State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2019
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"ט, 2019
מספר השאלון: 036282
נספח: נוסחאות ונתונים בפיזיקה ברמה של 5 יח"ל
תרגום לאנגלית (3)

Physics
Radiation and Matter

פיזיקה
קרינה וחומר

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 only in the answer booklet. Write "טיוטה" at the top of each draft page. Writing drafts on pages outside the answer booklet may lead to the disqualification of your exam.

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 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.
השתמש בעיפרון לסרטוטים בלבד.

כתוב במחברת הבחינה בלבד. רשום "טיוטה" בראש כל עמוד המשמש טיוטה.
כתיבת טיוטה בדפים שאינם במחברת הבחינה עלולה 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. A student was asked to investigate the properties of a converging lens [עדשה מרכזת].

As shown in Figure 1, she placed the lens L between a screen M and a linear light source [מקור אור קווי] AB (which is not a point source), whose size is smaller than the diameter of the lens.

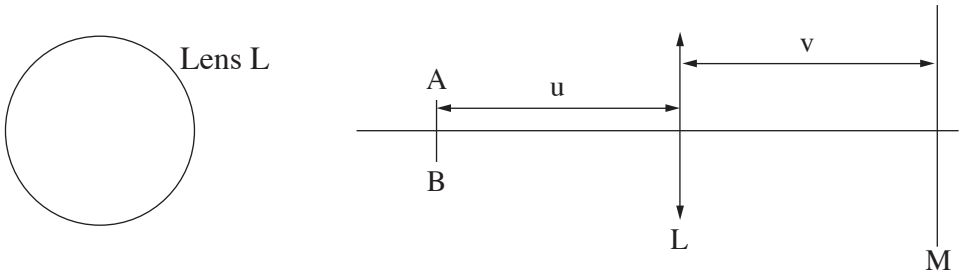


Figure 1

The student changed the location of the light source several times, and each time she repositioned the screen to obtain a clear image of the light source on the screen.

Each time, the student measured and recorded the distance of the light source from the lens, u , and the distance of the screen from the lens, v .

The following table presents the results of the student's measurements:

Measurement	**1**	**2**	**3**	**4**	**5**
u (m)	0.13	0.18	0.25	0.33	0.60
v (m)	0.44	0.22	0.16	0.14	0.12
1/u ( )					
1/v ( )					

א. Express 1/v as a function of 1/u, and show that there is a linear relationship between them.

(7 points)

ב. Copy the table to your answer booklet, and then fill in the missing values and the units.

(6 points)

ג. Sketch a graph of 1/v as a function of 1/u, and add the regression line [קו המגמה] to the graph.

(8 points)

ד. Find the focal length of the lens, **using only the graph**. Explain your reasoning. (7 points)

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

/Continued on page 3/

The student positioned the light source AB and the lens L so that a clear image was formed on the screen, and then covered part of the lens with an opaque black ring, as shown in Figure 2.

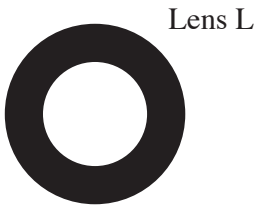


Figure 2

ה. Of the following sentences 1-6, copy to your answer booklet the sentence (or sentences) that correctly describe(s) the image that was obtained.

1. A partial, clear image was obtained on the screen, and its illuminance [עוצמת הארה] did not change.
2. A partial, clear image was obtained on the screen, and its illuminance was weaker.
3. A full, clear image was obtained on the screen, and its illuminance did not change.
4. A full, clear image was obtained on the screen, and its illuminance was weaker.
5. A full, fuzzy image was obtained on the screen, and its illuminance was weaker.
6. A partial, fuzzy image was obtained on the screen, and its illuminance was weaker.

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

/Continued on page 4/

2. Some students conduct three experiments.

In the first experiment, a collimated beam [אלומה מקבילה] of monochromatic light of wavelength $\lambda_1 = 600\text{nm}$ orthogonally strikes [פוגעת בניצב] a panel with two slits, S_1 and S_2. The slits are very narrow relative to the distance d between them. An interference pattern is obtained on a screen that is parallel to the panel. The screen is located a distance L from the panel (see Figure 1).

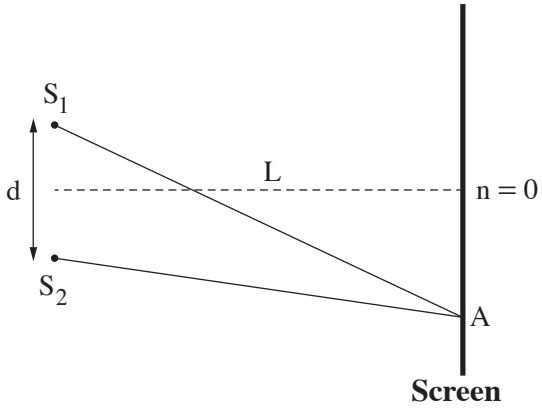


Figure 1

Assume that the small-angle approximation applies.

