**State of Israel**
**Ministry of Education**
Type of exam:
א. *Bagrut* for high schools
ב. *Bagrut* for external students
Exam date: Summer 2016
**Exam number: 036201, 656**
Attachment: Data and formulas for 5-point Physics
**English translation (3)**

# Physics

## Mechanics, Optics and Waves

For 5 points

### Instructions for examinees

א. Duration of the exam: Two and a half hours (150 minutes)

ב. Exam structure and breakdown of points:
This exam has two parts.

| | | | |
|---|---|---|---|
| Part One — Mechanics | — | $3 \times 25$ | 75 points |
| Part Two — Optics and Waves | — | $2 \times 12\frac{1}{2}$ | 25 points |
| Total | — | | 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. (Answers will be graded in the order that they appear in the test 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 sheet, 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 write out the formula with the inserted values or write the units, points may be deducted from your score.
(3) When you are asked to determine a value using data provided in the question, write out the mathematical expression including all or some of the given data. When necessary, you may also use basic constants, such as the free-falling acceleration $g$ or the gravitational constant G.
(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. Writing any sort of draft material outside the test booklet may lead to the disqualification of the exam!

**Good Luck!**

**מדינת ישראל**
**משרד החינוך**
סוג הבחינה:
א. בגרות לבתי ספר על-יסודיים
ב. בגרות לנבחנים אקסטרניים
מועד הבחינה: קיץ תשע"ו, 2016
**מספר השאלון: 036201, 656**
נספח: נתונים ונוסחאות בפיזיקה ל-5 יח"ל
**תרגום לאנגלית (3)**

# פיזיקה

## מכניקה, אופטיקה וגלים

לתלמידי 5 יחידות לימוד

### הוראות לנבחן

א. משך הבחינה: שעתיים וחצי (150 דקות).

ב. מבנה השאלון ומפתח ההערכה: בשאלון זה שני פרקים.
פרק ראשון — מכניקה — $3 \times 25$ — 75 נקודות
פרק שני — אופטיקה וגלים — $2 \times 12\frac{1}{2}$ — 25 נקודות
סה"כ — 100 נקודות

ג. חומר עזר מותר בשימוש:
(1) מחשבון.
(2) נספח נתונים ונוסחאות 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 מהציון.
(3) כאשר אתה נדרש להביע גודל באמצעות נתוני השאלה, רשום ביטוי מתמטי הכולל את נתוני השאלה או את חלקם; במידת הצורך אפשר להשתמש גם בקבועים בסיסיים, כגון תאוצת הנפילה החופשית g או קבוע הכבידה העולמי G.
(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

## Part One — Mechanics (75 points)

Answer three of the questions 1-5.

(Each question – 25 points; the point value of each item is given.)

**1.** Shimon is playing with his cat. Shimon pushes a toy mouse along the floor. The toy moves along a straight line from Point A toward Point B (see figure). At the same time, the cat begins to run from the same point heading in the same direction. Consider the air resistance to be negligible.


The cat accelerated from a state of rest at a steady rate of $1\frac{m}{s^2}$ for 2 seconds. It then continued moving at a constant velocity for an additional 5 seconds. Over the next second, it decelerated at a constant rate until stopping at Point B.

**א.** In your answer booklet, sketch a graph of the velocity of the cat as a function of time. (6 points)

**ב.** Calculate the distance between Point B and Point A. (4 points)

Shimon gave the toy an initial velocity at Point A and the toy reached Point B one and a half seconds **before** the cat reached that point.

The coefficient of friction ($\mu$) between the toy and the floor is constant.

**ג.** Calculate the initial velocity of the toy. (4 points)

**ד.** In your answer booklet, sketch a diagram of the forces acting on the toy and calculate the value of $\mu$. (6 points)

Later, Shimon played the game once more and gave the toy the same initial velocity. This time, the coefficient of friction ($\mu^1$) between the toy and the floor was double what it had been previously ($\mu^1 = 2\mu$).

**ה.** In which one of the following parameters of the toy's movement, 1-4, was there **no** change? Explain your answer.

