	0.0529 nm
hydrogen ground state energy	-13.6 eV
elementary charge e	1.602×10^{-19} C
electron mass	9.11×10^{-31} kg
proton mass	1.673×10^{-27} kg
	1.007276 u
neutron mass	1.675×10^{-27} kg
	1.008665 u
atomic mass unit u	1.66×10^{-27} kg
	931.49 MeV/c^2
r_0 (nuclear radii $\sim r_0 A^{1/3}$)	1.2×10^{-15} m
visible light wavelengths	approx. 400-700 nm
1 meter	= 100 cm = 1000 mm
	$= 10^6$ μm $= 10^9$ nm
	$= 10^{12}$ pm $= 10^{15}$ fm
1 eV	1.602×10^{-19} J
1 keV	1000 eV

1. A hydrogen atom makes a transition from a state of quantum number n = 2 to a state of quantum number n = 1. *According to the Bohr model*, which of the following statements are true?

   - I: The energy of the atom decreases by a factor of 2
   - II: The radius of the electron's orbit decreases by a factor of 2
   - III: The orbital angular momentum decreases by a factor of 2

   a) All three statements are false
   b) II is true; I and III are false
   c) II and III are true; I is false
   d) I and III are true; II is false
   e) III is true; I and II are false

2. The starship Enterprise travels at a speed of $0.9c$ relative to the Earth as it chases a Romulin vessel away from the Earth. ¿From the bridge of the Enterprise, Captain Picard sees the Romulin ship moving away at a velocity of $0.7c$. What is the velocity of the Romulin ship as measured by an observer on Earth?

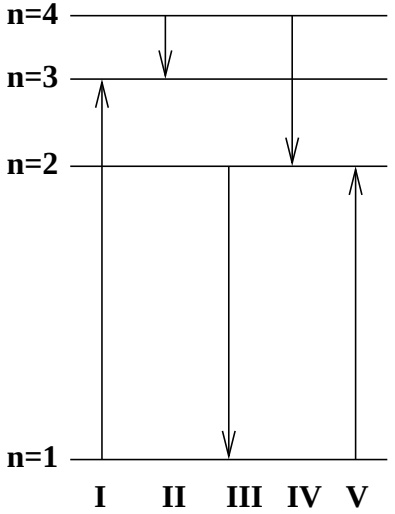


   a) $0.995c$ b) $0.20c$ c) $1.6c$ d) $0.98c$
   e) 0.63c

3. The total energy of an electron (rest mass = m) is three times its rest energy. What is the electron's momentum?

   a) $9mc$
   b) $\sqrt{3}mc$
   c) $\sqrt{8}mc$
   d) $2mc$
   e) $3mc$

4. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the <u>emission</u> of a photon with the shortest wavelength?



   a) V.
   b) I.
   c) IV.
   d) III.
   e) II.

5. A photoelectric effect experiment is done using light of some wavelength λ_1. The photoelectrons are observed to have a maximum kinetic energy of 7.0 eV. If the experiment is repeated using light of twice that wavelength, i.e. $\lambda_2 = 2\lambda_1$, on the same metal, it is found that the maximum electron kinetic energy is 2.0 eV. What is the work function of the metal?

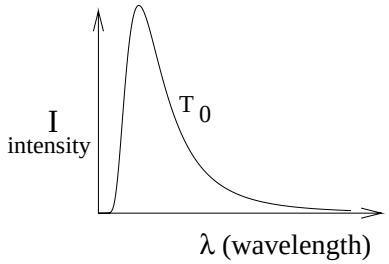
   a) 3.0 eV
   b) 4.3 eV
   c) 5.5 eV
   d) 2.0 eV
   e) 9.0 eV

6. Excited iron nuclei emit X-rays with 14.4 keV energy. The excited state of iron has a mean lifetime of 1×10^{-7}s. What is the approximate uncertainty in the energy of the emitted X-ray photon?

a) 4×10^{-10} eV
b) 7×10^{-9} eV
c) 7×10^{-3} eV
d) 2×10^{-14} eV
e) 8×10^{-11} eV

7. The figure shows a schematic plot of intensity I of blackbody radiation versus wavelength λ at temperature T_0. When the temperature increases above T_0 the wavelength corresponding to the maximum intensity will:

a) decrease initially and eventually increase
b) remains the same
c) increase initially, and eventually decrease
d) increase
e) decrease



8. A navigational beacon in deep space broadcasts at a radio frequency of 50 MHz. A spaceship approaches the beacon with a relative velocity of 0.40c. The frequency of the beacon radio signal that is detected on the ship is closest to:

a) 40
b) 60
c) 55
d) 66
e) 76

9. The Balmer series corresponds to transitions to the n = 2 state of hydrogen. What is the ratio of the longest wavelength in the Balmer series to the shortest?

a) 4
b) 9/5
c) 9/4
d) 3/2
e) 9

10. A pendulum inside a spaceship has a period of 4.0 s according to observers inside the ship. According to observers on earth, the pendulum has a period of 5.0 s. What is the speed v of the spaceship relative to earth?

a) $0.70\text{c} \leq v < 0.90\text{c}$
b) $0.50\text{c} \leq v < 0.70\text{c}$
c) $0.30\text{c} \leq v < 0.50\text{c}$
d) $v < 0.30\text{c}$
e) $v \geq 0.90\text{c}$

11. When a photon undergoes Compton scattering off an electron initially at rest, it will emerge with the longest wavelength if it scatters though an angle of:

a) 45°
b) 0°
c) 90°
d) 360°
e) 180°

12. A laser pulse has a total energy of 1.2 J. If the wavelength of this radiation is 463 nm, how many photons are emitted in one pulse?

a) 2.2×10^{17}
b) 3.4×10^{19}
c) 1.1×10^{17}
d) 6.9×10^{19}
e) 2.8×10^{18}

13. A nonrelativistic electron and a nonrelativistic proton have the same de Broglie wavelength. Which of the following statements about these particles are accurate?

a) The electron has more momentum than the proton
b) Both particles have the same speed.
c) The electron has less kinetic energy than the proton
d) Both particles have the same kinetic energy.
e) Both particles have the same momentum

14. The ground state energy of an electron in a one-dimensional infinite square well with zero potential energy in the interior and infinite potential energy at the walls is 2.0 eV. If the width of the well is doubled, the ground state energy will be:

a) 1.0 eV b) 2.0 eV c) 8.0 eV d) 0.5 eV
e) 4.0 eV

15. The atomic spacing in a single crystal of a typical metal is 0.3 nm. For an electron to be diffracted by such a crystal it should have a deBroglie wavelength comparable to this spacing. The kinetic energy of an electron that would best diffract from such a crystal is:

a) 0.1 eV
b) 511 keV
c) 1.22 MeV
d) 17 eV
e) 5×10^{-5} eV