State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2024
Exam number: 36361
Attachment: Formula and data sheets for 5-point Physics
English translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשפ"ד, 2024
מספר השאלון: 36361
נספח: דפי נוסחאות ונתונים בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

Physics
Mechanics

Instructions

א. Duration of the exam: Two and one-quarter hours.

ב. Exam structure and breakdown of points:
This exam has six questions. Answer three questions 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 non-graphing calculator. You may not use the programming options of a programmable calculator.
(2) Formula and data sheets (attached)
(3) A Hebrew–foreign language / foreign language–Hebrew dictionary

ד. Special instructions:
(1) Answer three questions only. If you answer more than three questions, only the first three answers in your answer booklet will be graded.
Clearly indicate the question and item number that you chose.
(2) When solving questions that require calculations, you must show the following steps: Write down the mathematical expression as it appears in the formula and data sheets; write down all derivations and change in subject of the formula required by the problem; insert the data in your derived expression; write the results of your calculations in decimal form using a suitable number of significant figures and suitable units of measurement.
(3) Use at least half a page for drawing graphs. Use a ruler to draw straight lines.
(4) 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 from the table in the formula and data sheets, or the free-fall acceleration g.
(5) In your calculations, use the value 10 m/s^2 for the magnitude of g, free-fall acceleration (near the surface of Earth).
(6) Write your answers in pen. Use pencil for sketches and graphs only.
(7) If you make a mistake, it is sufficient to cross out the incorrect text with a double line.

Write in the answer booklet only. Write "טיוטה" at the top of each draft page. If you write any draft material on pages not in the answer booklet, your exam may be disqualified.

Good Luck!

פיזיקה
מכניקה

הוראות

א. משך הבחינה: שעתיים ורבע.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שש שאלות, ומהן יש 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 לא גרפי. אין להשתמש באפשרויות התכנות במחשבון שיש בו אפשרות תכנות.
(2) דפי נוסחאות ונתונים (מצורפים).
(3) מילון עברי–לועזי / לועזי–עברי.

ד. הוראות מיוחדות:
(1) יש לענות על שלוש שאלות בלבד. אם תענו על יותר משלוש שאלות, ייבדקו רק שלוש התשובות הראשונות שבמחברת.
יש לציין באופן ברור את מספר השאלה שבחרתם ואת הסעיף.
(2) בשאלות שבפתרון שלהן נדרש חישוב, יש להציג את השלבים האלה:
רישום הביטוי המתמטי כפי שהוא כתוב בדפי הנוסחאות והנתונים המצורפים, פיתוח מתמטי ושינוי נושא נוסחה בהתאם לבעיה, הצגה מפורשת של הנתונים בביטוי שהתקבל, הצגת תוצאות החישוב באמצעות שבר עשרוני ובו מספר מתאים של ספרות משמעותיות וכן יחידות המידה.
(3) את הגרפים יש לסרטט בגודל של חצי עמוד לפחות. יש להשתמש בסרגל לסרטוט קווים ישרים.
(4) כאשר נדרשים להביע גודל באמצעות נתוני השאלה, יש לרשום ביטוי מתמטי הכולל את נתוני השאלה או את חלקם; במידת הצורך אפשר להשתמש גם בקבועים בסיסיים מתוך הטבלה שבדפי הנוסחאות והנתונים או בגודל תאוצת הנפילה החופשית g.
(5) בחישובים יש להשתמש בערך 10 m/s^2 לגודל של g — תאוצת הנפילה החופשית (בסמוך לפני כדור הארץ).
(6) יש לכתוב את התשובות בעט. מותר להשתמש בעיפרון לסרטוטים וגרפים בלבד.
(7) במקרה של טעות, אפשר להסתפק בהעברת קו חוצה כפול על המילים או המשפטים השגויים.

