State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2018
Exam number: 036003, 657
Attachment: Data and formulas for 5-point Physics
English translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ח, 2018
מספר השאלון: 036003, 657
נספח: נוסחאות ונתונים בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

Physics

Radiation and Matter

For 5 points

Instructions for examinees

א. Duration of the exam: Two hours.

ב. Exam structure and breakdown of points:
This exam has five questions. Answer three of them only.

Each question – $33\frac{1}{3}$ points; $3 \times 33\frac{1}{3} = 100$ points

ג. Material that may be used during the exam:
(1) A calculator.
(2) The physics formulas and data attached to this exam.
(3) A Hebrew-foreign language / foreign language-Hebrew dictionary.

ד. Special instructions:
(1) Answer the number of questions that you are asked to answer. Answers to additional questions will not be graded. (The answers will be graded in the order they appear in the answer booklet.)

(2) When answering questions that require calculations, write out the formulas that you use. Whenever you use a symbol that does not appear on the formula sheet, write out the meaning of that symbol in words. Before you perform your calculations, insert the appropriate values into the formulas.
Write your final answer in the appropriate units. If you do not write out the formula or do not write out the formula with the inserted values or do not write the units, points may be subtracted from your score.

(3) When asked to express a magnitude using data from the question, write a mathematical expression that includes some or all of the data given to you in the question.
If necessary, you may also use basic constants, such as the free-fall acceleration *g* or the speed of light *c*.

(4) In your calculations, use the value 10 m/s^2 for the magnitude of free-fall acceleration.

(5) Write your answers in pen. Writing in pencil or erasing with White-Out will preclude any possibility of appealing your score. Use pencil for sketches only.

Write in the answer booklet only, on separate pages, everything you want to write as a draft (notes, calculations, etc.). Write the word "טיוטה" at the top of each draft page. Writing any sort of drafts on pages outside of the answer booklet may lead to the disqualification of your exam!

Good Luck!

פיזיקה

קרינה וחומר

לתלמידי 5 יחידות לימוד

הוראות לנבחן

א. משך הבחינה: שעתיים.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה חמש שאלות, ומהן עליך לענות על שלוש שאלות בלבד.

לכל שאלה — $33\frac{1}{3}$ נקודות; $3 \times 33\frac{1}{3} = 100$ נקודות

ג. חומר עזר מותר בשימוש:
(1) מחשבון.
(2) נספח נוסחאות ונתונים בפיזיקה המצורף לשאלון.
(3) מילון עברי-לועזי / לועזי-עברי.

ד. הוראות מיוחדות:
(1) ענה על מספר שאלות כפי שהתבקשת. תשובות לשאלות נוספות לא ייבדקו.
(התשובות ייבדקו לפי סדר הופעתן במחברת הבחינה.)

(2) בפתרון שאלות שנדרש בהן חישוב, רשום את הנוסחאות שאתה משתמש בהן. כאשר אתה משתמש בסימן שאינו בדפי הנוסחאות, כתוב במילים את פירוש הסימן.
לפני שאתה מבצע פעולות חישוב, הצב את הערכים המתאימים בנוסחאות.
רשום את התוצאה שקיבלת ביחידות המתאימות.
אי-רישום הנוסחה או אי-ביצוע ההצבה או אי-רישום יחידות עלולים להפחית נקודות מן הציון.

(3) כאשר אתה נדרש להביע גודל באמצעות נתוני השאלה, רשום ביטוי מתמטי הכולל את נתוני השאלה או את חלקם;
במקרה הצורך אפשר להשתמש גם בקבועים בסיסיים, כגון תאוצת הנפילה החופשית g או מהירות האור c.

(4) בחישוביך השתמש בערך 10 m/s^2 לתאוצת הנפילה החופשית.

(5) כתוב את תשובותיך בעט. כתיבה בעיפרון או מחיקה בטיפקס לא יאפשרו ערעור. מותר להשתמש בעיפרון לסרטוטים בלבד.

כתוב במחברת הבחינה בלבד, בעמודים נפרדים, כל מה שברצונך לכתוב כטיוטה (ראשי פרקים, חישובים וכדומה). רשום "טיוטה" בראש כל עמוד טיוטה. רישום טיוטות כלשהן על דפים שמחוץ למחברת הבחינה עלול לגרום לפסילת הבחינה!

