

Physics Electricity

For students of 5 points

Instructions for examinees

א. Duration of the exam: One hour and three quarters

ב. Exam structure and breakdown of points:

There are five questions in this exam and you are required to answer only three.

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

ג. Material that may be used during the exam:

- (1) A calculator.
- (2) The physics data and 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) When solving 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, substitute the appropriate values into the formulas. Write your final answer in the appropriate units. If you do not write out the formula, or substitute values, or specify 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 provided in the question. If necessary, you may also use basic constants, such as g for free-fall acceleration or e for elementary charge.
- (4) In your calculations, use the value 10 m/s^2 for the magnitude of free-falling acceleration at the Earth's surface.
- (5) Write your answers in pen. Writing in pencil or erasing with White-Out will preclude any possibility of appealing your score. You may use a 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!

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 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-רשום הנוסחה או אי-ביצוע ההצבה או אי-רשום היחידות עלולים להפחית נקודות מן הציון.
- (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 החופשית.
- (5) כתוב את תשובותיך בעט. כתיבה בעיפרון או מחיקה בטיפקס לא יאפשרו ערעור. מותר להשתמש בעיפרון לסרטטים 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 שמוחוץ למחברת הבחינה עלול לגרום לפסילת הבחינה!

Good Luck!

בהצלחה!

Questions

Answer three of the questions 1-5.

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

1. A small sphere, B_1 , is held at Point A on a smooth horizontal surface.

The sphere has a mass m_1 and a charge q_1 .

Given: The measured electric potential at Point S on the horizontal surface was

$$V_s = -1000\text{V} .$$

The distance between Points S and A is 9 cm (see figure).

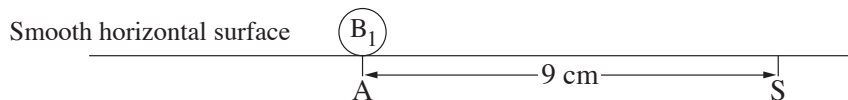


Figure 1

- א. Calculate the magnitude of the charge q_1 and determine its sign. (6 points)

- ב. Calculate the magnitude of the electrical field that the charge generates at Point S.

(5 points)

A second small sphere, B_2 , of mass m_2 and charge q_2 , is brought from infinity to Point S, and is held there.

Given: $m_2 = 2m_1$, $q_2 = 2q_1$.

- ג. Calculate the work that was done in bringing the sphere B_2 from infinity to Point S (ignore the gravitational force). (7 points)

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

Figure 2 below shows six illustrations describing the lines of a resultant electric field formed by two charged spheres.

