State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2022
Exam number: 036361
Attachment: Formula and data sheets for 5-point Physics
English translation (3)

Physics
Mechanics

Instructions

א. Duration of the exam: Two 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 to a reasonable number of decimal places, including the correct units of measurement.
(3) When the answer to a question must be expressed in words, be concise and on topic.
(4) When drawing graphs, use a ruler to draw straight lines.
(5) 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 .
(6) In your calculations, use the value $10\ m/s^2$ for the magnitude of free-fall acceleration (near the surface of Earth).
(7) Write your answers in pen. If you write in pencil or erase with White-Out you will not be able to appeal your grade. Use pencil for sketches and graphs only.

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!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשפ"ב, 2022
מספר השאלון: 036361
נספח: דפי נוסחאות ונתונים בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

פיזיקה
מכניקה

הוראות

א. משך הבחינה: שעתיים.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שש 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 לא גרפי. אין להשתמש באפשרויות התכנות במחשבון שיש בו אפשרות תכנות.
(2) hps 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 והסעיף שבחרתם.
(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 סביר של ספרות משמעותיות ויחידות המדידה המתאימות.
(3) בשאלות שהתשובה עליהן מילולית, יש לענות בקצרה אך ורק בנוגע למה שנשאלתם.
(4) בגרפים, יש לסרטט קווים ישרים באמצעות סרגל.
(5) כאשר אתם 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 .
(6) בחישובים יש להשתמש בערך $10\ m/s^2$ לגודל תאוצת הנפילה החופשית (בסמוך לפני כדור הארץ).
(7) יש לכתוב את התשובות בעט. אם תכתבו בעיפרון או תמחקו בטיפקס לא תוכלו לערער.
מותר להשתמש בעיפרון לסרטוטים וגרפים בלבד.

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

בהצלחה!

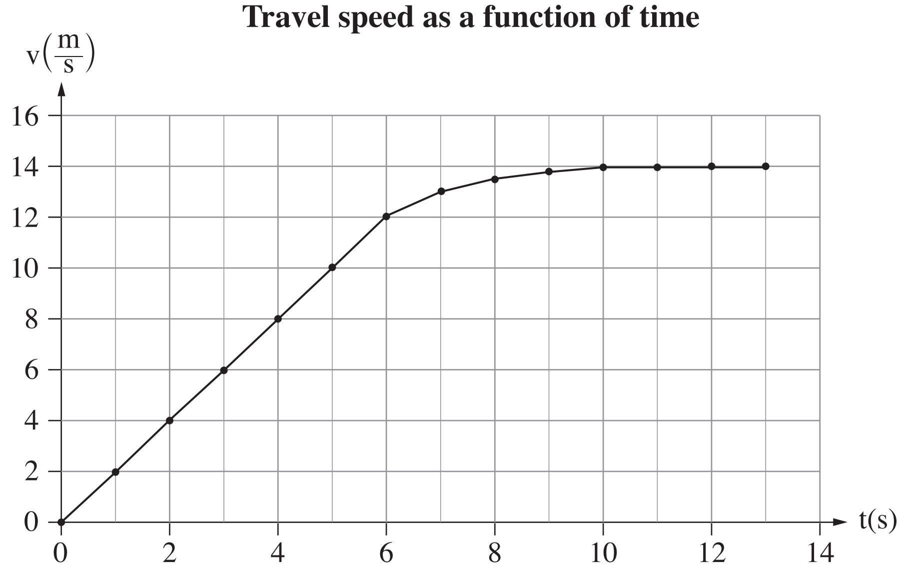
Questions

Answer <u>three</u> 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. A driver set off in a car from rest and traveled along a straight road. The graph below describes the car's travel speed as a function of time.

Travel speed as a function of time



א. Determine the type of motion (constant speed, uniformly accelerated, variable acceleration) at which the car is traveling in <u>each</u> of its three main stages of motion shown in the graph: $0 < t < 6s$, $6s < t < 10s$, $10s < t < 13s$. Explain your answers. (6 points)

The car's manufacturer claims that the car can accelerate from 0 km/h to 100 km/h in 2.6 seconds.