א. Determine whether the point where the path difference from the two slits equals 18 half-wavelengths is a point of constructive interference, a point of destructive interference, or an intermediate point [נקודת ביניים]. Explain your answer. (5 points)

Given: The distance between the center of the maximum of order n = 0 and the center of the maximum of order n = 8 equals 12cm.

ב. Calculate the width of the light band, Δx. (4 points)

In the second experiment, the students illuminate the slits S_1 and S_2 with a collimated beam of monochromatic light of wavelength λ_2. In this case, the width of the light band is 1.2 times smaller.

ג. Calculate the wavelength λ_2. (7 points)

Point A is located 3.75cm from the center of the maximum of order n = 0.

ד. For each of the wavelengths λ_1 and λ_2, determine whether Point A is a point of constructive interference, a point of destructive interference, or an intermediate point. Explain your answer. (6 points)

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

/Continued on page 5/

In the third experiment, the collimated beam of monochromatic light of wavelength $\lambda_1 = 600\text{nm}$ orthogonally strikes a panel with only one slit, of width w. On a screen that is parallel to the panel, a central maximum is formed, that is 2 times as wide as the light band obtained from the two slits S_1 and S_2 in the first experiment (see Figure 2).

The distance between the panel and the screen in the third experiment equals the distance L that was between the panel and the screen in the first experiment.

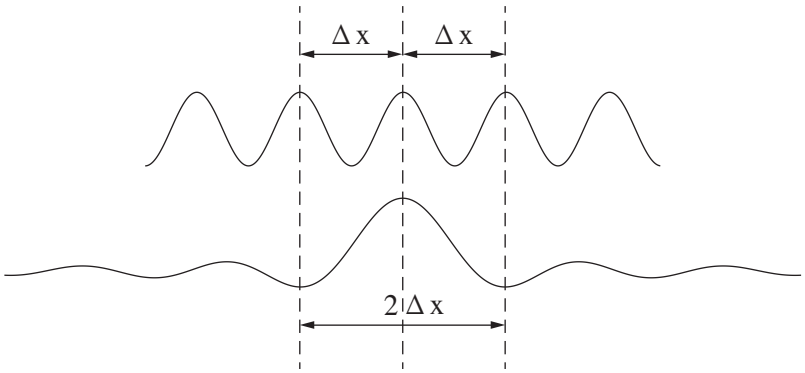


Figure 2

ה. Prove that, in this experiment, the slit width w is equal to the distance d between S_1 and S_2. (6 points)

Given: The distance between the panel and the screen is $L = 1.5\text{m}$.

ו. Calculate the slit width w. ($5\frac{1}{3}$ points)

/Continued on page 6/

3. Some students performed two experiments using a photoelectric cell.

In the first experiment, they illuminated the cathode (emitter) of the cell with several beams of monochromatic light, one after the other, and measured, for each beam separately, the stopping potential [מתח העצירה] (the minimum voltage at which no current flowed in the cell).

Based on the results of the experiment, the students drew a graph. The graph is shown in Figure 1.

Figure 1

א. Define the concept "threshold frequency f_0". (5 points)

ב. Using the graph, find the work function B of the cathode. Explain your reasoning. (5 points)

ג. Calculate the maximum wavelength at which the photoelectric effect occurs in this cell. (5 points)

In the second experiment, the students illuminated the cathode with a monochromatic light beam of frequency f_1, and measured the current I in the cell for different values of the voltage V between the anode and the cathode.

The results of the second experiment are shown in Figure 2.

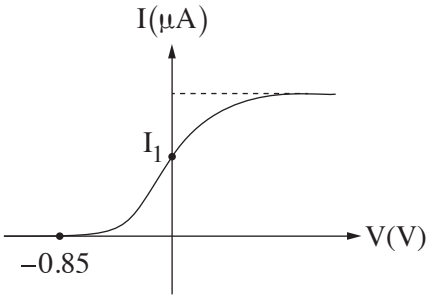


Figure 2

ד. Calculate the frequency f_1. (7 points)

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

/Continued on page 7/

ה. Calculate in units of joules the kinetic energy of the fastest electrons at the moment that they are ejected [נעקרו] from the cathode that is illuminated by a light beam of frequency f_1.

(7 points)

The students continued to illuminate the photoelectric cell with a beam of frequency f_1, and at the same time they illuminated the cell with an additional beam, of frequency f_2. They measured the total current I in the cell, for different values of the voltage V between the anode and the cathode.
Given: $f_0 < f_2 < f_1$.