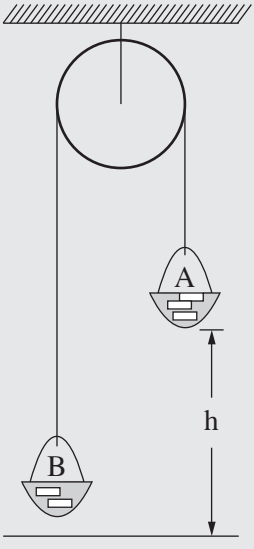
1. the acceleration
2. the time it took the toy to stop
3. the distance the toy traveled before it stopped
4. the average velocity

(5 points)

/Continued on page 3/

**2.** Two excerpts (Excerpt א and Excerpt ב) from a laboratory report written by a team of students are presented below. Read both excerpts and answer the items that follow each excerpt.

- Excerpt א -




Subject: Application of Newton's Second Law

The figure shows a system (an Atwood Machine) made up of a pulley that is attached to the ceiling and a rope that is wound around it. Baskets A and B are attached to the two ends of the rope and there are weights in each basket. The total mass of Basket A and the weights it contains is $m_A$ and the total mass of Basket B and the weights it contains is $m_B$. Basket A (the heavier one) is located at a height h above the floor (see figure). The baskets can move up and down.

In this system, the mass of the rope, the mass of the pulley and all of the frictional forces are negligible. Over the course of the experiment, the system is released from rest.

A stop-watch is used to measure the amount of time (t) from the moment the system is released from rest until the moment that Basket A hits the floor. The height and time measurements are used to calculate the acceleration (a) of Basket A.

Experiment 1

Objective: To test the hypothesis that Basket A falls with a constant acceleration

Procedure: Basket A was released several times, each time from a different height, with no change in the masses of the baskets. The acceleration (a) was then calculated.

The results and calculations for three measurements are presented in the table below.

| **h (m)** | **t (s)** | **a ($\frac{m}{s^2}$)** |
|---|---|---|
| 0.5 | 1.01 | 0.98 |
| 1 | 1.40 | 1.02 |
| 1.5 | 1.72 | 1.01 |

**א.** Briefly explain why, based on Newton's Laws, we would assume that Basket A falls with a constant acceleration. Do not base your answer for this item on the collected measurement data. (4 points)

**ב.** Show how the students calculated the acceleration in this experiment. (3 points)

**ג.** Do the findings presented in the table support the hypothesis that Basket A falls with a constant acceleration? Explain your answer. (3 points)

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

/Continued on page 4/

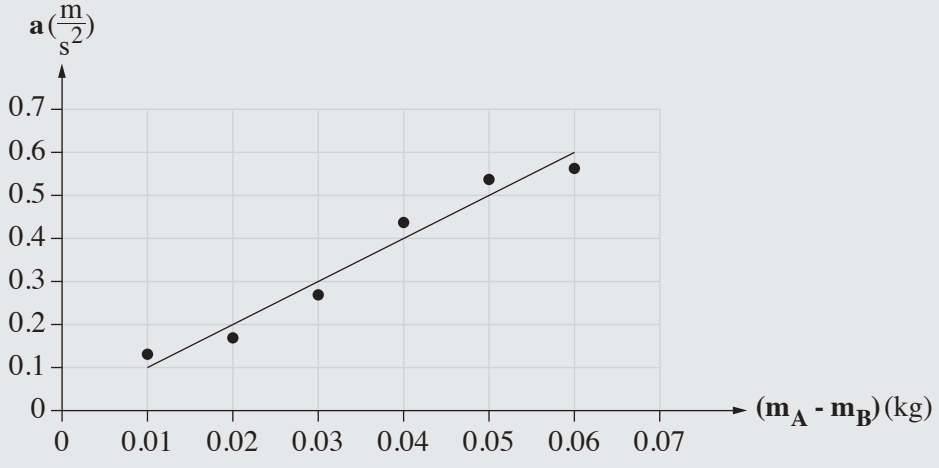
- Excerpt ב -

Experiment 2

Objective: To examine the relationship between acceleration and the difference between the masses of the two baskets while the overall mass of the system remains constant

Procedure: The duration of movement was measured several times and, each time, a weight was transferred from Basket B to Basket A.

