State of Israel
Ministry of Education

Type of exam:
א. *Bagrut* for high schools
ב. *Bagrut* for external students
Exam date: Summer 2016
Exam number: 036003, 657
Attachment: Data and formulas for 5-point Physics
English translation (3)

Physics

Radiation and Matter

For 5 points

Instructions for examinees

א. Duration of the exam: 105 minutes

ב. Exam structure and breakdown of points:
This exam contains five questions; you must answer only three of them.
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 data and physics formulas 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) In the solutions to 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. In your answers, write the appropriate units. If you do not write out the formula or do not write out the formula with the inserted values or if you 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 g for free-falling acceleration or c for the speed of light.
(4) In your calculations, use the value 10 m/s^2 for free-falling acceleration.
(5) Write your answers in pen. Writing in pencil or erasing with White-Out will prohibit 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" on 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!

מדינת ישראל
משרד החינוך
סוג הבחינה:
א. בגרות לבתי ספר על-יסודיים
ב. בגרות לנבחנים אקסטרניים
מועד הבחינה: קיץ תשע"ו, 2016
מספר השאלון: 657, 036003
נספח: נוסחאות ונתונים בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

פיזיקה

קרינה וחומר

לתלמידי 5 יחידות לימוד

הוראות לנבחן

א. משך הבחינה: שעה ושלושה רבעים (105 דקות).

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 מהציון.
(3) כאשר אתה נדרש להביע גודל באמצעות נתוני השאלה, רשום ביטוי מתמטי שיכלול 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. השתמש 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.)

1. Figure 1 (below) is a sketch of a ripple tank [אמבט גלים] in which two small balls, S_1 and S_2, are vibrating at a frequency f = 10 Hz. The two balls are sources of waves that are in phase with one another [שווי מופע]. The circles presented as solid lines represent the crests of the waves at a given moment and the circles presented as dotted lines represent the troughs of the waves at that same moment. The distance between Ball S_1 and Ball S_2 is 6 cm.

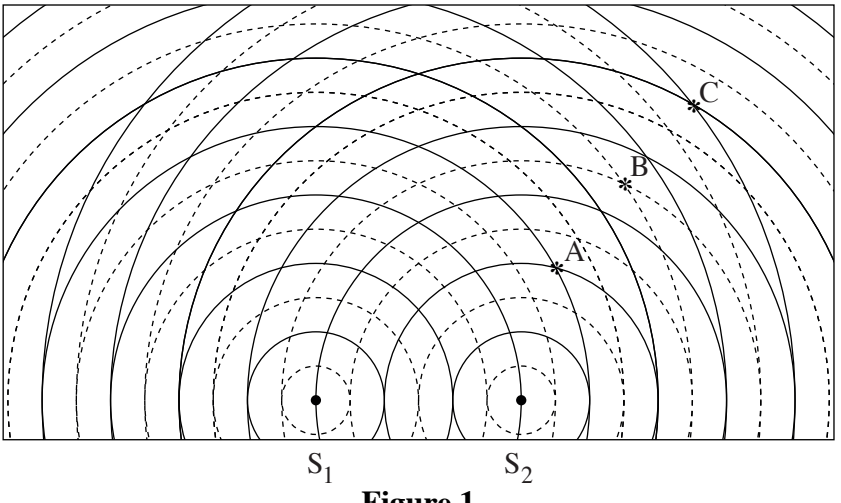


Figure 1

א. Use Figure 1 to find the wavelength λ of the waves produced in the tank. Show detailed calculations. (5 points)

ב. Calculate the velocity v of the waves in the tank. (4 points)

ג. Answer Sub-items (1) and (2) for each of the points A, B and C labeled in Figure 1.

(1) Express the following distances in terms of the wavelength λ: $AS_1 - AS_2$, $BS_1 - BS_2$, and $CS_1 - CS_2$.

(2) Based on the distances that you found, determine the type of interference (constructive / destructive / other) at each point. Explain your answers.

