State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2017
Exam number: 036282
Attachment: Data and formulas for 5-point Physics
English translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ז, 2017
מספר השאלון: 036282
נספח: נוסחאות ונתונים בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

Physics
Radiation and Matter
Reform for Meaningful Learning Program

פיזיקה
קרינה וחומר
על פי תכנית הרפורמה ללמידה משמעותית

Instructions for examinees

א. Duration of the exam: Two hours.

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 as specified. 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 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/s² 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" at the top of each draft page. If you write any sort of drafts on pages outside of the answer booklet, your exam may be disqualified!

Good Luck!

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 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 specified at the end of the item.)

1. A student performed experiments with a semi-circular prism made of a transparent material with an unknown index of refraction.
Figure 1 below shows a cross-section of this prism.
In the first experiment, the student directed a narrow beam of laser light several times at Point O (the center of the circle). Each time, the beam struck Point O at a different angle of incidence α and entered the prism. For each angle of incidence, the student measured the angle of refraction β in the prism.

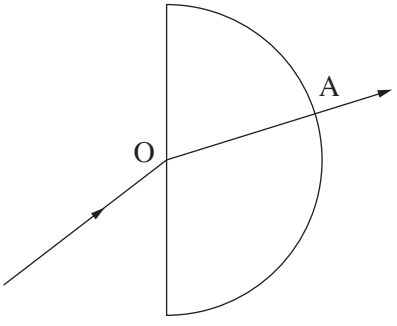


Figure 1

א. Copy Figure 1 to your answer booklet and clearly label the angles α and β. (4 points)

ב. Explain why the direction of the beam did not change when exiting the prism at Point A. (5 points)

The student presented the results of the measurements on the graph in Figure 2, which shows the sine of the angle of refraction β as a function of the sine of the angle of incidence α.

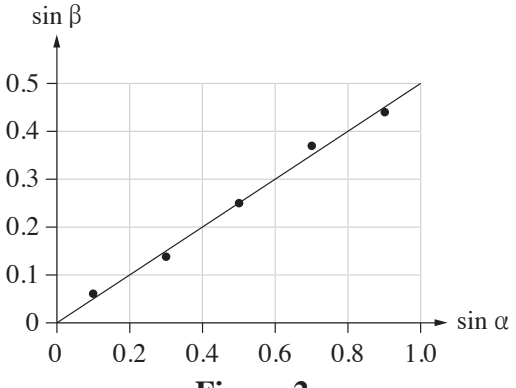


Figure 2

/Continued on page 3/

ג. Calculate the index of refraction n for the material of which the prism is made. Assume that the index of refraction of the air is n = 1.
Explain your reasoning in detail. ($7\frac{1}{3}$ points)

In the second experiment, the student directed a narrow beam that entered the same prism at point A and struck Point O as shown in Figure 3.

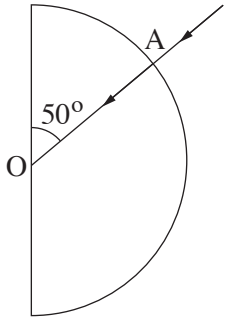


Figure 3

ד. Copy Figure 3 to your answer booklet, and sketch the approximate path of the beam until after it exited the prism.
Explain your reasoning in detail. (9 points)

In the third experiment, the student repeated the second experiment, but this time the prism was placed in water, and the beam was directed at Point A from within the water.

Given: the index of refraction of water is n = 1.33.

ה. Copy Figure 3 to your answer booklet again, and sketch the approximate path of the beam until after it exited the prism in the third experiment. Explain your reasoning in detail. (8 points)

/Continued on page 4/

2. In an experiment similar to Young's double-slit experiment, white light is projected through a filter that passes light of a certain wavelength. After the light has passed through the filter, it passes through two identical slits located at a distance d from each other.
The light reaches a screen located a distance L from the slits, and an interference pattern is obtained on the screen (see Figure 1).
The experiment is repeated several times, each time using a filter that passes light of a different wavelength.

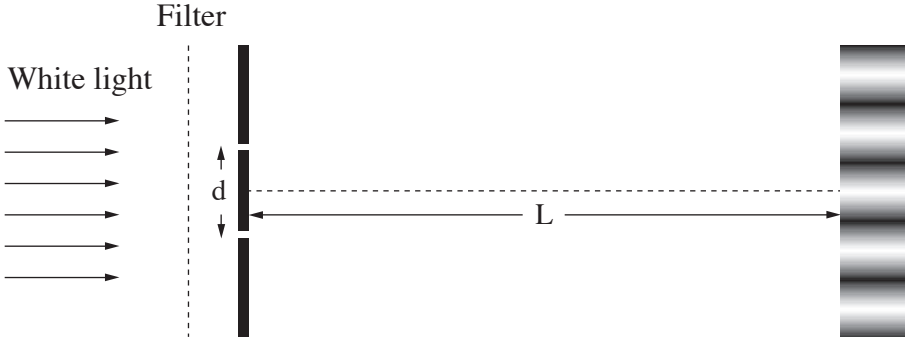


Figure 1

For the interference pattern obtained at each wavelength, the width of the 5 light bands closest to the center of the pattern (Segment AB) is measured. x = 0 denotes the center of the pattern (see Figure 2).

