State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2017
Exam number: 036002, 655
Attachment: Data and formulas for 5-point Physics
English translation (3)

Physics
Electricity

For 5-point students

Instructions for examinees

א. Duration of the exam: One hour and forty-five minutes.

ב. Exam structure and breakdown of points:
This exam has five questions. Answer only three of these questions.
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 formulas and physics data 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 that 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 sheets, 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 if you do not write out the formula with the inserted values, or if you do not write the units, points may be deducted from your score.
(3) When you are asked to express a value using data provided in the question, write out a mathematical expression that includes all or some of the given data. When necessary, you may also use basic constants, such as the free-falling acceleration *g* or the elementary charge *e*.
(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. You may use a pencil for drawings only.

Write in the answer booklet only, on separate pages, everything that 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!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ז, 2017
מספר השאלון: 036002, 655
נספח: נתונים ונוסחאות בפיזיקה ל–5 יח"ל
תרגום לאנגלית (3)

פיזיקה
חשמל

לתלמידי 5 יחידות לימוד

הוראות לנבחן

א. משך הבחינה: שעה וארבעים וחמש 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 היחידות עלולים להפחית נקודות מהציון.

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

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

(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 specified at the end of the item.)

1. Figure 1 shows a thin infinite plate charged with charge density $+\sigma$.

A point charge q is located at Point O, at a distance r to the right of the plate.

Ignore the gravitational force.

Given: At Point M, located at a distance d to the left of Point O, the resultant electrical field [השדה החשמלי השקול] becomes zero.

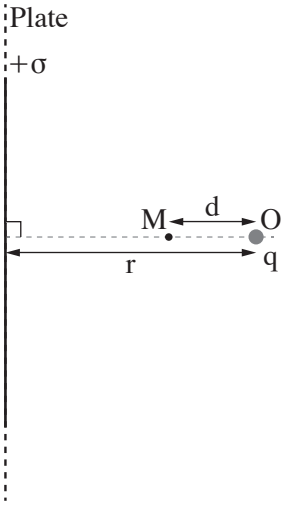


Figure 1

א. What is the sign of Charge q? Explain your answer. (5 points)

ב. Express the magnitude of Charge q in terms of the parameters σ and d. (8 points)

/Continued on page 3/

Later, Charge q is moved away from Point O to Point N, located at a distance 2r from the infinite plate (see Figure 2).

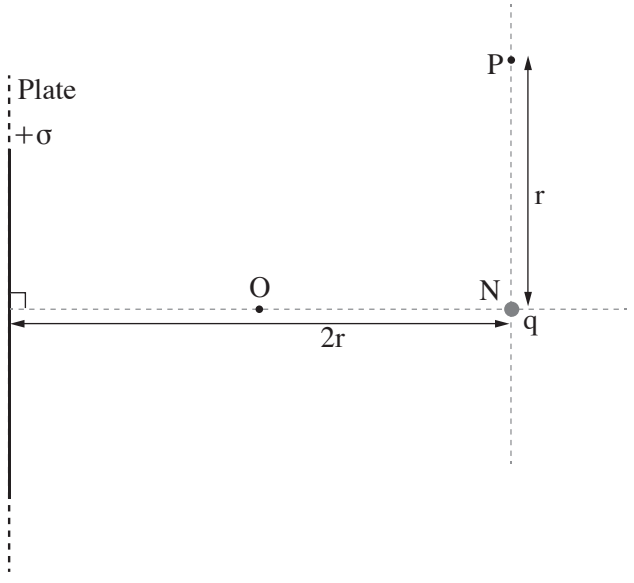


Figure 2

Now the field becomes zero at a distance s to the left of Point N.

ג. Determine whether the distance s is greater than, less than, or equal to the distance d (shown in Figure 1).
Explain your answer. (8 points)

ד. Express the amount of work required to move Charge q from Point O to Point N.
Use the parameters σ, ε_0, q, and r in your answer. (6 points)

Finally, Charge q is moved from Point N to Point P, which is located at a distance r from Point N. Points N and P are located on a line that is parallel to the infinite plate (see Figure 2).