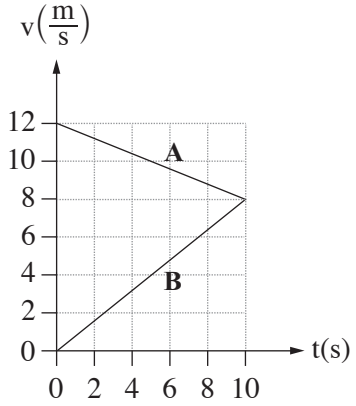
יש לכתוב במחברת הבחינה בלבד. יש לרשום "טיוטה" בראש כל עמוד המשמש טיוטה. כתיבת טיוטה בדפים שאינם במחברת הבחינה עלולה לגרום לפסילת הבחינה.

בהצלחה!

Questions

Answer three of the questions 1–6.
(Each question – $33\frac{1}{3}$ points; the point value of each item is given at the end of the item.)

1. Two cars, A and B, drove on a straight road. At time $t = 0$ both cars were at point $x = 0$. The graphs in the figure below describe the speed of cars A and B as a function of time, from time $t = 0$ until time $t = 10s$. We set the positive direction to be rightward.



א. Calculate the acceleration (magnitude and direction) of each of the cars during the interval $0 < t < 10s$. (8 points)

ב. Answer both Sub-Items (1) and (2) for time $t = 10s$.

(1) Determine whether the cars moved in the same, or in opposite, directions. Explain your answer.

(2) Determine whether the distance of Car A from the Point $x = 0$ was greater than, less than, or the same as, the distance of Car B from this point. Explain your answer.

(6 points)

After time $t = 10s$, Car A continued to move with the same acceleration you calculated in Item א, until it reached a bus stop and then stopped.

ג. **(1)** Calculate the distance of the bus stop from Point $x = 0$.

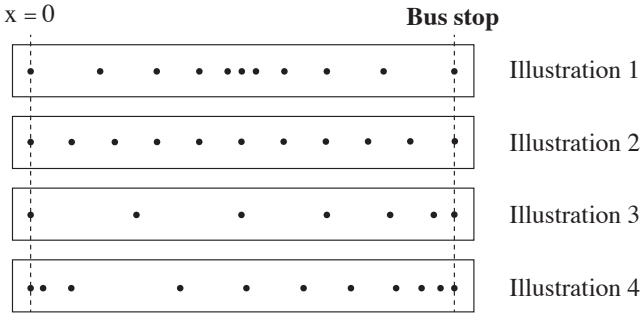
(2) Calculate the time that passed from time $t = 0$ until Car A arrived at the bus stop.

(8 points)

At time $t = 10s$, Car B began to slow down with a constant deceleration until it stopped at the same bus stop at which Car A had stopped.

ד. Calculate how much time passed from the moment Car A stopped at the bus stop until Car B stopped there. (7 points)

ה. A special device was installed on the underside of Car B, very close to the road, that releases a small drop of paint at regular time intervals onto the road, one drop at a time.
Determine which of the illustrations 1–4 below best illustrates the trace diagram that resulted from the paint drops during the motion of Car B from **time $t = 0$** until it stopped at the bus stop. ($4\frac{1}{3}$ points)

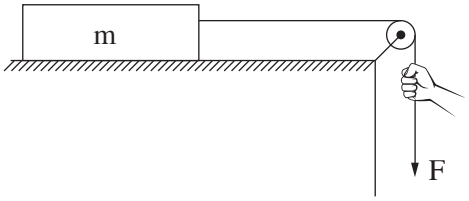


/Continued on page 3/

2. A physics student conducted an experiment in which a box of mass m is placed on a rough horizontal surface. The box is tied to a rope passing through a pulley, as shown in the illustration below.

The mass of the wire and the mass of the pulley are negligible. The coefficient of friction (static and kinetic) between the box and the surface is μ.

In the experiment the student pulled the end of the wire downwards with Force F and measured the magnitude of the acceleration, a, of the box as it moved. The student repeated the measurements several times, each time changing the magnitude of Force F and measuring the magnitude of the acceleration a.