The collected measurement data and the trend line are presented below.



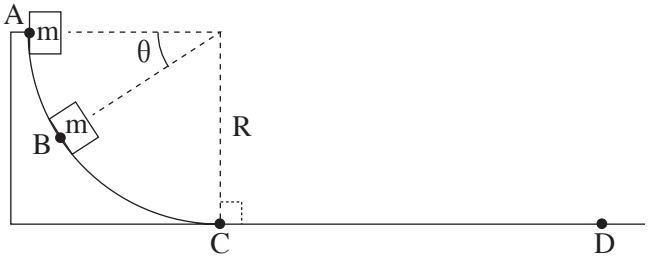

**ד.** In your answer booklet, sketch a diagram of the forces acting on each basket. Label each force in your diagram (by name). (4 points)

**ה.** Based on Newton's Laws, write an equation that describes the relationship between the acceleration and the difference between the masses of the two baskets. (6 points)

**ו.** Based on the graph shown in Excerpt ב from the students' report and the equation you wrote for Item ה, calculate the total mass of the baskets in the system ($m_A + m_B$). Show detailed calculations. (5 points)

/Continued on page 5/

**3.** An object with a mass m was released from rest at Point A and traveled along Track ABCD (see figure).
Section ABC of the track is smooth and its shape is that of a quarter-circle with the radius R. Section CD is rough and level.
Air resistance is negligible.




Use all or some of the parameters R, m, g and θ to answer Items א through ג.

**א.** Express the velocity of the object at Point B. (6 points)

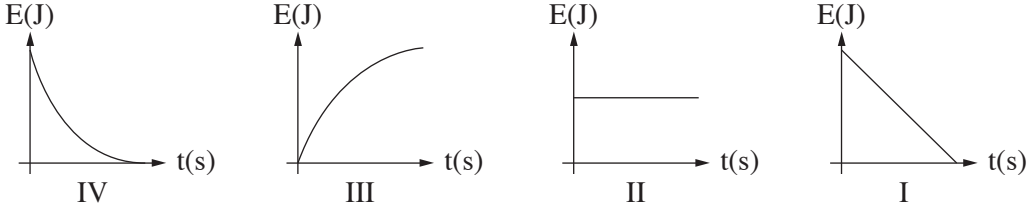
**ב.** Express the angular acceleration [תאוצה רדיאלית] of the object at Point B. (3 points)

**ג.** Express the tangential acceleration [תאוצה משיקית] of the object at Point B. (5 points)

After passing Point C, the object traveled with a constant acceleration until it stopped at Point D.
Given: Stopping distance CD = 2R.

**ד.** Based on energy considerations, calculate the coefficient of friction between the object and the rough, level section of the track. (6 points)

Four graphs that describe mechanical energy as a function of time are presented below.




**ה.** **(1)** Which of the graphs I-IV correctly describes the mechanical energy of the object over Section ABC as a function of time?
**(2)** Which of the graphs I-IV correctly describes the mechanical energy of the object over Section CD as a function of time?
Explain each of your answers. (5 points)

/Continued on page 6/

**4.** A box with a mass m = 0.5 kg traveled along a smooth horizontal surface toward a box that had a mass M and was at rest (see Figure 1).

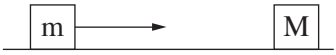



Figure 1

The two boxes collided in a perfectly elastic collision.
The velocities of the two boxes as a function of time are presented in the graph below.
Note: In the graph, time is shown in milliseconds [אלפיות שנייה].