ב. Assume that the acceleration declared by the manufacturer is constant, and calculate by what factor this acceleration is greater than the driver's actual maximum acceleration. (6 points)

ג. Calculate the approximate average speed of the car during the first 13 seconds of this trip. (6 points)

The car continued traveling along a straight road at a speed of $14\frac{m}{s}$. At a certain moment the driver noticed a ball rolling across the road and tried to avoid hitting it.
0.75 s passed from the moment the driver noticed the ball until he pressed the brakes (reaction time). The car's braking acceleration was $3.5\frac{m}{s^2}$.

ד. Calculate the time from the moment the driver pressed the brakes until the car stopped. (6 points)

ה. Calculate the <u>total</u> distance that the car traveled from the moment the driver noticed the ball until the car stopped. (6 points)

A National Road Safety Authority poster says: " 10 km/h slower—double your chance of living". The driver understood this to mean that if he reduces the speed of his car by 10 km/h its braking distance will be reduced by a factor of two. The braking distance is the shortest distance that the car travels from the moment the driver presses the brakes until the car stops.

ו. If the driver reduces the speed of the car by 10 km/h, will its braking distance be two times smaller, independently of its speed? Explain your answer. ($3\frac{1}{3}$ points)

/Continued on page 3/

2. A student conducted three experiments. He used a box whose mass is M and a smooth track.
In the first experiment the student set up the track horizontally and placed the box on the track (see Figure 1). He held the box in place and tied a weight of mass m_1 to the box using a string passed over a pulley. The student released the system from rest.
Assume that the mass of the string and the mass of the pulley are negligible and that, as the system moves, the weight does not reach the ground and the box does not reach the pulley.
The system's given acceleration is $\frac{g}{4}$.

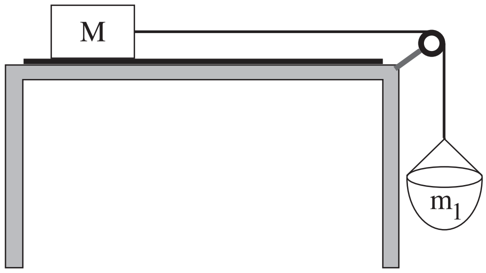


Figure 1

א. In your answer booklet, sketch a diagram of the forces acting on the box M and a diagram of the forces acting on the weight m_1 . Label each of the forces. (5 points)

ב. Express the mass of the weight m_1 in terms of the mass of the box M . (6 points)

ג. Calculate the ratio between the magnitude of tension in the string while the system was kept at rest and the magnitude of tension in the string after the system was released. (7 points)

In the second experiment the student raised one end of the track to make it slope at an angle of α relative to the horizon. He removed the weight m_1 from the system, placed the box M at the lower end of the track and gave the box a push so that it moved up the slope (see Figure 2). In this experiment the acceleration of the box was also $\frac{g}{4}$.

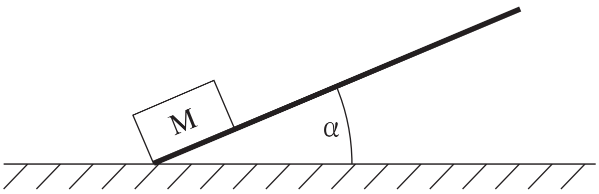


Figure 2

ד. Calculate the angle of the slope, α . (7 points)

After the box moved up the track it stopped momentarily, and then started moving back down the track.

ה. Determine whether the box's magnitude of acceleration at the moment it stopped was zero. Explain your answer. (5 points)

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

/Continued on page 4/

In the <u>third</u> experiment, the student placed an object in the box, and attached it to the wall of the box using a string that ran parallel to the track. He placed the box with the object inside it at the top of the track and released the box and object from rest (see Figure 3).