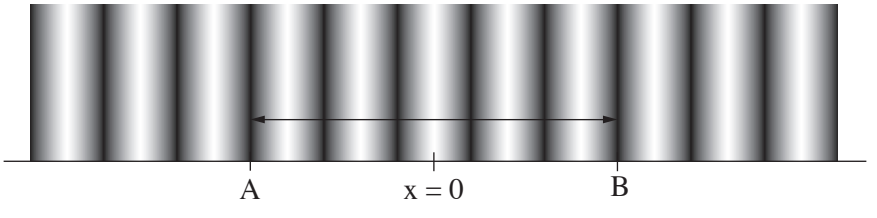


Figure 2

The table below shows the results of the measurements.

λ (μm)	0.47	0.52	0.58	0.61	0.65
AB (mm)	14	15.8	17.4	18.1	19.5

/Continued on page 5/

א. Without using the measurement results in the table, express the distance AB in terms of the parameters: λ, d, and L. (8 points)

ב. Sketch in your answer booklet a graph of the distance AB as a function of the wavelength, according to the results of the measurements. (9 points)

Given: L = 3m.

ג. Calculate the distance d between the slits, using the expression you found in Item א and the graph you sketched in Item ב. (10 points)

ד. In the experiment kit, there is an additional filter, which passes light of an unknown wavelength. When using this filter, the result AB = 15mm is obtained.

Find the wavelength that this filter passes.

Detail your reasoning. ($6\frac{1}{3}$ points)

/Continued on page 6/

3. A system is composed of a photoelectric cell, a (very sensitive) ammeter, and ideal wires.

The work function of the cathode in the cell is B = 2eV.

A beam of light of wavelength λ strikes the cathode (see Figure 1).

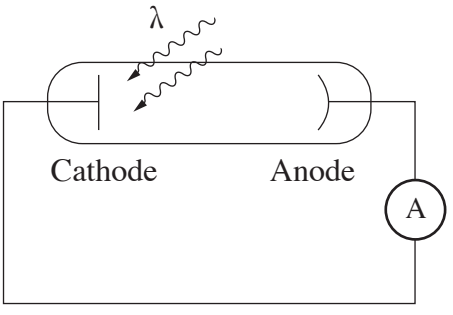


Figure 1

א. Calculate the range of wavelengths for which current will flow in the circuit. (8 points)

Given: The ammeter reads $2 \cdot 10^{-8}$ A.

ב. Calculate the minimum number of photons striking the cathode in the course of one second. (7 points)

Given: The wavelength of the beam of light striking the cathode is $\lambda = 420\text{nm}$.

ג. Calculate the maximum velocity of the electrons emitted from the cathode. ($9\frac{1}{3}$ points)

/Continued on page 7/

A voltage source V whose value can be changed is added to the system. Points A and B in Figure 2 denote the terminals of the voltage source.

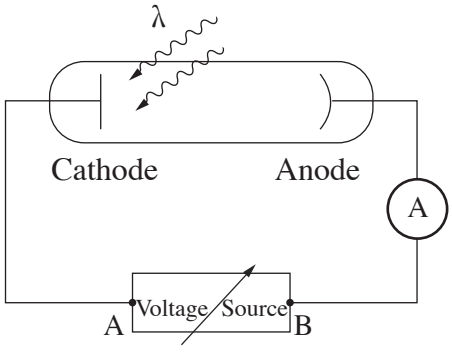


Figure 2

At a certain voltage V_{AB}, the intensity of the current in the circuit becomes zero.

ד. Is the terminal A positive or negative? Explain your answer. (4 points)

ה. What is the voltage (in absolute value) between the terminals of the voltage source? Detail your reasoning. (5 points)

/Continued on page 8/

4. In the year 1913, the physicist Niels Bohr published an article in which he proposed a model of the hydrogen atom. This model was an extension of the planetary model that Ernest Rutherford had proposed. Bohr's model was the first model to use quantum principles.

א. Explain the concept "energy level" ["רמת אנרגייה"] according to Bohr's model. (5 points)

ב. Sketch the energy level diagram of a hydrogen atom, showing the first 4 levels and the ionization level. (10 points)

An electron in the hydrogen atom fell from energy level n = 4 to level n = 2. As it was falling, a single photon was emitted.