בהצלחה!

Questions

Answer three of the questions 1-5.

(Each question – $33\frac{1}{3}$ points; the point value of each item is given at the end of the item.)

1. The following diagram is a sketch of an interference pattern. The pattern was created by a collimated beam of monochromatic light that passed through a pair of parallel slits in an opaque panel. The wavelength of the beam is λ.

The beam struck the panel in a direction perpendicular to the plane of the slits, and the pattern was obtained on a screen that was parallel to the plane of the slits.

The bands of light obtained are labeled with the letters א-ט. Light band ה is the middle band.

א. Of the light bands א-ט, which light band (or bands) received light from one of the slits that traveled a path three wavelengths longer than the light that came from the other slit? Explain your answer. (7 points)

ב. Which place (or places) received light from one of the slits that traveled a path 1.5 wavelengths longer than the light that came from the other slit?
In your answer, use the letters that represent the light bands. (7 points)

The distance between the slits is d = 0.2 mm, and the distance of the screen from the plane of the slits is 1.2 m.

A ruler was added at the bottom of the sketch of the interference pattern. The scale of the ruler is in centimeters.

ג. Calculate the width of the light band in such a way that the relative error in measurement will be as small as possible. Give a detailed answer. (6 points)

ד. Calculate the wavelength of the light beam. (7 points)

ה. Explain why it is preferable to use a diffraction grating instead of a pair of slits, in order to measure the wavelength as precisely as possible. (3 points)

Given: a diffraction grating in which the distance between each pair of adjacent slits is equal to the distance d between the pair of slits presented in the question.

ו. Determine whether the distance between the maxima in the pattern obtained from the pair of slits is greater than, equal to, or less than, the distance between the principal maxima in the pattern obtained from the diffraction grating. Explain your answer. ($3\frac{1}{3}$ points)

/Continued on page 3/

2. The cathode [פולט] of a photoelectric cell was illuminated by three light beams in succession.
The wavelengths of the beams were: $\lambda_1 = 200\text{nm}$, $\lambda_2 = 450\text{nm}$, $\lambda_3 = 650\text{nm}$.
The threshold wavelength (corresponding to the threshold frequency) is $\lambda_0 = 539\text{nm}$.

א. For each of the beams, determine whether a current was generated in the photoelectric cell. If not, explain why. (7 points)

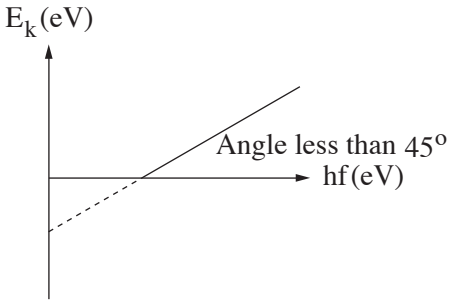
ב. Define the concept "work function" (bond energy) of a metal. (6 points)

ג. Calculate the work function of the metal that the cathode is made of. ($7\frac{1}{3}$ points)

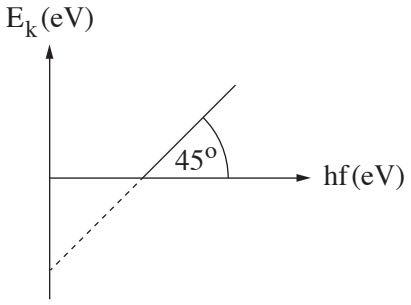
ד. Calculate the frequency of light that will cause emission of electrons that have a maximum kinetic energy of $E_k = 0.5\text{eV}$. (7 points)

Graphs I-IV below describe kinetic energy of an electron $E_k(\text{eV})$ as a function of photon energy $hf(\text{eV})$. The two axes are drawn to the same scale.