Results of the measurements are presented in the following table:

$\mathbf{F}$ (N)	3.5	4.0	4.5	5.0	5.5
$\mathbf{a}\left(\frac{\text{m}}{\text{s}^2}\right)$	1.9	2.7	3.4	4.2	5.0

א. Sketch a free-body diagram [תרשים כוחות] of the forces acting on the box. Label each force with its name and specify what exerts the force. (6 points)

ב. Without relying on measurements taken by the student, develop an expression for the acceleration of the box a as a function of the force F.
Express your answer in terms of the parameters m, μ, g. (8 points)

ג. **(1)** Draw a scatter diagram (dots on a coordinate system) illustrating the magnitude of the acceleration of the box a as a function of the force F.
(2) Add the best-fitting line (regression line) to your scatter diagram.
(8 points)

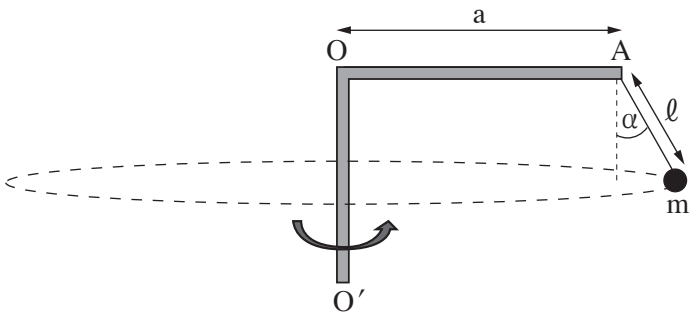
ד. Use the graph that you drew to answer the two Sub-Items (1)–(2).
(1) Calculate the mass m of the box.
(2) Calculate the coefficient of friction μ between the box and the surface.
(7 points)

ה. The student made an additional measurement, in which she pulled the wire with a force $F = 1.5\text{N}$.
Determine what the box's acceleration was in this case. Explain your answer. ($4\frac{1}{3}$ points)

/Continued on page 4/

3. The illustration below describes a device built from a horizontal bar AO of length $a = 3m$, attached to a vertical axis OO'. A string with a small body m on its end is attached to the bar at Point A.

We know that $m = 2kg$ and the length of the string is $\ell = 1m$. The mass of the string is negligible. The device rotates at a constant frequency f, and the body m travels in a horizontal circular path. In this state, the angle between the string and the vertical direction is $\alpha = 30^o$.



א. Below are four free-body diagrams, 1–4. The lengths of the vectors are relative (proportional) to the magnitudes of the forces.

Determine which diagram best describes the forces acting on the body m while the device is rotating. (5 points)

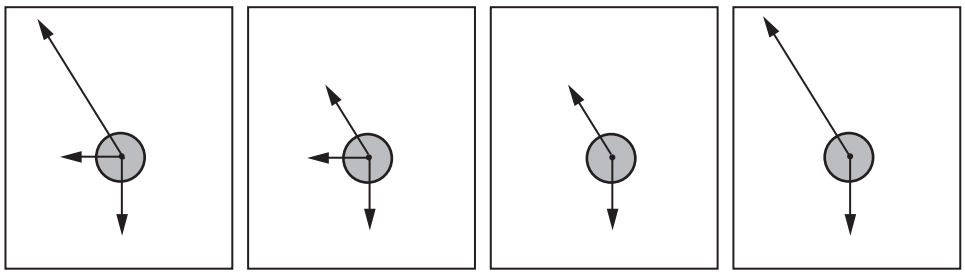


Diagram 4 **Diagram 3** **Diagram 2** **Diagram 1**

ב. Calculate the tension in the string while the device is rotating. (8 points)

ג. Determine whether the tension in the string while the device is <u>not</u> rotating is greater than, less than, or equal to, the tension that you calculated in Item ב. Explain your answer. (8 points)

ד. Calculate f, the rotation frequency. (8 points)

ה. We know that the maximum tension the string can withstand before it tears is 45N.