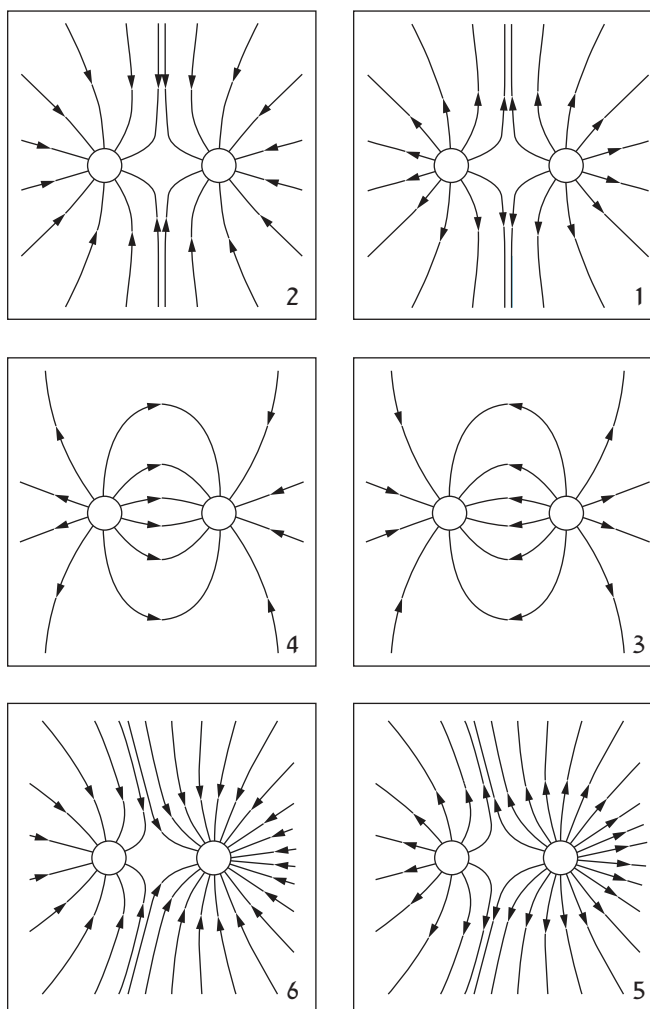


Figure 2

7. Which one of the illustrations 1-6 correctly describes the resultant field formed by the two charged spheres B_1 and B_2 when the sphere on the left is B_1 and the sphere on the right is B_2 ? Explain your answer. (7 points)

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

Both spheres are released and allowed to move over the smooth horizontal surface. At a certain moment Sphere B_1 passes Point D and Sphere B_2 passes Point H.

Points D and H are not marked in Figure 1.

- ה. Determine whether the magnitude of the electric force exerted on Sphere B_1 at Point D is smaller than, greater than or equal to the magnitude of the electric force exerted on Sphere B_2 at Point H. Explain your answer. (5 points)
- ו. Determine whether the magnitude of the velocity of Sphere B_1 at Point D is smaller than, greater than, or equal to the magnitude of the velocity of Sphere B_2 at Point H. There is no need to explain. ($3\frac{1}{3}$ points)

2. The image below shows the battery of an older-generation cell-phone (Generation 2).



Figure 1

This battery's specifications are: amount of energy stored in the battery, 3.2 Wh (watt $\times$ hour); emf, 3.7 V; electric charge, 860 mAh (milliampere $\times$ hour).

- א. Express the amount of energy stored in the battery in Joules (J), and the electric charge in Coulombs (C). (5 points)

To test this battery, we construct a circuit consisting of the battery and a device that simulates the cell-phone.

The tests measure the current intensity and the terminal voltage for various cell-phone states, for example: on standby, on a call, and when surfing the web.

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

The table below shows some of the test results.

Current intensity (mA)	50	100	200	400	600	800
Terminal voltage (V)	3.5	3.3	3.0	2.7	2.2	1.7

- ב. Based on the results shown in the table, draw a graph of the terminal voltage as a function of the current intensity in the battery. (7 points)
- ג. (1) Use the graph to find the emf of the battery. Explain your reasoning.
(2) Use the graph to calculate the internal resistance of the battery.
(8 points)
- ד. (1) Calculate the power delivered [הספק מושקע] by the battery (P_{in}) when current intensity is $I = 300$ mA.
(2) Calculate the power consumed [הספק מנוצל] by the device (P_{out}) when current intensity is $I = 300$ mA.
(8 points)

The graph below describes the power consumed by the device as a function of the resistance of the device.

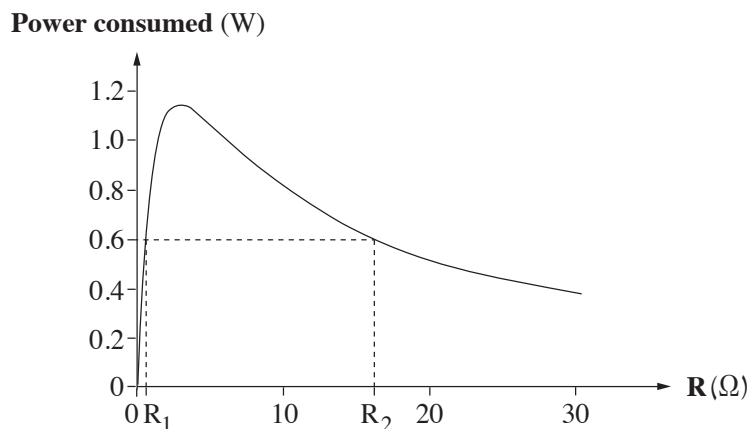


Figure 2

For two different resistances of the device, R_1 and R_2 ($R_2 > R_1$, see Figure 2), the consumed power is 0.6W.

- ה. At which resistance, R_1 or R_2 , will the battery heat up more? Explain your answer.
(5 $\frac{1}{3}$ points)

3. Given: an electric circuit that includes a non-ideal voltage source, a variable resistor, a light bulb, and two ideal voltmeters, as described in Figure 1. The variable resistor is made of conducting wire wrapped around a cylinder made of an insulating material (see Figure 2). The distance between its ends is $BC = 1\text{m}$. (Note: This is the distance between the ends of the resistor, not the length of the wire of which the resistor is made). The specifications of the variable resistor: The total length of the wire is $\ell = 100\text{m}$, its cross-sectional area is $A = 1\text{mm}^2$, and its resistivity [התנגדות סגולית] is $\rho = 9 \cdot 10^{-7} \Omega\text{m}$.

