State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2018
Exam number: 36371
Attachment: Data and formulas for 5-point physics
English translation (3)

Physics
Electricity

Instructions for examinees

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

ב. Exam structure and breakdown of points:
There are six 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!

Good Luck!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ח, 2018
מספר השאלון: 36371
נספח: נוסחאות ונתונים בפיזיקה ברמה של 5 יח"ל
תרגום לאנגלית (3)

פיזיקה
חשמל

הוראות לנבחן

א. משך הבחינה: שעה וארבעים וחמש דקות.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שש 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־רישום הנוסחה או אי־ביצוע ההצבה או אי־רישום 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 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 1-6.

(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 $V_s = -1000V$.

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

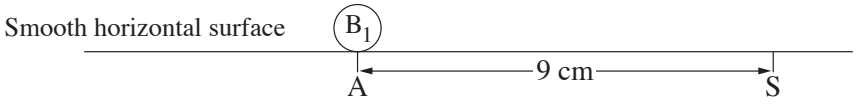


Figure 1

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.)

/Continued on page 3/

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

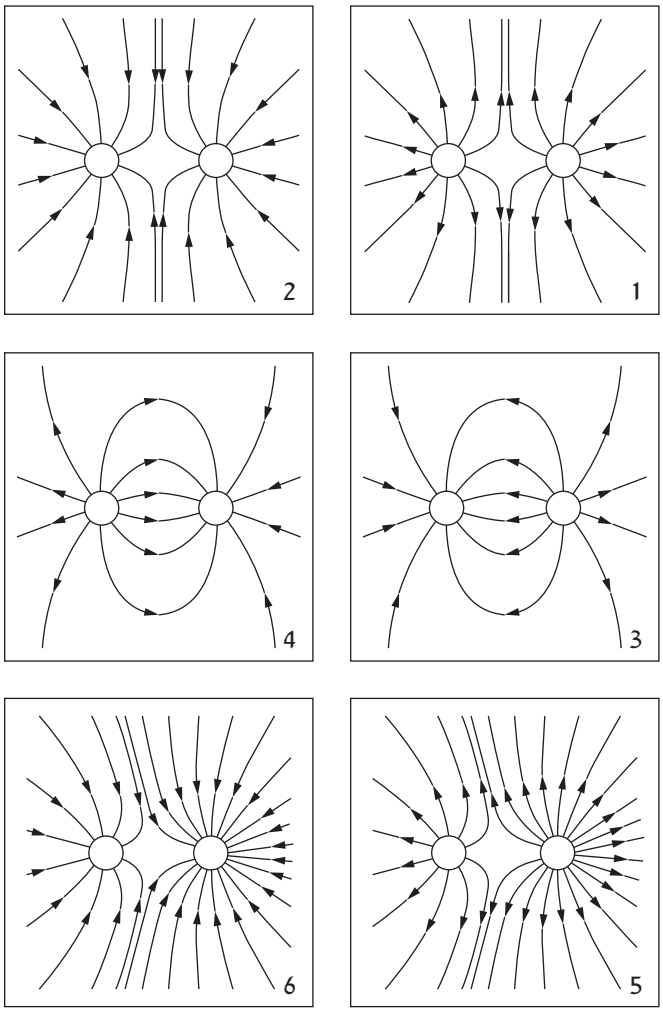


Figure 2

ד. 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.)

/Continued on page 4/

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).

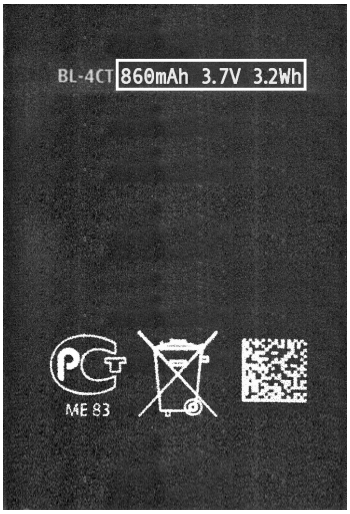


Figure 1

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

/Continued on page 5/

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.