Calculate the maximum rotation frequency at which the device can rotate without the string tearing. ($4\frac{1}{3}$ points)

/Continued on page 5/

4. Two boxes A and B with masses m_A and m_B, respectively, move towards each other on a frictionless horizontal surface as described in Figure 1.

Figure 1

We know that $m_A = 0.14kg$. The mass of Box B is unknown.
A motion sensor tracks the motion of the boxes and measures their velocities as a function of time.
We set the positive direction to be rightward.
The results of the sensor's measurements are displayed in graphs 1, 2 in Figure 2.

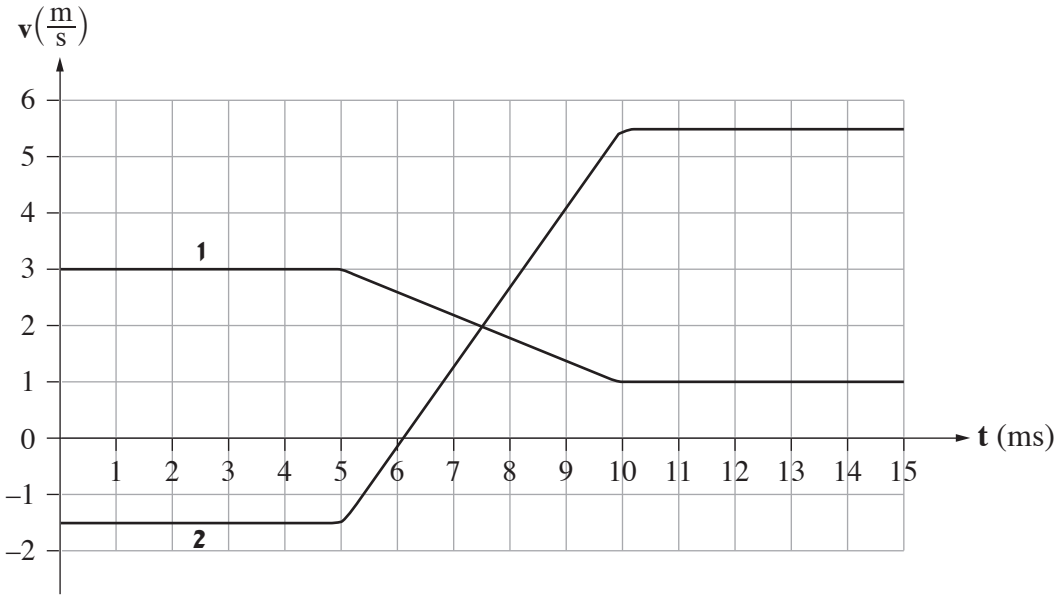


Figure 2

Note: The values on the time axis are in units of ms (milliseconds).

א. Determine which of the graphs, 1 or 2, represents the velocity of Box B.
Explain your answer. (4 points)

ב. Calculate m_B, the mass of Box B. (9 points)

ג. Calculate the impulse (magnitude and direction) that Box B exerted on Box A. (8 points)

ד. Calculate the average force (magnitude and direction) that Box B exerted on Box A.
(8 points)

ה. Two students were asked about the magnitude of the impulse that Box A exerted on Box B.
Student 1 argued that an impulse of greater magnitude was exerted on the box whose mass was greater.
Student 2 argued that an impulse of equal magnitude was exerted on each box, regardless of the mass of the boxes.
Which of the two students is correct? Explain your answer.
($4\frac{1}{3}$ points)

/Continued on page 6/

5. A body of mass $m = 2kg$ is placed on a rough horizontal surface. The coefficient of kinetic friction between the body and the surface is $\mu = 0.2$.

We define a location axis, x , whose origin is $x_0 = 0$ at the position where the body is placed, and whose positive direction is to the right (see Figure A).