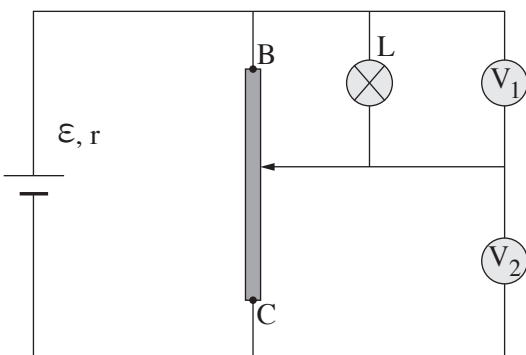


Figure 1

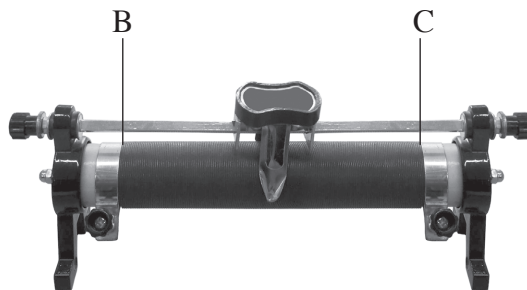


Figure 2

- א. Calculate the total resistance of the variable resistor. Pay attention to the units. (6 points)

Students placed the wiper [גרר] at end B of the variable resistor and recorded the readings on the voltmeters. They then moved the wiper up to end C, and recorded the readings on the voltmeters at various points where the wiper was positioned. The students drew a graph of the results they obtained.

Figure 3 below shows some of the readings on the two voltmeters as a function of the distance x of the wiper from end B.

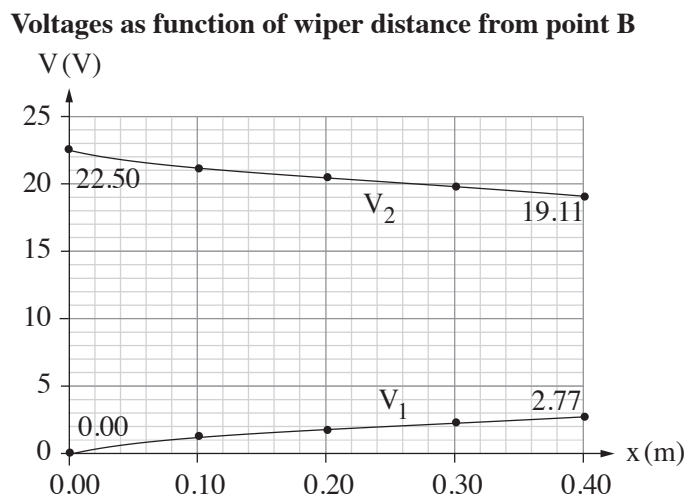


Figure 3

- א. Calculate the current that flows in the voltage source when the wiper is at point B.
 (5 points)

A student claimed that the emf of the voltage source is 22.5V, like the maximum value of V_2 , whereas his partner in the experiment claimed that he was mistaken.

- א. Decide who is correct and explain why. (7 points)
- ב. (1) Calculate the intensity of the current through the light bulb when $x = 0.4\text{m}$.
 (2) Calculate the resistance of the light bulb.
 (10 points)

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

Immediately after the wiper passed the location $x = 0.4\text{m}$, the light bulb burned out.

- ה. Which of the graphs 1-4 in Figure 4 (below) correctly represents the voltages measured after the light bulb burned out? Explain your answer. ($5\frac{1}{3}$ points)