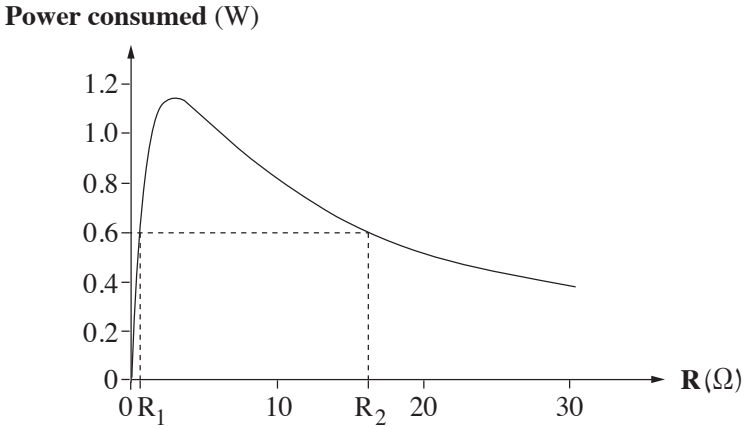


Figure 2

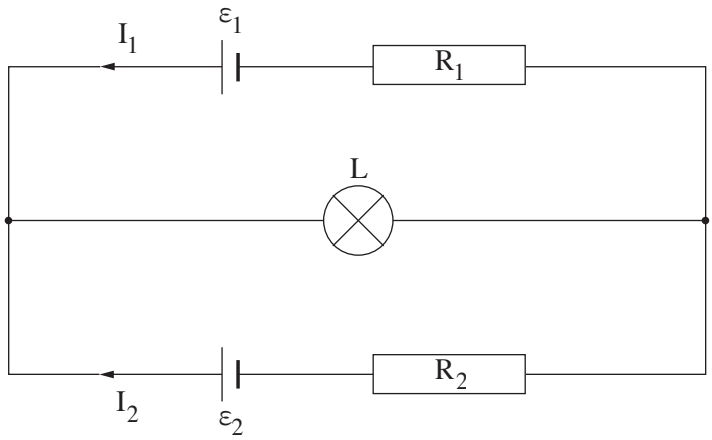
For two different resistances of the device, R_1 and R_2 ($R_2 > R_1$, see Figure 2), the consumed power is 0.6W.

ה. At which resistance, R_1 or R_2, will the battery heat up more? Explain your answer.

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

/Continued on page 6/

3. In the diagram below, the electric circuit is composed of two ideal voltage sources, ε_1 and ε_2, a light bulb L, two resistors R_1 and R_2, and ideal wires.



An ammeter is added to the circuit to measure the current I_3 that passes through the light bulb, and a voltmeter is added to measure the voltage on the resistor R_2.
Both meters are ideal meters.

א. Copy the diagram to your answer booklet. Add the ammeter and voltmeter to the diagram in your answer booklet. (8 points)

Given: $\varepsilon_1 = 18V$, $\varepsilon_2 = 30.4V$, $R_1 = 10\Omega$, $R_2 = 12\Omega$. The light bulb is marked 36W, 12V.

ב. Calculate the resistance of the light bulb, R_L. (6 points)

Each of the two Kirchhoff laws is an application of a law of conservation.

ג. **(1)** Write <u>both</u> of Kirchhoff's laws (in words).

(2) For <u>each</u> of Kirchhoff's laws, list the conservation law it derives from.
($6\frac{1}{3}$ points)

ד. Provide equations that can be used to calculate the intensity of the current I_3 flowing through the light bulb. **There is no need to provide calculations.** (6 points)

The ammeter reading is 2.5A and the voltmeter reading is 20.4V.

ה. Calculate the intensity of the current that passes through the voltage source ε_1.
(7 points)

/Continued on page 7/

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

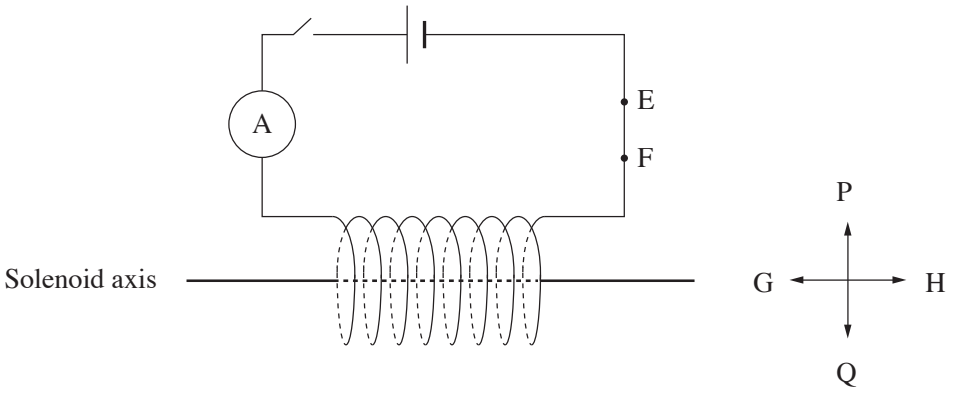


Figure 1

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.