ה. Determine the amount of work required to move the charge from N to P. Explain your answer. ($6\frac{1}{3}$ points)

/Continued on page 4/

2. Figure 1 below shows an electrical circuit that includes connecting wires whose resistance is negligible, two switches S_1 and S_2, a voltage source whose electromotive force (emf [כא"מ]) is ε and whose internal resistance is $r = 1\Omega$, and four resistors whose resistances are: $R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, $R_4 = 4\Omega$.

Note: The figure specifies only the placement of resistors R_3 and R_4.
The other two resistors are denoted as R_x and R_y.

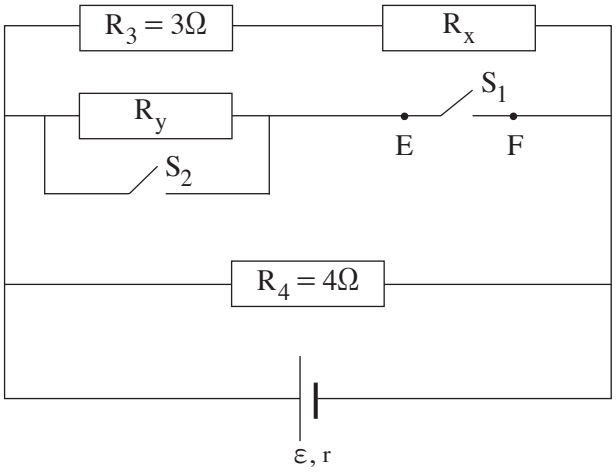


Figure 1

At first, Switch S_1 is closed and Switch S_2 is open (current does not flow through it).

Given: The equivalent resistance of the four resistors is $R_T = 1\Omega$.

א. Determine which resistor, R_x or R_y, is R_1, and which is R_2.
Explain your reasoning in detail. (6 points)

ב. Given: The current flowing through R_3 is 3A.

(1) Calculate the intensity of the current flowing through the voltage source.

(2) Calculate the emf of the voltage source.

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

/Continued on page 5/

Next, Switch S_1 is opened (both switches are open).

ג. Determine whether the current through the voltage source increases, decreases, or does not change as a result of opening Switch S_1. Explain your answer. (6 points)

ד. Calculate the voltage V_{EF} (the voltage on Switch S_1). (6 points)

Finally, students who are not studying in the physics track entered the laboratory. They closed both switches and added an ideal ammeter to the circuit in parallel to Resistor R_y (see Figure 2).

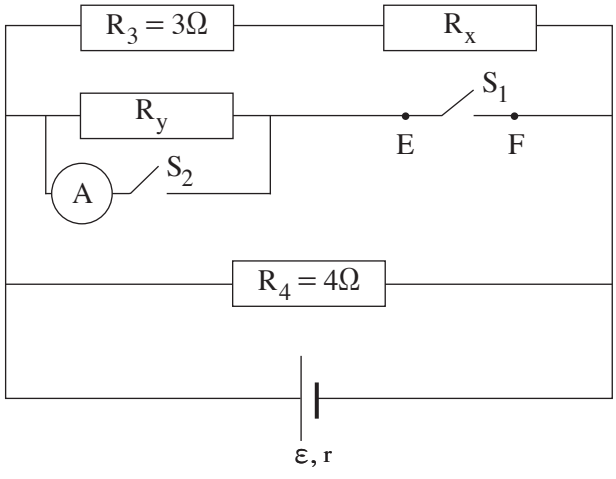


Figure 2

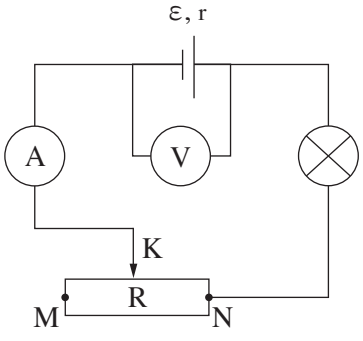
ה. **(1)** Calculate the intensity of the current shown on the ammeter.

(2) Determine the intensity of the current through Resistor R_4. Explain your answer.

(7 points)

/Continued on page 6/

3. A student built a circuit that included a non-ideal voltage source, a light bulb whose resistance was constant throughout the experiment, a variable resistor R, ideal measuring instruments (voltmeter and ammeter), and connecting wires whose resistance was negligible.
The ends of the variable resistor are labeled M and N, and its wiper is labeled K (see figure).