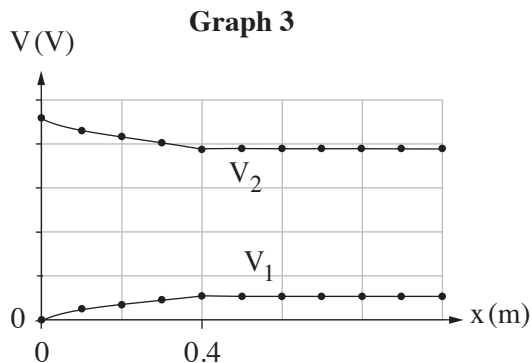
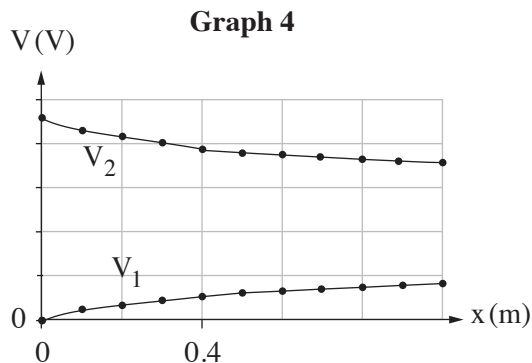
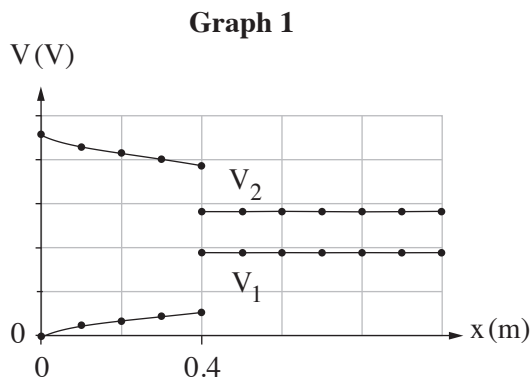
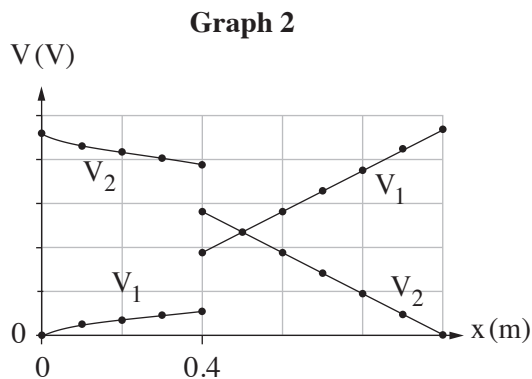


Figure 4

4. Figure 1, below, describes an electric circuit that contains a voltage source, a (long) solenoid [סילונית], an ammeter, a switch, and wires.

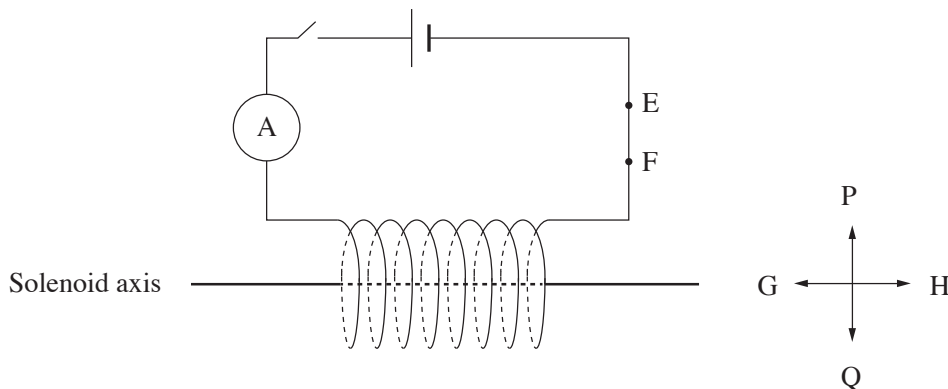


Figure 1

The switch was closed and a current I_1 flows through the solenoid.

- א. (1) Determine the direction of the current in the circuit: from E to F or from F to E.
(2) Determine the direction of the magnetic field, B_1 , in the solenoid: Q, P, H, or G (see the arrows in Figure 1). Explain your answer.
(8 points)

A square, conductive frame, abcd, was placed inside the solenoid (as shown in Figure 2).

A current I_2 flows through the frame. Side cd of the frame is parallel to the solenoid's axis.

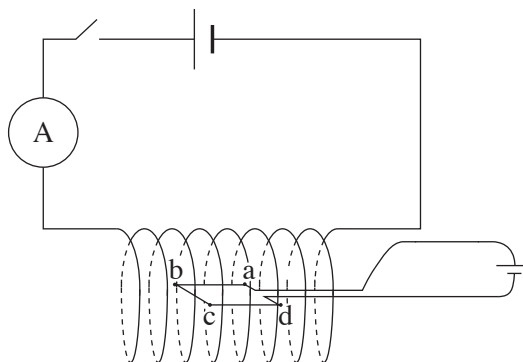


Figure 2

Given: The turn density of the solenoid is 6000 turns per meter, $I_1 = 0.1\text{A}$, $I_2 = 20\text{A}$, the side length of the frame abcd is 4 cm.