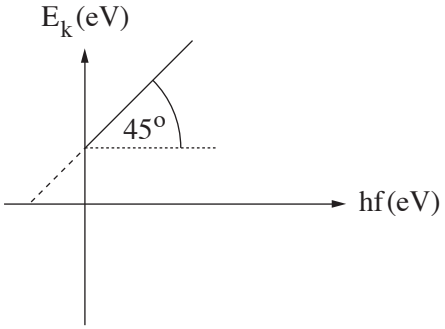
Graph II



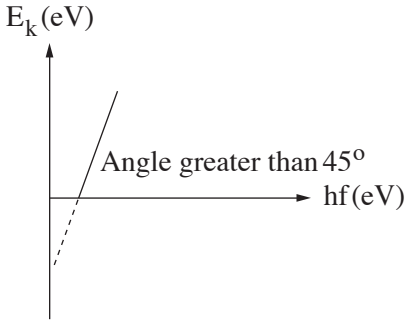
Graph I



Graph IV



Graph III



ה. **(1)** Determine which graph correctly describes the dependence of the kinetic energy of an electron emitted from the cathode on the energy of a photon that struck the cathode.

(2) Copy the correct graph to your answer booklet.
Add numeric values to this graph at the points where the (linear) curve intersects the horizontal axis (hf) and the vertical axis (E_k). Explain your considerations.
(6 points)

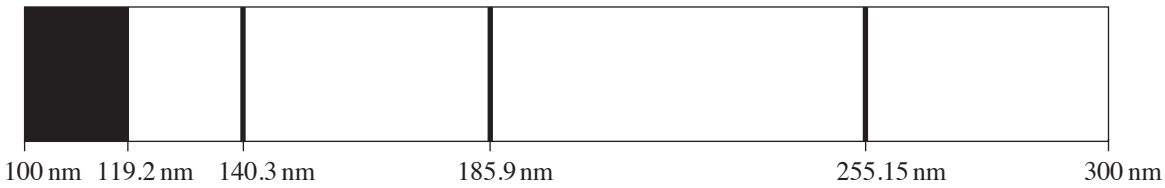
/Continued on page 4/

3. Researchers conducted an experiment to measure the energy levels of a mercury atom.

To do this, they projected ultraviolet radiation through a tube containing a low-density gas of mercury atoms. All the mercury atoms were at ground state.

The wavelengths of the ultraviolet radiation they used were in the range 100nm – 300nm.

Using a spectrometer, the researchers obtained the absorption spectrum of the mercury atoms shown in the following diagram:



The absorption spectrum includes a dark band in the range 100nm – 119.2nm and three discrete dark spectral lines, corresponding to wavelengths 140.3nm, 185.9nm, and 255.15nm.

א. Explain why dark lines are always obtained in the absorption spectrum. (6 points)

ב. Calculate the ionization energy of the mercury atoms. (6 points)

ג. In your answer booklet, sketch a diagram of the four energy levels of the mercury atom that were obtained in the experiment, and calculate the energy of <u>each</u> level.
<u>Show detailed calculations</u>. (8 points)

ד. Calculate the maximum velocity of the electrons that were emitted from the mercury atoms in this experiment. (6 points)

The researchers also calculated the emission spectrum of the mercury atoms for the energy levels obtained in the experiment.

ה. **(1)** Add arrows to the diagram you drew in Item ג representing all the spectral lines of the emission spectrum.

(2) Calculate the energy of the emitted photons whose wavelengths are in the visible light range (400nm – 700nm).

($7\frac{1}{3}$ points)

/Continued on page 5/

4. Given: the nucleus $^4_2\mathrm{He}$ of the isotope helium-4.

א. Why does this nucleus remain stable despite the repulsive electrical forces exerted inside it? (8 points)

ב. Give an example of a nucleus that is a different isotope of helium (even if this isotope does not actually exist). (5 points)

ג. Let us call the nucleus $^4_2\mathrm{He}$ "particle system in state 1". We disassemble the nucleus $^4_2\mathrm{He}$ until all its components are at rest far away from each other. Let us call this particle system "particle system in state 2".

Is the energy of the particle system in state 1 greater than, less than, or equal to the energy of the system in state 2? Of the answers 1-4 below, copy the correct answer to your answer booklet, and explain your reasoning.