We exert a rightward horizontal force F on the body and the body begins to move over the surface.

When the body reaches Point A , of coordinate $x_A = 5m$, the force F stops acting.

From Point A the body continues to move over the surface until it stops at Point B .

Let x_B be the location of Point B .

Note: Figure A is not drawn to scale.

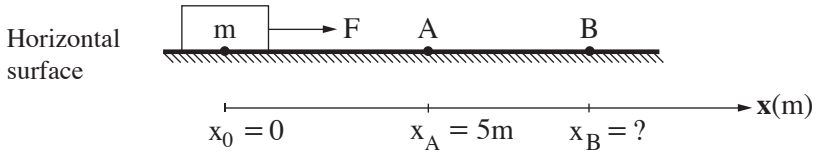


Figure A

The graph in Figure B displays the magnitude of the force F as a function of the body's position.

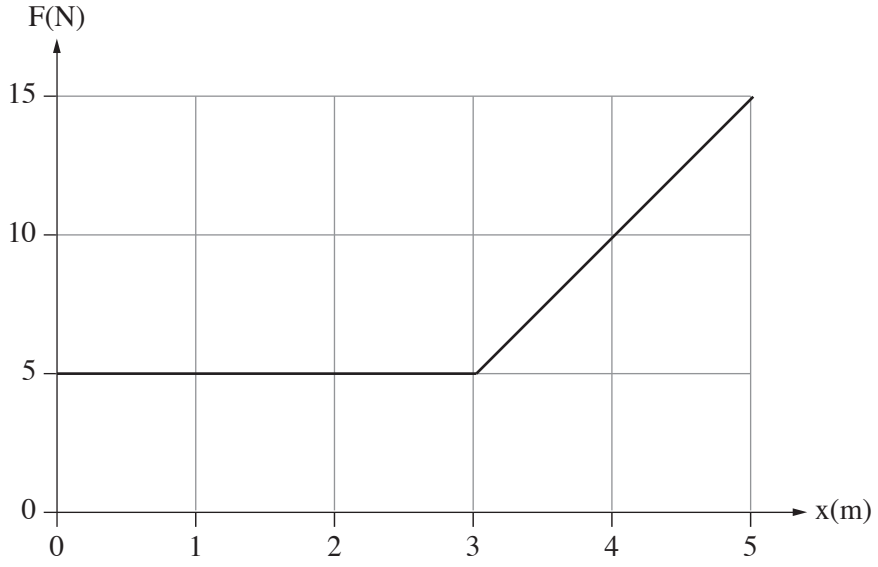


Figure B

א. Determine what is the physical quantity expressed by the area enclosed between the graph and the location axis (x) while the force F is exerted, and calculate the size of the enclosed area. (6 points)

ב. Calculate the work of the friction force from the time the body began to move until it reached Point A . (8 points)

ג. Calculate the speed of the body as it passed through Point A . (8 points)

ד. Calculate x_B , the coordinate of Point B at which the body stopped. (7 points)

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

/Continued on page 7/

In another experiment, we exert a non-horizontal force F_1 on the body; the force is tilted upwards at an angle α (see Figure C) in such a way that the body remains on the surface during its motion.
The graph in Figure B also describes the magnitude of the horizontal component of the force F_1 as a function of the body's position.
Under the influence of the force F_1 the body begins to move over the surface from the Point $x_0 = 0$.
When the body reaches Point A, the force F_1 stops acting.
The body continues to move over the surface from Point A until it stops at Point C.
Let x_C be the location of Point C.
Note: Figure C is not drawn to scale.

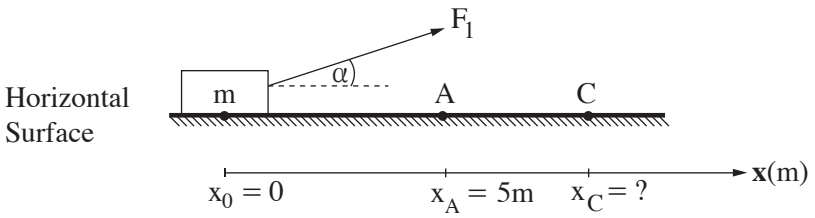


Figure C

ה. Consider the expressions 1–4 below, and choose the correct one. Explain your answer.