ו. **(1)** Determine whether the absolute value of the voltage at which the current I becomes zero, is greater than, smaller than, or equal to 0.85V. Explain your answer.

(2) Determine whether the current I for the voltage V = 0 will increase, decrease, or stay unchanged, relative to the current I_1 that is marked on Figure 2. Explain your answer.

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

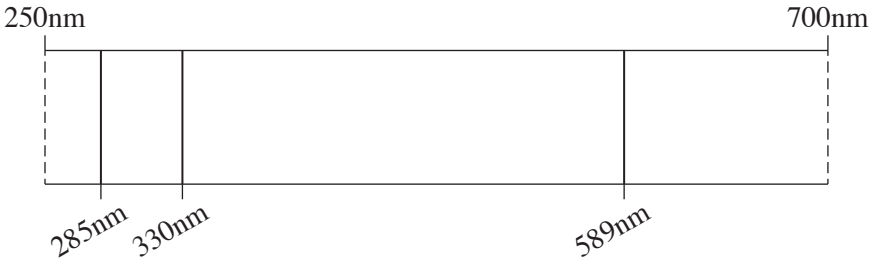
/Continued on page 8/

4. Some roads in Israel are lighted using sodium lamps that emit orange-yellow light.
Monochromatic radiation of wavelength 200nm was passed through a tube containing a gas with a small amount of vaporized sodium, Na. This radiation ionizes the sodium atom, and an electron whose kinetic energy is 1.06eV is emitted.

א. Define the term "ionization energy" [אנרגיית יינון]. (5 points)

ב. Calculate the ionization energy of sodium. (6 points)

In another case, electromagnetic radiation in the range $250\text{nm} < \lambda < 700\text{nm}$ was passed through the tube, and the absorption spectrum of sodium gas in this range was obtained (see figure).



ג. Using the data given in the question, sketch a diagram of the energy levels of sodium (including the ionization level). Show detailed calculations. (8 points)

ד. Determine whether the 589nm line that is seen in the absorption spectrum is black (to a close approximation) or colored. Explain your answer. (5 points)

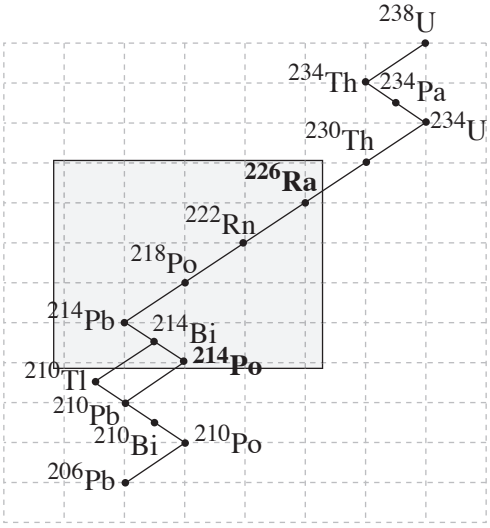
ה. Add arrows representing the spectral lines of the emission spectrum to the diagram that you sketched in Item ג. (4 points)

ו. Using the data given in the question, calculate the wavelengths of the radiation emitted from the tube in the visible light range ($400\text{nm} < \lambda < 700\text{nm}$). ($5\frac{1}{3}$ points)

/Continued on page 9/

5. Today four radioactive decay series are known. This question relates to the uranium-238 series.

Radium-226 $\left({}^{226}_{88}\mathrm{Ra}\right)$ and polonium-214 $\left({}^{214}_{84}\mathrm{Po}\right)$ are natural radioactive isotopes that are members of this series. Polonium-214 is a product in the decay chain of radium-226 (see diagram).



א. Determine the number of α decays and the number of β^- decays that occur in the decay chain from radium-226 to polonium-214. Explain your answers. (8 points)

In one of the stages of this chain, the radioactive isotope radon-222 $\left({}^{222}_{86}\mathrm{Rn}\right)$ is formed. Due to the health hazard posed by radon gas when it accumulates in enclosed spaces (such as basements and bomb shelters), it is a subject of much technological and scientific interest.

ב. Determine the atomic number and the mass number of the daughter nucleus Y that is formed from the decay of radon-222. (7 points)

Measurements of a sample of radon-222 showed that its radioactive activity [הפעילות הרדיואקטיבית] decreases by a factor of 8 over the course of 11.475 days.

ג. **(1)** Calculate the half-life , $T_{1/2}$, of this isotope.

(2) Calculate the decay constant λ of this isotope.

(11 points)

The nuclear binding energy of the isotopes radium-226 and polonium-214 are $E_{B(Ra)} = 1732.62$ MeV and $E_{B(Po)} = 1666.02$ MeV, respectively.

ד. Determine which of the two isotopes is more stable. Explain your answer. ($7\frac{1}{3}$ points)

Good Luck!

בהצלחה!