1. The energy of the particle system in state 1 is greater than that which is in state 2.

2. The energy of the particle system in state 1 is equal to that which is in state 2.

3. The energy of the particle system in state 1 is less than that which is in state 2.

4. It cannot be determined, because the answer depends on the state chosen for the zero energy level.

(5 points)

Given: The atomic mass of $^4_2\mathrm{He}$ is $M\left(^4_2\mathrm{He}\right) = 4.002602\mathrm{u}$,

an electron's mass is $m_e = 0.000549\mathrm{u}$, a proton's mass is $m_p = 1.007276\mathrm{u}$,

and a neutron's mass is $m_n = 1.008665\mathrm{u}$.

ד. Calculate the nuclear binding energy [אנרגיית הקשר הגרעינית] of the nucleus of the helium isotope $^4_2\mathrm{He}$. (11 points)

ה. Given: two different nuclei. How can we determine which of the nuclei is more stable? Of the answers 1-4 below, copy the correct answer to your answer booklet.

You do not need to explain.

1. By the nuclear binding energy.

2. By the nuclear binding energy divided by the number of nucleons.

3. By the nuclear binding energy divided by the number of protons.

4. By the number of nucleons.

($4\frac{1}{3}$ points)

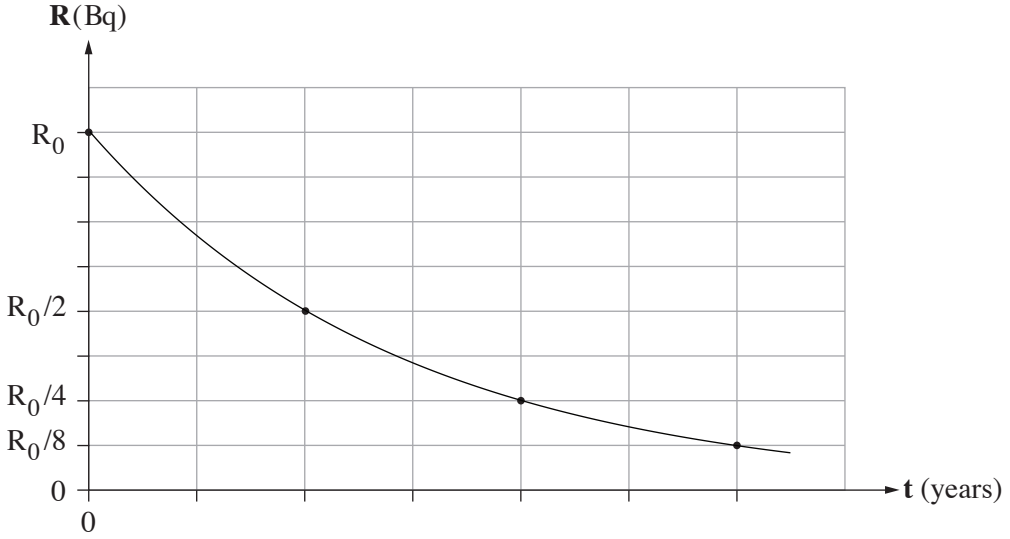
/Continued on page 6/

5. Natural strontium is a stable metallic element that was discovered in 1790. The radioactive isotope $^{90}_{38}Sr$ was discovered during nuclear experiments conducted in the 1940s.

א. What is the meaning of the numbers 38 and 90 in the notation $^{90}_{38}Sr$?
(6 points)

Two experiments were conducted, Experiment I and Experiment II.

Experiment I was conducted on a sample of $^{90}_{38}Sr$ of mass 2 grams. The half-life of this sample is 29 years. The following graph shows the activity R (in Bq – disintegrations per second) as a function of time t (in years) for this sample.



ב. Calculate after how much time the activity dropped to $\frac{R_0}{8}$. Show your calculation in detail. (6 points)

ג. Calculate (approximately) the number of nuclei in the sample at time $t = 0$ for this sample whose mass is 2 grams. (6 points)

ד. **(1)** Calculate the decay constant, in units of $\frac{1}{s}$.

(2) Calculate the activity R_0 (the activity at time $t = 0$).

($8\frac{1}{3}$ points)

Experiment II was conducted on a sample of the isotope $^{90}_{38}Sr$ whose mass was 1 gram.

ה. Copy the graph to your answer booklet, and label the curve with the number I.
Add the curve for Experiment II to the same set of axes in your answer booklet, and label the curve with the number II. (7 points)

Good Luck!

בהצלחה!