(12 points)

/Continued on page 3/

ד. Point D, which is not labeled in the figure, is located on a second-order maximum line.
Given: The distance between Point D and the source S_2 is 8.2 cm.
Calculate the distance between Point D and the source S_1.
Note: There are two possible answers. Find both of them. (6 points)

Figure 2 (below) is a photograph of another ripple tank.
Given: The frequency of each of the two sources is f = 10 Hz.

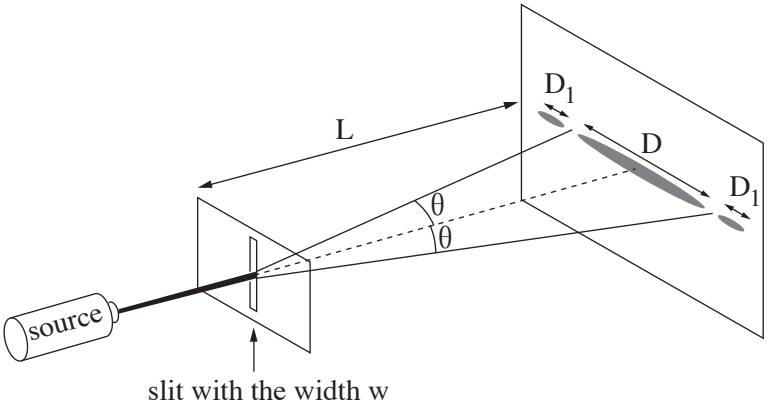
Figure 2

The tank was photographed a second time, 0.55 seconds after the first photo was taken. The second photo is not shown.

ה. **(1)** Is the location of the gray bands in the second photo different from their location in the first photo? Explain your answer.
(2) Is the location of the black areas in the second photo different from their location in the first photo? Explain your answer.
($6\frac{1}{3}$ points)

/Continued on page 4/

2. The diffraction of light can be explained only by the wave model of light. When a narrow beam of monochromatic light passes through a rectangular slit (see figure), a characteristic diffraction pattern is seen on a screen.
Note: The figure below is not drawn to exact scale (L >> D).



א. Name three parameters that affect the width D of the central spot of light seen on the screen. (6 points)

In a physics lab, students performed a series of experiments to investigate diffraction.
Given: The distance between the slit and the screen is L = 1.7 m.
The collected measurement data are presented in the table below.

0.15	0.10	0.08	0.04	**w** (mm)
14	24	26	54	**D** (mm)
6.7	10	12.5	25	$\frac{\mathbf{1}}{\mathbf{w}}$ $(\frac{1}{\text{mm}})$

ב. In your answer booklet, sketch a graph of $\frac{1}{w}$ as a function of D. (11 points)

ג. Assume that the angle θ is small (sin θ ≈ tan θ). Refer to the graph that you drew and calculate the wavelength, λ, of the light emitted from the light source. (7 points)

ד. Calculate the width of the first-order spot of light, D1, when the width of the slit is w = 0.04 mm. (5 points)

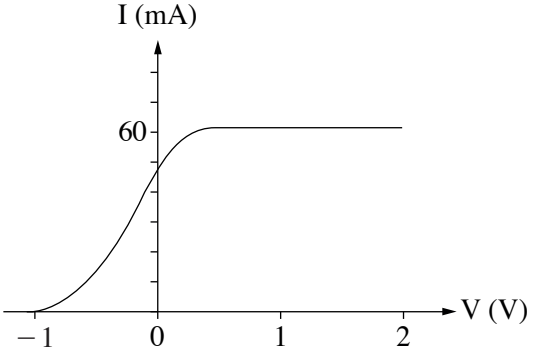
ה. What are two changes that will occur in the central bright spot, if the source of monochromatic light is replaced by a source of white light? Explain your answer. ($4\frac{1}{3}$ points) /Continued on page 5/

3. Physics students conducted three experiments, A, B and C, to study the photoelectric effect. The same photoelectric cell was used for all three experiments.

In Experiment A, they used a source that emitted radiation with a frequency $f = 7 \cdot 10^{14}$ Hz and a power P = 1 W.

א. Calculate the number of photons emitted by the source over one minute. (7 points)

The photoelectric cell used in Experiment A is described by Graph 1 (below).