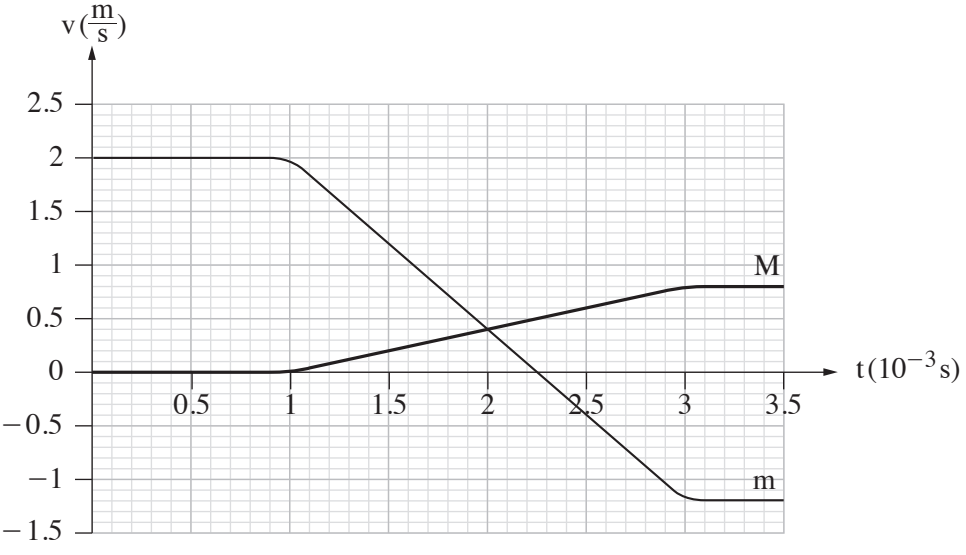



Figure 2

Use the graph to answer the items below.

**א.** Describe in words the movement of the box with mass m over the period of time described in the graph. (3 points)

**ב.** Calculate the mass M. (5 points)

**ג.** Calculate the average resultant force [הכוח השקול הממוצע] that acted on the box with mass M during the collision. (5 points)

**ד.** In the graph, we can see that during the collision, the slopes of the two curves differed in terms of their magnitude and their sign. Explain this difference, based on Newton's Laws. (5 points)

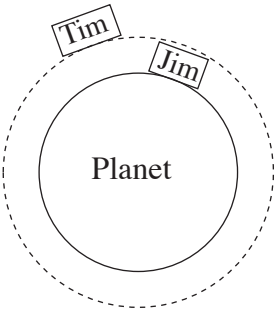
**ה.** Prove that the collision was perfectly elastic. (4 points)

**ו.** The box with mass M was removed and replaced with another box with a mass M'. The collision between the boxes remained perfectly elastic. Calculate the maximum value of M' for which the direction in which the box with the mass m is traveling will not change after the collision. (3 points)

/Continued on page 7/

**5.** In an imaginary scenario, two astronauts, Tim and Jim, explored a planet that does not rotate around its axis. Tim sat in a chair inside a spaceship that orbited the planet, moving along a circular route with the motor off.
Jim sat in a chair inside a vehicle located on the surface of the planet (see figure).

The two astronauts each have the same mass: m = 100 kg.




**א.** Which astronaut exerted a greater force upon his chair: Tim or Jim?
Explain your answer without doing any calculations. (6 points)

On the floor of the vehicle parked on the surface of the planet, there was a scale. When Jim stood on the scale, it read 2000 N.
Jim began to travel along a circular route that followed the equator of the planet. He noticed that the more he increased his velocity, the smaller the value reported by the scale.

**ב.** Explain why the value reported by the scale decreased. (3 points)

Given: When the vehicle reached a velocity $v = 1.25 \cdot 10^4 \frac{m}{s}$, the scale reported a value of 980 N.

**ג.** Calculate the radius of the planet. (6 points)

**ד.** Calculate the mass of the planet. (6 points)

**ה.** The acceleration of the spaceship steadily orbiting the planet (uniform circular motion) was $a$.
We will use g* to indicate the gravitational acceleration at the height at which the spaceship orbited the planet.
Which one of the statements below, 1-3, is correct?
Explain your answer.

1. $a > g^*$
2. $a = g^*$
3. $a < g^*$

(4 points)

/Continued on page 8/

## Part Two —Optics and Waves (25 points)

Answer two of the questions 6-8.
(Each question is worth $12\frac{1}{2}$ points; the point value of each item is given.)

**6.** A student wanted to check the type of lenses used in her aunt's glasses.
To do this, the student placed two identical spoons on a table and placed one of the lenses over one of the spoons.
A photograph that the student took of the spoons and the glasses is shown below.

