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GUIDELINES

to solving tasks on the topic "Mechanics"

in the Physics course

for foreign students

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PREFACE

Methodical instructions to solving tasks on the topic "Mechanics" in the Physics course are intended for foreign students of International Education Faculty NTU “KhPI”.

The tasks presented in the collection are placed by topics within each section. Examples of problems with proper algorithm of the solution are given. The presence of a certain number of similar tasks allows you to optimally select tasks for independent students work in the classroom and at home.

These tasks can be used to control the level of learning material by foreign students of International Education Faculty, especially during distance learning. When solving problems, students will find useful the English-Turkish dictionary, which contains a translation of basic terms on the topic "Mechanics".

INTRODUCTION

Physics is the science about nature, properties and structure of matter, the laws of its motion. The first part of physics its **mechanical motion**. **Mechanics** is the body position changes in space relative to other bodies over time. Mechanics has different branches and consists of **kinematics, dynamics and statics**. Kinematics studies the motion of bodies without revealing its causes. Dynamics considers motion and its causes. Statics studies the conditions of bodies' equilibrium state.

Physical quantities are used to describe material systems, objects and processes – quantitative characteristics of certain properties or phenomena.

Physical quantities are scalar or vector characteristics. **Vector** quantities are characterized by a numerical value and direction in space, and **scalar** – has only a numerical value.

All natural phenomena are reflected in space and time. **Space** determines the duration and order of objects relative to each other.

Time determines the duration of existence of objects, changes their state and the processes occurring in them. The unit of measurement of time in the International System of Units (SI) is the **second** (s).

A point mass is a physical model of a body, the size of which in the conditions of the problem can be neglected in comparison with the distances to which it moves.

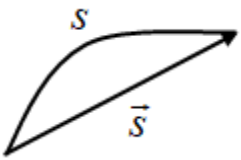
Movement is divided into translational and rotational. In **translational** motion, any straight line imaginary in the body remains parallel to itself, and in **rotational** – all points of the body move in circles, the centers of which are located on one straight line – **the rotational axis**.

SPEED. UNIFORM MOTION

The trajectory is an imaginary line that describes a body during mechanical motion. Lines are straight and curved, so according to the trajectory, the movement is divided into **rectilinear** and **curvilinear**.

The path is the length of the trajectory described by the body over time. In SI system the measurement basic unit of the path is the meter, abbreviated m.

Multiples units of length can also be used, for example,



1 m = 10 dm = 100 cm = 10^2 cm = 1000 mm = 10^3 mm = 1000 000 μm = 10^6 μm

Displacement $\vec{s}$ is a vector quantity that connects the initial and final positions of a point mass. The module of displacement is measured in meters.

Velocity $\vec{v}$ is a vector quantity that is equal to the ratio of the displacement to the time interval during which the displacement occurred.

$$\vec{v} = \frac{\Delta \vec{s}}{\Delta t}$$

The unit of speed in SI is a meter per second (m/s). This means that the body travels a distance of 1 meter in 1 second. Considering that the unit of time in SI is the second, and that other units of time can be used, namely, 1 min (minute) = 60 s; 1 y (year) = 60 min = 3600 s; 1 d (day) = 24 h = 1440 min = 86400 s; 1 y = 365.25 d = 8766 h = 525960 min = 31557600 s. It is possible to use other units of speed such as kilometers per hour, meters per minute, etc.

The quantity of the speed is a scalar quantity equal to the distance traveled Δs over a period of time Δt:

$$v = \frac{\Delta s}{\Delta t}.$$

The average speed is defined as the ratio of the distance traveled for the all-time of movement

$$\vec{v}_{average} = \frac{s}{t}$$

From the formula for determining the speed of the body, you can find the path traversed by the body for any time interval:

$$\Delta s = v \cdot \Delta t \,,$$

or body movement time

$$\Delta t = \frac{\Delta s}{v} \,.$$

A motion is said to be **uniform** if, at regular intervals, the body or material point overcomes equal segments of the path, that is, the speed of motion is constant. During uniform rectilinear motion, the distance traveled is equal to the displacement modulus.

Example of solving tasks

How fast was the cyclist moving if he covered 2,7 kilometers in 15 minutes?

Given:	*SI:*	*Solving:*
t=15 min	15·60 s = 900 s	We use the formula to find the uniform speed movement and substitute the values:
s=2,7 km	2,7·1000 m = 2700 m	$v = \frac{s}{t} = \frac{2700}{900}\left[\frac{m}{s}\right] = 3\frac{m}{s}$
Find:		*Answer:* The cyclist was moving with speed of 3 m/s.
v - ?		