Graph 1

Use the graph to answer Items ב through ד.

ב. Calculate the number of photons that caused electrons to be emitted from the cathode over one minute. (7 points)

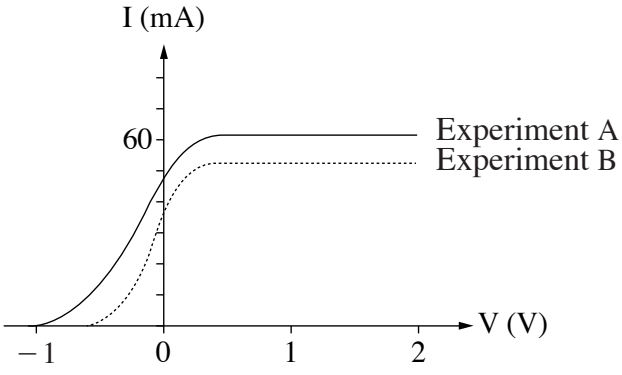
ג. Find the maximum kinetic energy of the emitted electrons. Explain your answer. (6 points)

ד. Calculate the maximum wavelength of radiation that can cause electrons to be emitted from this cathode. (8 points)

(Note: Item ה for this question is on the next page.)

/Continued on page 6/

ה. Graph 2 shows the results of two of the three experiments: Experiment A, which is described at the beginning of Question 3, and Experiment B.



Graph 2

(1) Was the frequency of the radiation emitted by the source that the students used in Experiment B less than, more than or equal to the frequency of the radiation emitted by the source used in Experiment A?
Explain your answer.

In Experiment C, the students moved the source of radiation used in Experiment B closer to the photoelectric cell, which increased the intensity of the light that hit the cathode.

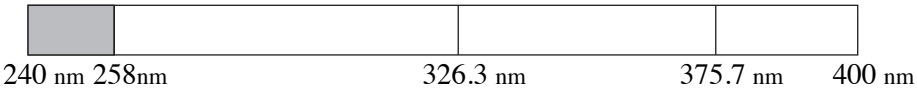
(2) Is the stopping potential [מתח העצירה] that was measured in Experiment C different from the stopping potential that was measured in Experiment B? Explain your answer.

($5\frac{1}{3}$ points)

/Continued on page 7/

4. Physics students wanted to examine the energy levels of atoms of a certain element. To do so, they put a sample of the element into a container and performed two experiments, one after the other. Assume that all of the atoms are in their ground state [רמת היסוד].

In the first experiment, they directed ultraviolet (UV) radiation within the range $240\text{nm} \leq \lambda \leq 400\text{nm}$ at the container. They used a spectrometer to examine the radiation after it had passed through the container. The following did not appear in the obtained spectrum: any wavelength within the range $240\text{nm} \leq \lambda \leq 258\text{nm}$, a wavelength of 326.3 nm or a wavelength of 375.7 nm (see figure).



א. **(1)** What type of spectrum was examined: absorption or emission? Explain your answer.

(2) Explain why the continuous section of ultraviolet radiation within the range $240\text{mm} \leq \lambda \leq 258\text{mm}$ did not appear in the obtained spectrum.

(8 points)

ב. **(1)** Calculate the ionization energy of an atom in the sample.

(2) Calculate the energy of two of the excited levels of this atom.

(7 points)

In the second experiment, a beam of electrons that were accelerated (outside the container) by a voltage of 3.1 V passed through the container. Electrons with the following energies were observed in the beam that exited the container: 0.1 eV, 1 eV and 3.1 eV.

ג. Calculate the energy of the two excited levels observed in the second experiment. (6 points)

ד. Based on the results of the two experiments, draw a diagram of the energy levels of the examined atom that includes the five energy levels that you found. (9 points)

The students used a spectrometer to examine the electromagnetic radiation emitted from the container during the second experiment.
They found that two wavelengths were obtained within the visible range ($400\text{nm} \leq \lambda \leq 700\text{nm}$).