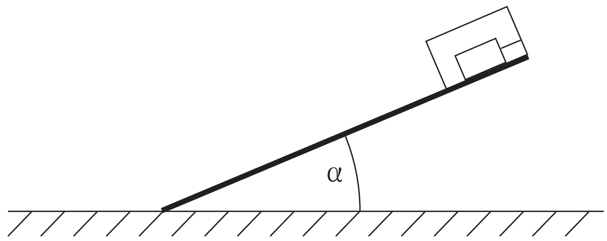


Figure 3

ו. What was the magnitude of tension in the string while the box descended?
Explain your answer. $(3\frac{1}{3}$ points)

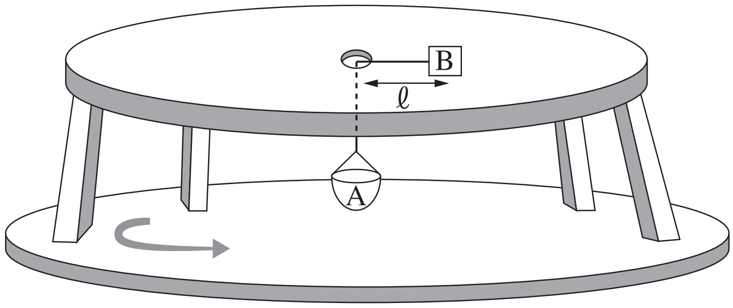
/Continued on page 5/

3. Consider a given system composed of a horizontal table with a hole at its center, and two objects, A and B (see figure). Object B is lying on the table and Object A is a basket suspended under the table with a rope that passes through the hole and is attached to Object B. The friction between the rope and the edge of the hole in the table is negligible.

The distance between Object B and the hole in the center of the table is ℓ .

The table and Object B , which is on the table, are positioned on a platform that is rotating at a constant frequency, f . The center of the table is the center of rotation.

The distance ℓ and the frequency of rotation , f , remain constant throughout this question.



Given: $m_A = 0.1\text{kg}$, $m_B = 0.3\text{kg}$, $\ell = 0.4\text{m}$.

In this state, there is no friction between Object B and the table.

א. Sketch a diagram of the forces acting on each of the two objects in this state. Label each of the forces. (5 points)

ב. Calculate the frequency, f . (7 points)

In another instance, a weight was added to the basket, A. This weight's mass was the same as the basket's mass. The distance ℓ and the frequency f remained unchanged.

In this state there is static friction between Object B and the table.

ג. What are the magnitude and direction of the static frictional force exerted on Object B ? (7 points)

ד. Calculate the minimum coefficient of static friction μ_s between the table and Object B that allows this motion. (6 points)

Without removing the added weight from the basket, another object, C , of mass m_C , was attached above Object B .

In this state, the two objects, B and C , rotate together in a circular motion whose radius is ℓ and frequency is f .

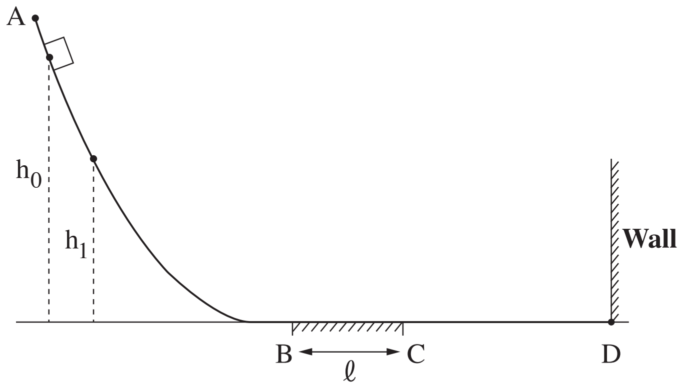
ה. If the mass of Object C were equal to the mass of Object B $(m_B = m_C)$, explain why no static frictional force would be exerted between Object B and the table. (5 points)

ו. If the mass of Object C were greater than the mass of Object B $(m_B < m_C)$, what would be the direction of the static frictional force exerted by the table on Object B ? Explain your answer. ($3\frac{1}{3}$ points)

/Continued on page 6/

4. A small object of mass m is sliding along a track ABCD that is attached to the wall at Point D (see figure).

Segments AB and CD of the track are smooth. The length of the horizontal segment, BC , is ℓ , and the coefficient of friction between it and the object is μ .