- ב. Calculate the magnetic force (magnitude and direction) exerted on each of the sides ab, bc. List your considerations. (11 $\frac{1}{3}$ points)

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

The frame was taken out of the solenoid and a very long conductive wire was placed inside it along the solenoid axis. The current through the wire is $I_3 = 20\text{A}$.

The diagram below shows a side-view (cross-section) of the solenoid and wire. Current I_1 in the solenoid flows clockwise, and the current I_3 in the wire flows 'out of the page'.

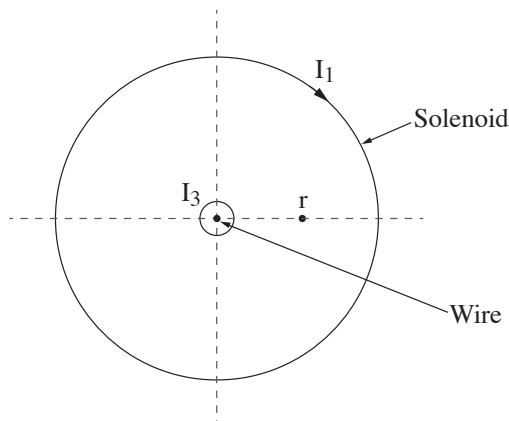


Figure 3

- א. Copy Figure 3 to your answer booklet. In the figure in your notebook, at Point r , mark the direction of the magnetic field, B_1 , generated by the solenoid, and the direction of the magnetic field, B_3 , generated by the wire. (8 points)
- ב. Calculate at what distance from the solenoid's axis the magnitude of the field B_1 will equal the magnitude of the field B_3 . (6 points)

5. The diagram below describes a system that contains two smooth rails, PQ and KL, whose resistance is negligible.

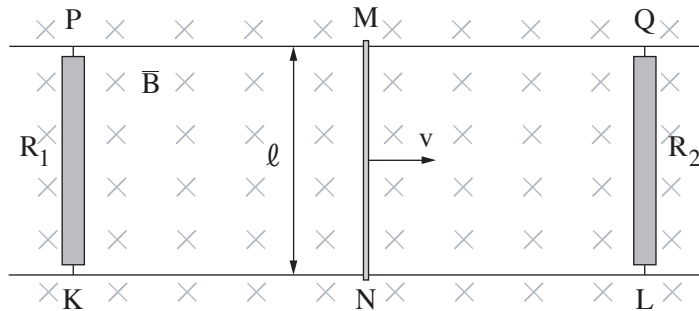
The rails are resting on a horizontal table parallel to each other. The distance between the rails is ℓ .

Resistor R_1 connects between points P and K on the rails, and Resistor R_2 connects between points Q and L on the rails.

A conductive rod, MN, with negligible resistance, moves on the rails without friction at a constant velocity of magnitude v ; its direction of movement is to the right. The rod remains perpendicular to the rails.

The system is located inside a uniform magnetic field of magnitude B , directed 'into the page' and perpendicular to it.

Air resistance is negligible.



Given: $R_2 = 10\Omega$, $R_1 = 5\Omega$, $B = 10^{-2}\text{T}$, $v = 5\frac{\text{m}}{\text{s}}$, $\ell = 0.1\text{m}$.

An induced emf was generated in the rod MN.

- א. Determine which point, M or N, has a higher potential. Explain your answer.
(5 points)
- ב. Calculate the induced emf between Points M and N. (5 points)
- ג. Calculate the current intensity and determine its direction in each of the following components: Resistor R_1 , Resistor R_2 , and Rod MN. (10 points)
- ד. Determine whether there is an external force acting on the rod MN (the rod is moving at a constant velocity).
If there is, calculate its magnitude and determine its direction.
If not, explain your answer. (8 points)
- ה. What is the source of the energy in this system? (5 $\frac{1}{3}$ points)

Good Luck!

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בהצלחה!

זכות היוצרים שמורה למדינת ישראל
אין להעתיק או לפרסם אלא ברשות משרד החינוך