ACCELERATION. ACCELERATED MOVEMENT. FREE FALL

If the body moves so that its speed changes, it means that the body moves **unevenly**.

Acceleration of body motion is a vector physical quantity that characterizes the rate of change of velocity of body motion ($\Delta \underline{v}$) and is equal to the ratio of the change in velocity of body motion to the time interval (Δt),for which this change occurred:

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}.$$

The magnitude of the acceleration is

$$a = \frac{\Delta v}{\Delta t}.$$

If the direction of velocity and acceleration are the same, then this movement is **accelerated**, and if they have opposite directions, the movement is **slowed down** (or braking).

The unit of acceleration is **the meter per second squared**, m/s^2.

The fall of bodies in airless space, that is, the fall only under the action of gravity, is called **free fall**. In the case of a free fall, all bodies fall to Earth with the same acceleration, which is called the **free fall acceleration**. The free fall acceleration vector is

always directed vertically downwards. Near the Earth's surface, ie at a small (compared to the radius of the Earth) distance, the acceleration of free fall is almost constant and is approximately equal to 9.8 m/s^2.

When solving problems on the movement in the vertical direction, for example, in a free fall, the distance traveled is denoted by the letter h (instead of s) and is determined by the formula

$$h = \frac{gt^2}{2},$$

landing speed

$$v = g \cdot t,$$

and the time of the fall

$$t = \sqrt{\frac{2h}{g}}.$$

If the body has an initial velocity, the corresponding formulas are given in Table 1.

Table 1 − Formulas for describing accelerated motion

The body falls from a height	**The body is thrown vertically upwards**
Path, [m] $$h = v_0 t + \frac{gt^2}{2}$$ Velocity, [m/s] $$v = v_0 + gt$$ Fall time, [s] $$t = \sqrt{\frac{2h}{g}}$$ Speed during fall, [s] $$v = \sqrt{2gh}$$	Path, [m] $$h = v_0 t - \frac{gt^2}{2}$$ Velocity, [m/s] $$v = v_0 - gt$$ Rise time, [s] $$t = \frac{v_0}{g}$$ Lifting height, [m] $$h = \frac{v_0^2}{2g}$$

Example of solving tasks

In some parts of the road, the velocity of a freely falling body increased from 7 m/s to 21 m/s. Find the time during which the change of speed took place and the path traveled by the body during this time.

Given: v_0 = 7 m/s v = 21 m/s	*Solving:* Using the formula for finding the acceleration, express from it time and substitute our values:
Find: t - ? h - ?	$t = \frac{v - v_0}{g} = \frac{21-7}{9,81}\left[\frac{\frac{m}{s}}{\frac{m}{s^2}}\right] = 1,43\,s$ To find a path use the formula for the path of the body $h = v_0 t + \frac{gt^2}{2} = 7 \cdot 1,43 + \frac{9,81 \cdot 1,43^2}{2} = 20,04\,m$ *Answer:* t = 1,43 s; h = 20,04 m.

ROTATIONAL MOTION

In this section, we will consider only uniform motion in a circle, that is, a curvilinear motion in which the trajectory of the body is a circle, and the linear velocity does not change over time.

The angle of rotation φ is the segment of the circle on which the body moved; in rotational motion it is analogous to the distance traveled s in translational motion. The angle of rotation is measured in radians. An angle of **1 radian** is a central angle that rests on an arc of a circle whose length is equal to the radius of that circle. Since the total angle is 360 °, then $2\pi = 360°$, and 1 radian = 57.3º.

$$\varphi[radian] = \frac{\varphi[\deg ree] \cdot 3{,}14[radian]}{180[\deg ree]}$$

The number of rotations (turns) ***N*** made by the body for the time interval ***t*** is related to the angle of rotation as

$$\varphi = 2\pi N .$$

The period of time during which the radius makes one rotations is called **the period *T***. The period is measured in units of time - seconds (s).

$$T = \frac{t}{N} .$$

The physical quantity that characterizes the number of rotations per unit time is called **the rotational frequency *f***.

The unit of rotational frequency in SI is the rotations per second

[***f***] = r/s = s^{-1} = Hertz = Hz.

Rotation period and rotational frequency are mutually inverse quantities:

$$T = \frac{1}{f}.$$

To characterize the motion of the body in a circle using **angular velocity -** a physical quantity that is numerically equal to the angle of rotation of the radius per unit time

$$\omega = \frac{\varphi}{t}.$$

The unit of angular velocity in SI is the radian per second:

[$\boldsymbol{\omega}$] = rad/s = s^{-1}.