**א.** For each of the sub-items below, (1)-(3), determine which term correctly describes the image of the spoon seen through the lens.
**(1)** upright or inverted (upside-down)
**(2)** real or virtual
**(3)** enlarged or reduced in size
(one point)

**ב.** Is the lens a converging lens [עדשה מרכזת] or a diverging lens [עדשה מפזרת]? Explain your answer.
(2 points)

/Continued on page 9/

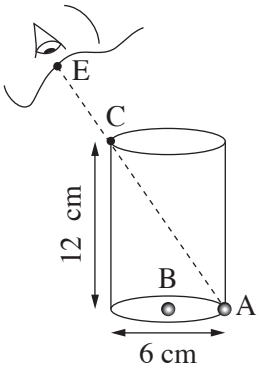
**ג.** Use a precise drawing of the paths of <u>three</u> rays to find the image of the spoon.
Given: The focal length of the lens is $|f| = 12$ cm, the distance between the object and the lens is 6 cm and the height of the object is 3 cm.
In your drawing, use a scale of 1 square = 1 cm.
(5 points)

**ד.** Use formulas to calculate the height of the image and the distance between the image and the lens.
Do the results of your calculations match the values obtained in your drawing?
($4\frac{1}{2}$ points)

/Continued on page 10/

**7.** The figure below shows an empty cylindrical container. The height of the container is 12 cm and its diameter is 6 cm.

There are two very small beads at the bottom of the container. Bead A is next to the wall of the container and Bead B is located at the center of the floor of the container.




A student looked into the container in the direction EC (Point C is located on the lip of the container).

When the container was empty, the student saw only Bead A.

The container was filled to the top with a clear liquid. The student looked in the same direction and saw only Bead B.

**א.** Copy the figure of the container and the student's eye into your answer booklet, <u>without</u> the dotted line.

To your sketch, add a ray of light that starts from Bead B, passes through the liquid to Point C and reaches the student's eye.

In your sketch, label the angle of incidence [זווית הפגיעה] ($\alpha$) and the angle of refraction [זווית השבירה] ($\beta$) in the path of the ray of light from the liquid into the air.

(4 points)

**ב.** Calculate the index of refraction [מקדם השבירה] of the liquid.

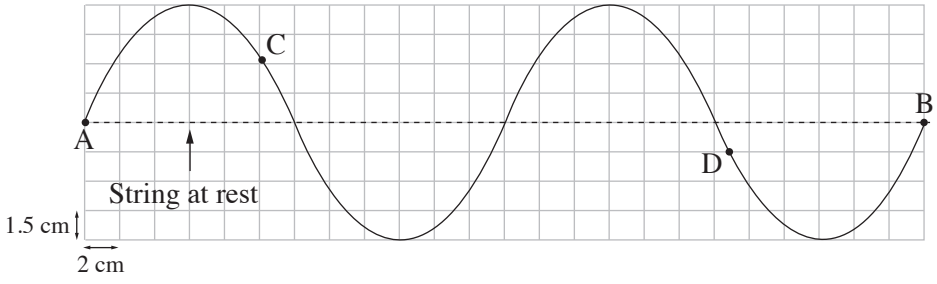
(4 points)

**ג.** Does the student see Bead B at its true depth or higher or lower than its true depth?

Draw an additional sketch of the container and the path of the rays to explain your answer. ($4\frac{1}{2}$ points)

/Continued on page 11/

**8.** The figure below shows a periodic wave propagating along the length of a taut string. The wave is produced at End A and propagates over a tenth of a second toward End B, which is attached to the wall. Each square in the diagram represents an area of 1.5 cm × 2 cm.




**א.** Refer to the figure and find the following:

**(1)** the amplitude of the wave

**(2)** the frequency of the wave

**(3)** the wavelength

**(4)** the speed of the wave

(4 points)

**ב.** Two points are labeled on the string in the figure: Point C and Point D. Determine the direction of the movement of <u>each</u> of these points at the moment described in the figure (upward / downward / to the right / to the left). (2 points).

**ג.** What is the condition for the creation of a standing wave? (2 points)

**ד.** What would the period [זמן המחזור] of the wave need to be for a standing wave with two antinodes [נקודות טבור] to be produced on the string? ($4\frac{1}{2}$ points)

**Good Luck!**

**בהצלחה!**