ג. Calculate the frequency of the emitted photon. (7 points)

ד. Calculate the velocity of the electron at energy level n = 2. (8 points)

ה. The absorption spectrum of hydrogen cannot be explained by Rutherford's model. Explain why. ($3\frac{1}{3}$ points)

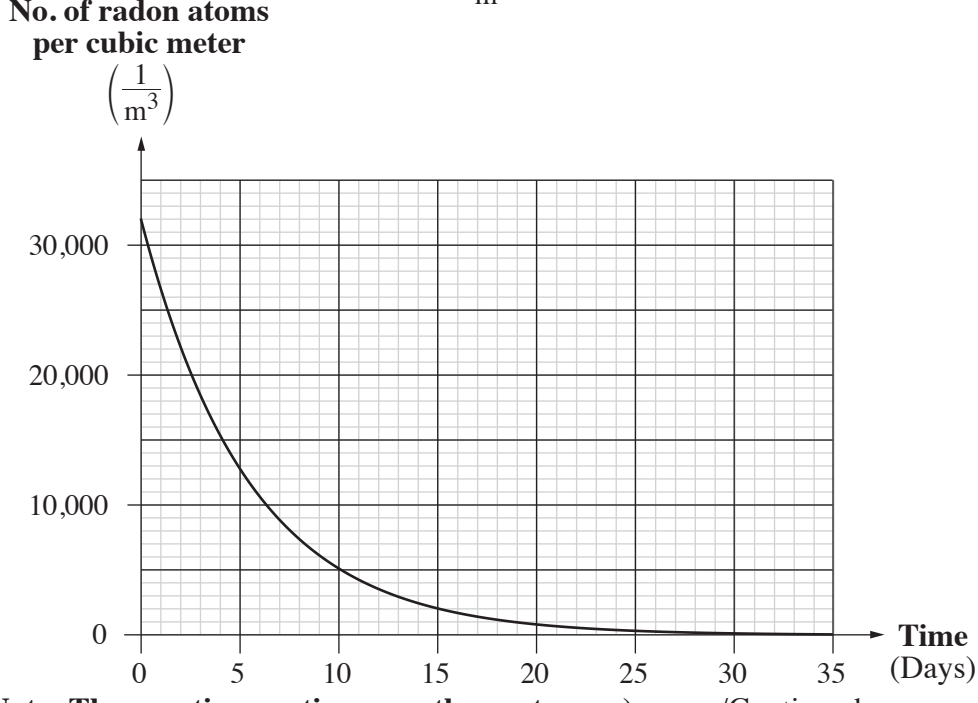
/Continued on page 9 /

5. Radon, $\frac{222}{86}Rn$, is a naturally occurring radioactive element found in the ground, and in small quantities, also in water. Radon decays into polonium, Po, which is also a radioactive element, and alpha radiation is emitted. Alpha radiation energy is high enough to harm molecules in the human body, so this radiation is liable to be a health hazard.
The Ministry of Environmental Protection [המשרד להגנת הסביבה] has set a standard for the maximum permitted level of radon activity per cubic meter in residential buildings in Israel: $200\frac{Bq}{m^3}$, $(Bq = \frac{1}{s})$.

א. Explain the physical meaning of the statement: "The maximum level of radon activity per cubic meter permitted in residential buildings in Israel is $200\frac{Bq}{m^3}$". (4 points)

ב. In the decay of a radon nucleus to polonium, a single alpha particle is emitted. Write the equation of this decay, and write the mass number and atomic number of the polonium nucleus. (8 points)

The graph below shows the number of radon atoms per cubic meter of a radon sample as a function of time. Initially, the number of radon atoms per cubic meter measured was $32{,}000\frac{1}{m^3}$.



(Note: The question continues on the next page.) /Continued on page 10 /

ג. Using the graph, determine the approximate half-life of radon.
Detail your reasoning. ($6\frac{1}{3}$ points)

ד. **(1)** Write an equation that describes activity as a function of time.

(2) Calculate how long after starting measurement will the activity level per cubic meter of the radon sample reach the standard established by the Ministry of Environmental Protection.

(10 points)

Calculations showed that during the 10 days from starting measurement, more than 25,000 polonium atoms per cubic meter were formed.
An actual measurement that was made 10 days after starting measurement found almost no polonium atoms.
Given: All radon that decays, turns into polonium.
The region that was examined was closed, so no polonium atoms could have escaped from it.

ה. Explain the contradiction between the calculated results and the results of the actual measurement. (5 points)

Good Luck!

בהצלחה!