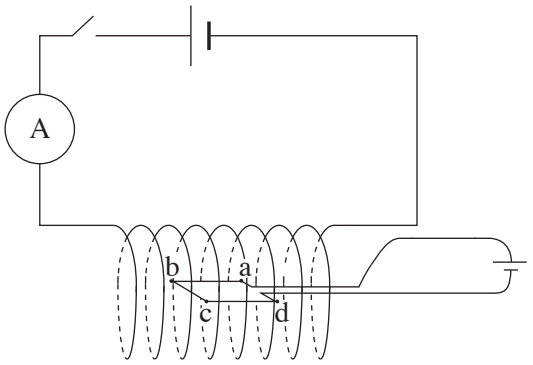


Figure 2

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.)

/Continued on page 8/

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 $I_3 = 20A$.

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'.

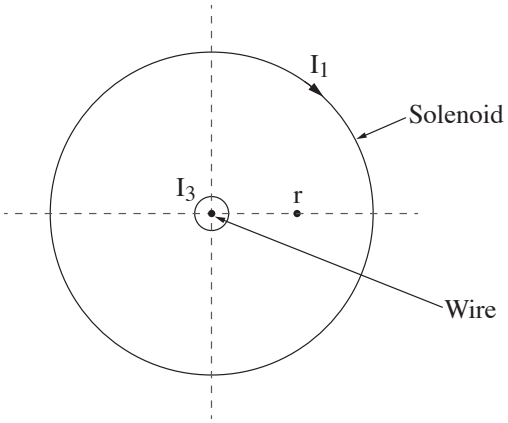


Figure 3

ג. 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)

ד. 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)

/Continued on page 9/

Capacitance

5. In an experiment, a student constructed a series electric circuit using the following components: battery, switch, resistor R, capacitor C, wires, and meters - an ammeter and three voltmeters to measure the voltage between the battery terminals (V_1), the voltage on the resistor (V_2), and the voltage on the capacitor (V_3).

Capacitor C is a parallel-plate capacitor with no dielectric material between the plates ($\varepsilon_r = 1$).

Given: The battery, wire connectors, and meters are ideal.

א. In your answer booklet, draw a diagram of the electric circuit described above.

(4 points)

ב. Write an equation for the relationship between the three voltage measurements V_1, V_2, and V_3. (1 point)

Step 1 of the experiment

At the time $t = 0$, when the capacitor was not charged, the student closed the switch.

The graph below describes current intensity in the circuit as a function of time from $t = 0$.

Current in the circuit as a function of time

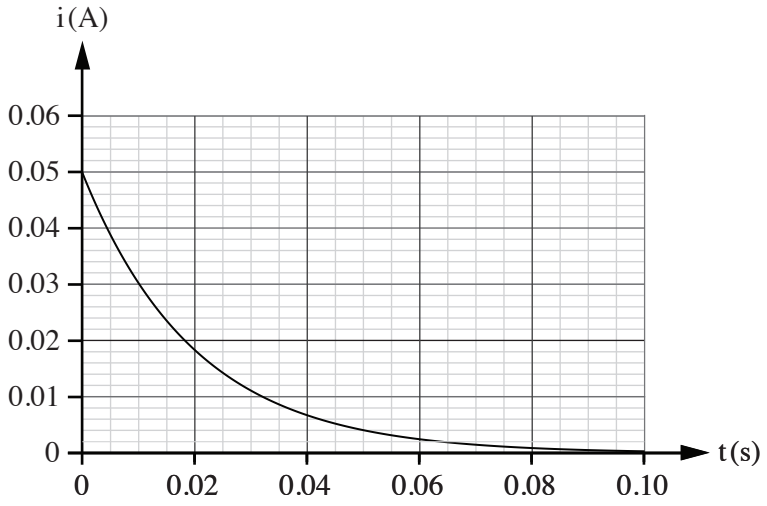


Figure 1

Given: $C = 20\mu F$.

ג. Use the graph to calculate:

(1) the resistance of Resistor R

(2) the voltage on the resistor (V_2) at time $t = 0$.

(10 points)

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

/Continued on page 10 /

Step 2 of the experiment:

After a very long interval the student opened the switch and doubled the distance between the plates.

ד. Calculate the voltage on the capacitor (V_3) after the change. (7 points)

ה. Determine whether, after the change, the electric field intensity between the plates increased, decreased, or remained unchanged. Explain your answer. (5 points)

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

/Continued on page 11/

Step 3 of the experiment:

The student returned the capacitor to its original state at time $t = 0$ in Step 1.

She filled the entire volume between the plates with a substance whose dielectric constant [מקדם דיאלקטרי] is $\varepsilon_r = 3$, then she closed the switch and waited a long time.

The four graphs in Figure 2, below, describe current intensity as a function of time. The solid lines describe the current in the circuit before adding the dielectric substance (as shown in Figure 1), and the dashed lines describe the current in the circuit after adding the dielectric substance.