ה. Calculate the two wavelengths obtained in the experiment. ($3\frac{1}{3}$ points)

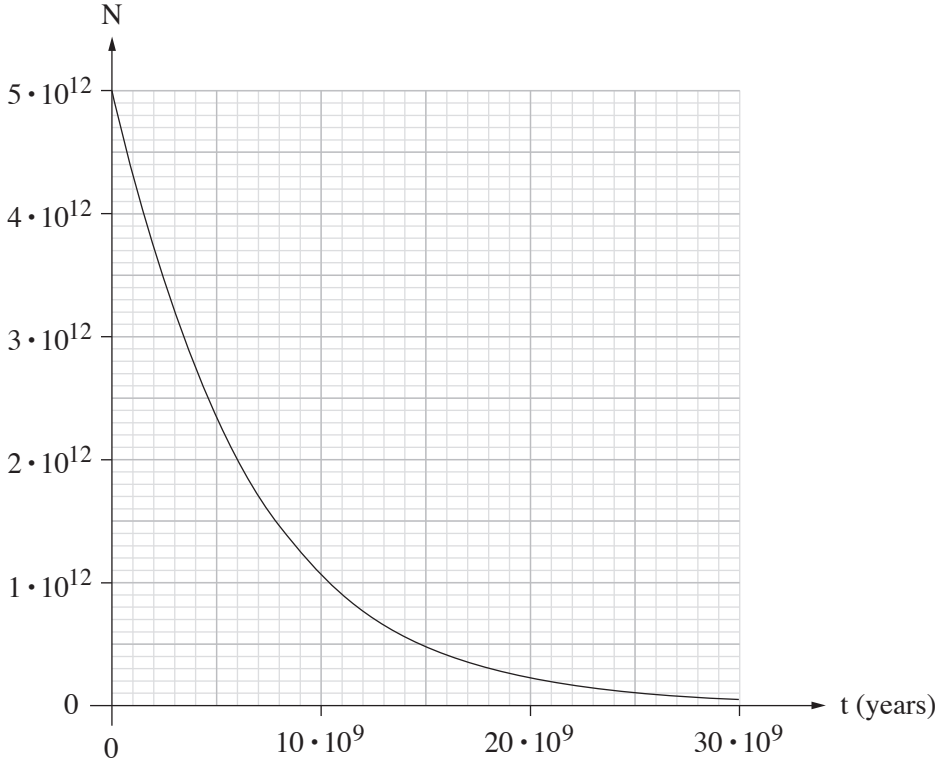
/Continued on page 8/

5. Today, we know of about 30 isotopes of the element uranium, only a few of which are found in nature. The isotope ^{238}U, which is the most common, accounts for about 99.28% of the uranium found in nature. A series of decay events occur in a ^{238}U nucleus, until a stable lead nucleus is obtained. Over the course of these decay events, X α particles and Y β^- particles are produced. The equation for this process is as follows:

$$^{238}_{92}U \longrightarrow {}^{206}_{82}Pb + X \cdot {}^{4}_{2}\alpha + Y \cdot {}^{0}_{-1}\beta^-$$

א. Calculate the number of α particles (X) and the number of β^- particles (Y) that are emitted over the series of decay events. (8 points)

The graph below shows the number (N) of ^{238}U nuclei as a function of time (t), over the course of the radioactive decay.



ב. **(1)** Define the term "half-life".

(2) Use the graph to find the half-life of ^{238}U.

(10 points)

(Note: This question continues on the next page.)

/Continued on page 9 /

The long half-life of ^{238}U makes it possible to determine the age of the Earth.

ג. Explain why an element with a long half-life is needed if we want to determine the age of the Earth. ($5\frac{1}{3}$ points)

In a sample of rock that was formed when the Earth was created (t = 0), there were $5 \cdot 10^{12}$ atoms of ^{238}U.

Today, that sample contains both ^{238}U atoms (N_U) and lead atoms (N_{Pb}).

Given: $N_{Pb} = 2.53 \cdot 10^{12}$

Assume that all of the lead atoms in the sample are the product of the decay of ^{238}U and also assume that the half-life of the intermediate products of the radioactive series is negligible in comparison to the half-life of uranium.

ד. Use the information given above to calculate the age of the Earth. (10 points)

Good Luck!