Angular velocity is related to frequency and period:

$$\omega = 2\pi f = \frac{2\pi}{T},$$

and with a linear velocity ***v*** as

$$v = \omega \cdot R$$

where ***R*** is the radius of the circle along which the point rotates.

Example of solving problems

In one minute the wheel of a bicycle makes 120 turns. What is the period and frequency of rotation of the wheel?

Given:	*SI*:	Solving:
t = 1 min	60 s	We use the formula for finding the velocity and substitute our data::
N = 120		$f = \frac{N}{t} == \frac{120}{60} = 2\frac{1}{s} = 2\,Hz$
Find:		To find the value of the period, use the second part of this formula and express T:
T - ?		$T = \frac{1}{f} = \frac{1}{2} = 0.5\,s$
f - ?		Answer: T = 0,5 s; f = 2 Hz.

TASKS "SPEED. UNIFORM MOTION"

1. The train traveled 20,000 m in 900 *s*. What is the speed of the train?

2. A passenger train covered a distance of 30 000 *m* in 1800 *s*. What is the speed of the train?

3. Determine the speed of a pedestrian who walked 30 m in 10 s.

4. A man, moving uniformly, crossed the bridge in 120 *s*. What is the speed of a man if the length of the bridge is 360 *m*?

5. In 5 hours the cyclist covered a distance of 99 km. What is the speed of the cyclist moving?

6. Calculate the speed of a skier who has covered a distance of 20 km in 3 hours.

7. Calculate the speed of a pedestrian, if the path of 20 km it passes in 5 hours.

8. The car traveled a distance of 500 m in 25 s. Find the speed of the car.

9. A bullet fired from a rifle flew to a target at a distance of 1000 m in 2.5 s. Find the speed of the ball.

10. Moving uniformly, the passenger jet TU-104 flew 8250 m in 30 seconds. What is the speed of the plane?

11. In what time will a racing car moving at a speed of 180 km/h travel 360 km?

12. The cruising speed of the modern Ukrainian aircraft AN-158 is 820 km/h How much time will the plane spend the distance 410 km?

13. A helicopter flies at a speed of 20 m/s. How long will it fly over a 5 m long river?

14. The train was moving at an average speed of 40 m/s. How long was the journey between the two cities, if the distance between them is 62 km?

15. A cyclist rides at a speed of 5 m/s. In what time will he overcome 99 m?

16. The man walked for 2 hours at a speed of 5.4 km/h. What distance did he take?

17. Find the distance that the bus will cover in 4 hours if it is moving at a constant speed of 45 km/h.

18. The tourist walked for 20 minutes at a speed of 1.5 m/s. What distance has he taken during this time?

19. For 30 s the train was moving at a speed of 20 m/s. How far did the train travel during this time?

20. A spacecraft was moving at a speed of 100 m/s for 20 s. What distance did the spacecraft cover during this time?

TASKS "ACCELERATION. ACCELERATED MOTION. FREE FALL"

1. The body falls without initial velocity. What is the velocity of its motion after 3 s of fall?

2. Determine the height from which the free fall of the body from which lasts 3.2 s.

3. Determine the velocity of the body after 2 s of free fall.

4. The body falls freely. What is the motion of the body in 4 seconds of falling?

5. How long does a free fall from a height of 45 m last?

6. How long does a body fall without an initial velocity from a height of 12.8 m?

7. A stone falls without an initial velocity from a height of 80 m. What distance does it take in the first second of its movement?

8. What is the depth of the mine, if the free-falling stone reaches the bottom in 2 s after the start of the fall?

9. The height of the tower is 532 m. Bricks were dropped from its highest point. Will it fall to the ground in a while?

10. The stone falls freely from the cliff. What distance will he take in the eighth second from the beginning of the fall?

11. A brick falls freely from the roof of a building 122.5 m high. What distance will the brick take in the last second of its fall?

12. Determine the depth of the well, if the stone that fell into it touched the bottom of the well 1 s after the start of motion.

13. A pencil falls from the table 80 cm high to the floor. Determine the time of fall.

14. After a while the stone will fall to the ground from a height 15 m?

15. A stone thrown up fell to the ground after 4 seconds. Determine the initial speed of its movement.

16. The boy throws the ball horizontally from a window at a height of 45 m. The initial speed of the ball is 10 m/s. How long will he fly to the ground?

17. At what speed should the body be thrown vertically upwards so that it returns back in 10 s?

18. The boom is launched vertically upwards with an initial velocity of 40 m/s. In how many seconds will it fall back to the ground?