The student changed the position of Wiper K several times, and each time recorded the values shown on the voltmeter and ammeter.
The table below shows the results of the measurements.
One of the rows in the table is associated with Point N.

Wiper position	**V**(V)	**I**(A)
1	21.1	0.29
2	17.5	0.60
3	14.5	0.91
4	12.5	1.20
5	9.0	1.49

א. Sketch in your answer booklet a graph of the voltage V as a function of the current I. Make sure to follow all the rules for sketching a graph. (10 points)

/Continued on page 7/

ב. Based on the graph:

(1) Determine the electromotive force (emf; [כא"מ]) of the voltage source. Detail your reasoning.

(2) Calculate the internal resistance (r) of the voltage source.

(8 points)

When the wiper is in one of the positions 1-5, the light bulb emits light at an intensity that is higher than for any other position of the wiper. Remember that the resistance of the light bulb is constant throughout the experiment.

ג. Determine at which of the positions 1-5 (see table) the light bulb shines at the highest intensity. Explain your answer. (6 points)

ד. Calculate the power of the light bulb at this point. ($4\frac{1}{3}$ points)

The student replaced the light bulb in the given circuit with a different light bulb, whose resistance was higher.
He repeated the experiment and sketched a graph of V as a function of I.

ה. Determine whether the regression line of the results from the second experiment is expected to coincide with the regression line in the graph that you drew in Item א. Explain your answer.

(5 points)

/Continued on page 8/

4. Using a mass spectrometer, it is possible to separate charged particles that have different masses and charges (ions). In the separation process, the ions first pass through a region that has an electric field and a magnetic field ('velocity selector'). Afterwards, the ions continue to a region where there is a magnetic field only.

Figure 1 below describes a velocity selector.
In the selector, there is a uniform magnetic field B whose direction is 'into the page', as shown in the figure.
Between Plates C_1 and C_2, there is a uniform electric field E whose direction is parallel to the plane of the page (the fields B and E are perpendicular to each other). One of the plates is positively charged and the other is negatively charged.

Ignore the gravitational force and the air resistance.

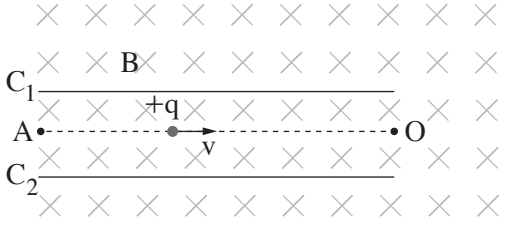


Figure 1

A positive ion +q moves to the right between the two plates, in a straight line AO that is parallel to the plates.

א. Sketch in your answer booklet a diagram of the forces exerted on the ion, and label <u>each</u> of the forces with its name. (4 points)
ב. Which plate, C_1 or C_2, is positively charged? <u>Explain your answer</u>. (4 points)
ג. Develop an expression for the magnitude of the velocity v with which the ion moves along the line AO. (6 points)

The positive ion was replaced with a negative ion –q whose velocity is equal to that of the positive ion, without changing the magnetic field.
ד. Is it necessary to reverse the direction of the electric field between the plates in order that this ion too will move to the right along line AO? <u>Detail your reasoning</u>. (5 points)

/Continued on page 9/

Three ions, 1, 2, and 3, enter the spectrometer. They travel one after the other within the velocity selector along line AO at the same velocity v. From Point O, they continue into a region where there is only a magnetic field, of the same intensity and direction as the field in the velocity selector. Due to the influence of the magnetic field, each particle moves along one of the trajectories א, ב, or ג. Each trajectory is semicircular, as shown in Figure 2.