The object at rest was released from a height of h_0 (see figure). The object slid on the track toward the wall, collided with the wall at Point D in a perfectly elastic collision, and slid back along the track. On its way back, the object reached a maximum height of h_1 .

א. Sketch a diagram of the forces exerted on the object as it moved over Segment BC from Point B to Point C . Label each of the forces. (4 points)

ב. Derive an expression for the work done by the force of friction as the object moved from the height h_0 to the height h_1 on its way back up the track. Use the parameters ℓ , m , and μ . (4 points)

After the object reached height h_1 , it continued moving back and forth on the track ABCD several times. Each time, the object reached a different maximum height, h_n . The object's height , h_n , was measured $n = 5$ times.

ג. Derive an expression for the height h_n as a function of n . Use the parameters h_0 , ℓ , and μ . (6 points)

The measurements are shown in the table below:

Measurement number n	1	2	3	4	5
h_n(m)	1.30	1.12	0.88	0.73	0.53

ד. **(1)** Sketch a scatter diagram (points on a coordinate system) of h_n as a function of n .

(2) Add the best possible line (a trend line) to your scatter diagram.

(8 points)

Given: $\ell = 0.25\text{m}$.

ה. Use the graph you plotted to find:

(1) the initial height h_0 from which the object was released

(2) the coefficient of friction μ

(8 points)

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

/Continued on page 7/

In a further experiment, the wall was coated with a certain substance and the object at rest was released from height h_0 again.
In this additional experiment the height h_1' that was measured was smaller than the value of h_1 measured in the previous experiment.

ו. Determine whether the work of the normal force that the wall exerted on the object in the collision in this experiment was positive, negative, or zero.
Explain your answer. $(3\frac{1}{3}$ points)

/Continued on page 8/

5. Israeli rhythmic gymnast, Linoy Ashram, won a gold medal at the 2021 Tokyo Olympics in the individual all-around competition. One of her successful routines was a ball routine.
A student who is also a rhythmic gymnast performed a first routine with a ball of mass 400 grams. She threw the ball up vertically from a height of 1 meter. The ball reached a maximum height of 6 meters above the ground and fell to the ground. Assume negligible air resistance throughout all stages of the ball's motion.

א. Calculate the speed of the ball when it struck the ground. (6 points)

ב. Was the ball's speed when it left the student's hand lower, higher, or equal to the ball's speed at the moment it struck the ground? Explain your answer. (5 points)

After the ball struck the ground, it bounced up vertically. The ball's speed immediately after bouncing back up from the ground was the same as its speed when it struck the ground.

ג. Was any impulse exerted on the ball as it struck the ground? If there was, calculate the magnitude of the impulse; if not, explain. (6 points)

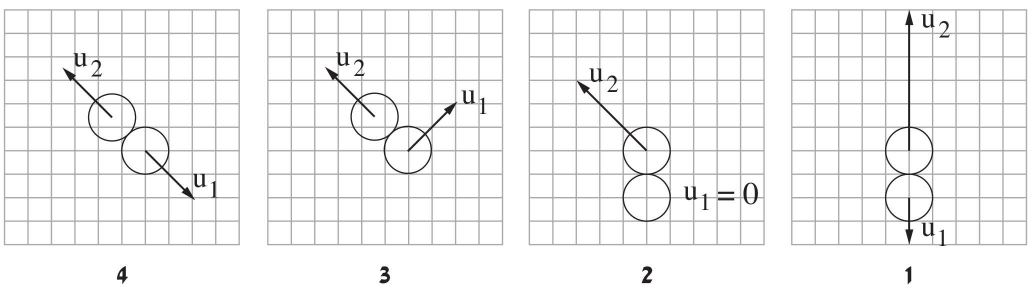
ד. Was any work done on the ball as it struck the ground? If there was, calculate the magnitude of the work; if not, explain. (6 points)

The student performed a second routine, this time with two identical balls, Ball 1 and Ball 2 . She threw Ball 1 in the same way as in the first routine, but this time she placed Ball 2 in the path of Ball 1 as Ball 1 bounced back up from the ground. She released Ball 2 from rest at a height of 1 meter, exactly when Ball 1 reached this height, and the two balls collided.
Assume that the collision between the balls was perfectly elastic, that it was very short, and that it was a head-on collision (the direction in which Ball 1 traveled before the collision merged with the vertical line connecting the centers of the two balls).