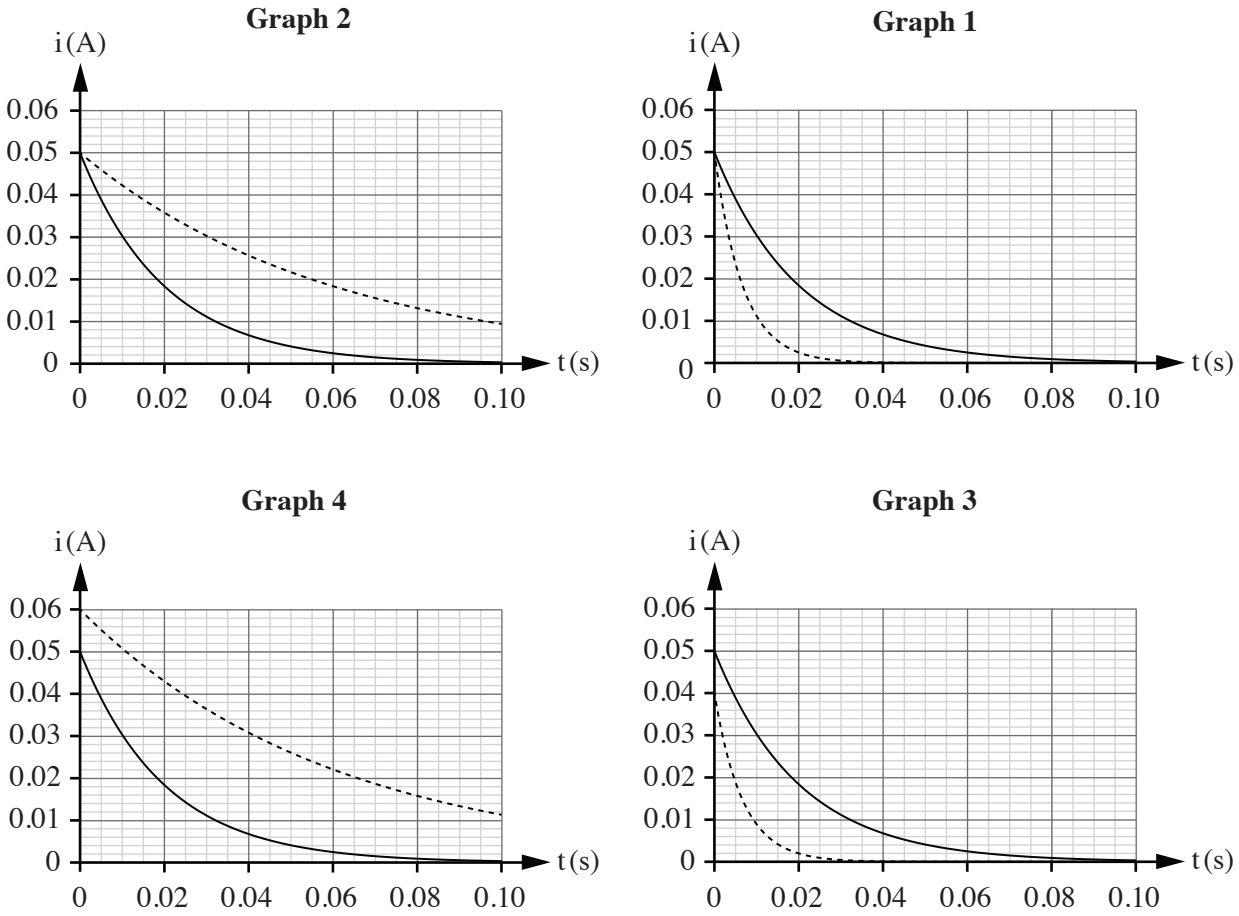


Figure 2

١. Determine which one of the four graphs, 1-4, correctly describes the current as a function of time in both states. Explain your answer. ($6\frac{1}{3}$ points)

/Continued on page 12/

Induction

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

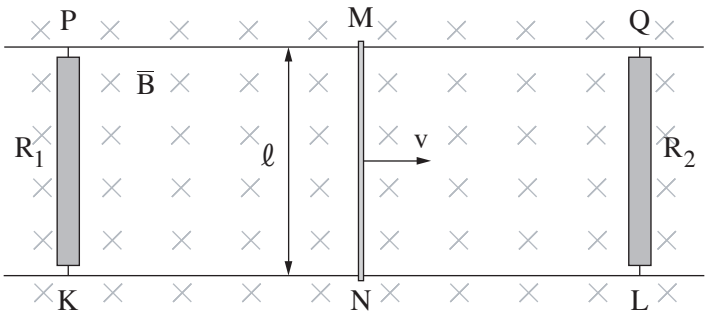
The rails are resting on a horizontal table parallel to each other. The distance between the rails is ℓ.

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

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! **בהצלחה!**