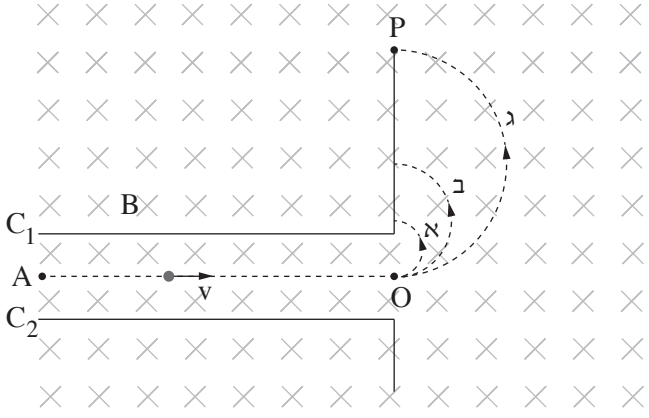


Figure 2

The table below shows mass and charge data for the three ions.

Ion	Mass	Charge
1	$M_1 = m$	$Q_1 = q$
2	$M_2 = m$	$Q_2 = 2q$
3	$M_3 = 2m$	$Q_3 = q$

ה. Determine on which trajectory, א, ב, or ג, each of the ions moves. Detail your reasoning. (9 points)

Given: $E = 6.15 \cdot 10^3 \frac{V}{m}$, $B = 0.1T$, $m = 1.3 \cdot 10^{-26} kg$, $q = 1.6 \cdot 10^{-19} C$

ו. Calculate the distance OP. ($5\frac{1}{3}$ points)

/Continued on page 10/

5. A student performed a series of experiments to investigate the formation of induced current. She passed a constant electric current, I, through a straight, very long (infinite) wire located in the plane of the page (see Figure 1).
In the first experiment, she placed a square frame, ABCD, in the plane of the page to the left of the wire, and brought it closer to the wire at a constant velocity v, in the plane of the page, with Side CD parallel to the wire.

The effects of gravity and of the earth's magnetic field are negligible.

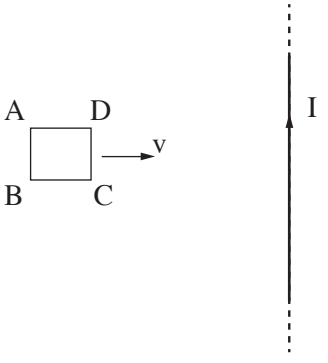


Figure 1

א. What is the direction of the magnetic field that the wire created in the region where the the frame moved? Choose one of the following: rightward; leftward; up; down; into the page; out of the page. (4 points)

ב. Determine whether the current in Side AB flows from A to B or from B to A. Explain your answer, using Lenz's Law. (6 points)

In the second experiment, the student placed the frame in the plane of the page to the right of the wire and moved it away from the wire at a constant velocity, v (see Figure 2).

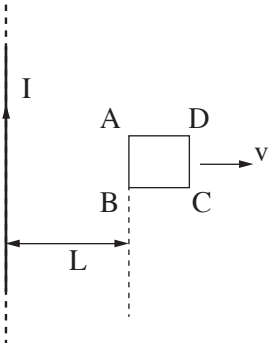


Figure 2

/Continued on page 11/

ג. Determine whether the current in side AB now flows from A to B or from B to A. (6 points)

At a certain moment, when Side AB of the frame was at a distance L from the wire (see Figure 2), a current I_1 flowed through it in the direction that you determined in Item ג. The length of the side of the frame is a.

ד. **(1)** Copy the diagram of the frame ABCD to your answer booklet. Add to the diagram arrows showing qualitatively the direction and magnitude of the magnetic forces exerted on each of its sides. Make sure that the lengths of the arrows represent the relative magnitudes of each of the forces.

(2) Express the magnitude of the resultant magnetic force [הכוח המגנטי השקול] that is exerted on the frame in terms of the parameters I, I_1, a, and L, and determine its direction.

(12 points)

In the third experiment, the frame ABCD moved in the plane of the page at a constant velocity v. The direction of the velocity was parallel to the wire (see Figure 3).

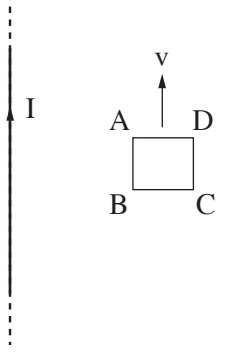


Figure 3

ה. Determine whether current flows in Side AB.
If so, determine its direction (from A to B or from B to A).
If not, explain why.
($5\frac{1}{3}$ points)

Good Luck!

בהצלחה!