ה. Calculate the speed of <u>each</u> of the balls immediately after the collision ended. (6 points)

The student performed the two-ball routine several times, and each time the collision between the balls was perfectly elastic.
Sometimes the collision was head-on and sometimes it was not head-on.

ו. Each of the diagrams below, 1-4, shows two balls immediately after collision. The arrows on the balls in the diagrams represent their velocities (in uniform scale) immediately after the collision ended.
Determine which diagram could describe the state of the balls in one of the student's routines. Explain your answer. ($4\frac{1}{3}$ points)



/Continued on page 9/

Gravitation

6. SPACE IL engineers are designing a spacecraft that will be launched to the moon in a few years. This spacecraft, called Beresheet 2, is designed to carry two landers that will be landed on two sites on the moon. The following question was inspired by the Beresheet 2 program, but the data presented is different from the data in the actual program.

A spacecraft carrying two landers, Lander 1 and Lander 2 is launched from Earth on a rocket and is traveling toward the moon.

א. Calculate at what distance from the center of Earth the magnitude of the gravitational force exerted by Earth on the rocket is equal to the magnitude of the gravitational force exerted by the moon on the rocket. (7 points)

In Items ב-ה assume that the gravitational force that Earth exerts on the spacecraft and landers is negligible compared with the gravitational force exerted on them by the moon.

The spacecraft delivers each of the landers into a different circular orbit around the moon: Lander 1 into a circular orbit of radius r_1 and Lander 2 into a circular orbit of radius r_2. When Lander 1 completes nine orbits around the moon, Lander 2 completes ten orbits around the moon.

ב. Calculate $\frac{r_1}{r_2}$. (8 points)

Lander 2 travels in a circular orbit around the moon at a height of $h = 260$ km above the surface of the moon.

ג. Does Lander 2 have any acceleration as it moves in its circular orbit around the moon? If it does, calculate the magnitude of the lander's acceleration; if not, explain why Lander 2 has no acceleration. (8 points)

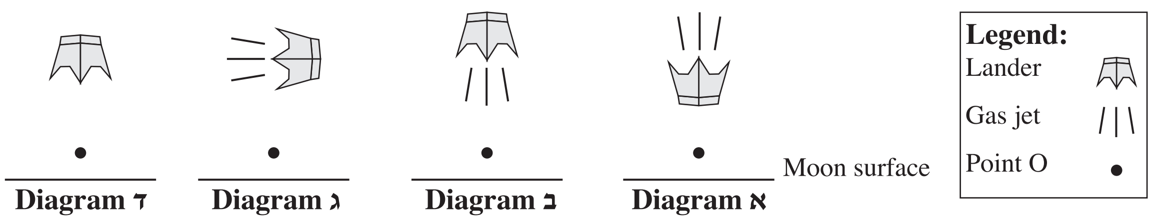
In the universal gravitation formula, the masses of two objects appear symmetrically. This is consistent with one of Newton's laws.

ד. Name the law (or write it in words), and explain how it is connected with the universal gravitation formula. (5 points)

The motion of each of the two landers is controlled by a jet engine that emits gas when it is running. During the moon landing stage of Lander 1, the lander travels toward the moon on a straight trajectory that is perpendicular to the surface of the moon, and stops (momentarily) at a certain point, O, above the surface of the moon.

Diagrams א-ג below, describe states in which the engine emits gas jets in different directions, and diagram ד describes a state in which the engine is **off** and does not emit a gas jet.

ה. Determine which of the graphs א-ד describes a state that allows the lander to stop momentarily at Point O. Explain your answer. ($5\frac{1}{3}$ points)



Good Luck!
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בהצלחה!
זכות היוצרים שמורה למדינת ישראל
אין להעתיק או לפרסם אלא ברשות משרד החינוך