19. The balloon rises evenly vertically upwards at a speed of 4 m/s. At an altitude of 217 m it bursts. In how many seconds will the bullet fall to the ground?

20. An anti-aircraft gun projectile fired vertically upwards at a speed of 800 m/s reached the target in 6 s. What is the velocity of the projectile at the time of reaching the target?

TASKS "ROTATIONAL MOTION"

1. The chuck of the electric drill rotates with a frequency of 750 revolutions per minute. How many revolutions does the chuck make in 1 s? Determine the period of its rotation.

2. A rotating bicycle wheel makes 90 revolutions in 0.5 minutes. With what period does the wheel rotate?

3. Why is the period of rotation of the helicopter propeller, if in 20 s it makes 400 revolutions?

4. At what frequency does the drum of the washing machine rotate, if in 2 minutes it makes 1600 revolutions?

5. Calculate the speed of the motor shaft, if he made 500 revolutions in 10 s.

6. The air conditioner fan makes one revolution in 0.5 s. How often does it rotate?

7. The CD in the CD-ROM drive makes one revolution in 0.01 s. How often does it rotate?

8. The motor shaft makes 480 revolutions per minute. With what period does it rotate?

9. The microprocessor cooler of a personal computer makes 3000 revolutions per minute. With what period does it rotate?

10. The fan rotates at a constant speed and in 2 minutes makes 2400 revolutions. Determine the fan speed.

11. The cyclist was traveling at a speed of 25.2 km/h. How many revolutions did the wheel make in 10 minutes?

12. The car is moving on a road with a radius of 20 m. Determine how many turns the car will make if its speed is 5 m/s.

13. In 18 seconds the wheel of the car made 24 turns. Determine the period of rotation of the point on the rim of the wheel.

14. What is the rotational frequency of the points of the electric drill chuck, if per minute the chuck makes 900 revolutions?

15. At what frequency do the fan blades rotate if they make 1 revolution in 0.2 s?

16. It is known that the fan of a personal computer microprocessor rotates at a frequency of 3600 r/m. What is the period of rotation of the fan blade points?

17. In 2 minutes the body makes 240 revolutions. Why is the period of rotation equal to the rotational frequency?

18. Calculate the speed if the wheel of the car makes 100 revolutions in 10 seconds.

19. In 2 minutes the wheel of a motorcycle makes 480 turns. Why is the period of rotation equal to the rotational frequency?

20. The body made 15 full revolutions in 25 s. Determine the period and speed.

Control question

1. What is physics?
2. What is mechanical motion?
3. What is mechanics?
4. What value is called physical?
5. What quantities are called vector?
6. What quantities are called scalar?
7. What is space?
8. What is time?
9. What point is called material?
10. What is a trajectory?
11. What is the path?
12. What is motion?
13. What is velocity?
14. What motion is called uniform?
15. What is acceleration?
16. What is free fall?
17. What is the angle of rotation?
18. What is a period?
19. What is the frequency of rotation?
20. What speed is called angular?

ENGLISH-TURKISH DICTIONARY

English	Turkish
acceleration	hızlanma
angle of rotation	dönüş açısı
area	alan
average speed	ortalama sürat
concept	konsept
constant speed	sabit hız
curvilinear	eğrisel
curvilinear motion	eğri çizgisel hareket
device	cihaz
direction	yön
displacement	yer değiştirme
distance	mesafe
dynamics	dinamik
experiment	deney
formula	formul
free fall	serbest düşüş
gravitational	yerçekimsel
instantaneous speed	anlık hız
international system of units	uluslararası birimler sistemi

Table continuation

English	**Turkish**
kinematics	kinematik
law	yasa
length	uzunluk
linear	doğrusal
linear motion	doğrusal hareket
matter	önemli olmak
measurement	ölçüm
mechanical motion	mekanik hareket
mechanics	mekanik
motion	haraket
nature	doğa
object	nesne
period	dönem
phenomenon	fenomen
physical quantity	fiziksel miktar
physics	fizik
point mass	malzeme noktası
quantity	parçacık
rectilinear	doğrusal
rectilinear motion	doğrusal hareket

Table continuation

English	**Turkish**
reference frame	referans çerçevesi
rotating speed	açısal hız
rotation frequency	dönüş frekansı
rotational motion	rotasyonel hareket
scalar	skaler
size	boyut
space	uzay
speed	hız
statics	istatik
symbol	sembol
term	dönem
time	zaman
trajectory	Yörünge
uniform movement	tekdüze hareket
vector	vektör
view	görünüm
way	yol

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