1. $x_C < x_B$

2. $x_C = x_B$

3. $x_C > x_B$

4. We cannot determine the relationship between x_B and x_C without additional information.

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

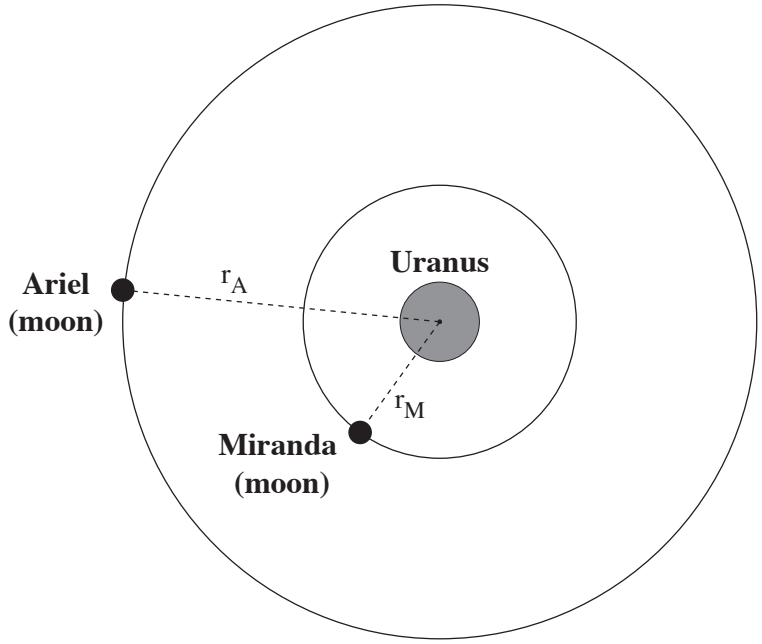
/Continued on page 8/

Gravity

6. In 1781 the astronomer Sir William Herschel discovered the planet Uranus.
Data about the planet Uranus are presented in the attachment: "נוסחאות ונתונים בפיזיקה" (formula sheet).

א. Calculate the magnitude of the free-fall acceleration near the surface of the planet Uranus. (6 points)

Two of the moons that orbit the planet Uranus, Ariel and Miranda, are shown in the figure below (assume circular orbits). The figure is not drawn to scale.
Miranda circles Uranus with an orbital radius of $r_M = 13 \cdot 10^7\,\text{m}$ and orbital period of T_M.
Ariel circles Uranus with an orbital radius of $r_A = 19 \cdot 10^7\,\text{m}$ and orbital period of T_A.



ב. Calculate the magnitude of **Miranda's** radial acceleration in its motion around Uranus. (8 points)

ג. Calculate **Miranda's** orbital period T_M in its motion around Uranus. (8 points)

ד. Calculate the ratio of Ariel's orbital period to Miranda's orbital period, $\frac{T_A}{T_M}$. (7 points)

We want to launch two artificial satellites to orbit Earth:
Satellite א that will travel in a circular orbit whose radius is equal to the radius of Miranda's orbit around Uranus, and
Satellite ב that will travel in a circular orbit whose radius is equal to the radius of Ariel's orbit around Uranus.

ה. Determine whether the ratio of the orbital period of Satellite ב to the orbital period of Satellite א $\left(\frac{T_{ב}}{T_{א}}\right)$ in their motions around Earth will be the same as, or different from, the ratio of the orbital periods of Ariel and Miranda $\frac{T_A}{T_M}$ that you calulated in Item ד.
Explain your answer. ($4\frac{1}{3}$ points)

Good Luck!

בהצלחה!