TASHKENT UNIVERSITY OF TECHNOLOGY

Physics

Variant 3

CONSTRUCTOR KNOWLEDGE

Part 1

Physics. Questions 1–10

Write your answer on Answer Sheet No. 1 to the right of the corresponding question number. Where applicable, include the units of measurement. If you need to correct an answer, cross out the incorrect one, enter the question number in the table below, and write the correct answer in the field to the right.

1. A football rolling off the pitch began to decelerate at a constant rate of $4\,\mathrm{m/s^2}$ due to friction with the grass and came to a stop after 4 s. Find the speed of the ball the moment it rolled onto the grass.
2. A go-kart moves at a constant speed of 36 km/h under the action of a driving force of 100 N. Find the power of the go-kart.
3. A gas occupies a volume of 4 L at a temperature of 300 K. The gas is heated at constant pressure until its volume becomes 6 L. Find the final temperature of the gas.
4. A gas receives 20 J of heat. At the same time, 20 J of positive work is done on the gas. By how many joules does the internal energy of the gas increase?
5. Two point charges, $q_1 = 3 \cdot 10^{-6}$ C and $q_2 = 4 \cdot 10^{-6}$ C, are placed in a vacuum 2 cm apart. Find the magnitude of the Coulomb force between the charges.
6. When a charge of $q = 4$ C moves through a section of an electric circuit, the electric field performs $A = 36$ J of work. Find the voltage across this section of the circuit.
7. The table below shows the dependence of the current I on time t in an oscillating LC circuit. Using these data, determine the period of the current oscillations in the circuit.

t, ms	0	4	8	12	16	20	24
I, mA	0	4	0	−4	0	4	0

8. A diffraction grating has a period of $d = 2 \cdot 10^{-6}$ m. The first-order maximum is observed at an angle $\sin\theta = 0.30$. Determine the wavelength of the light.
9. The wavelength of a photon is 500 nm. Determine the frequency of the photon.
10. The half-life of a radioactive bismuth isotope is 19 min. How long will it take for 75% of the nuclei in a sample to decay?

Part 2

> **Physics. Questions 11–14**
>
> *Use Answer Sheets No. 2 to write your solutions and answers to questions 11–14. Write your solution as completely and in as much detail as possible. Remember that even if you are unable to solve the problem completely, you may still receive some points for significant progress according to the marking criteria.*

11. (2 points) A spring is stretched by 4 cm when a force of 20 N is applied. Determine the spring constant if the spring is stretched by 8 cm.

12. (3 points) A sample of 0.2 mol of helium is initially at a temperature of 22°C. During heating, the internal energy of the gas increases by 49.86 J. The gas is then cooled isochorically back to its initial temperature. Determine:
1. To what temperature was the helium heated?
2. How much heat was released during the isochoric cooling?
3. Did the helium return to its initial thermodynamic state? Explain your answer.

13. (2 points) A resistor with resistance $R = 6\,\Omega$ is connected to a DC voltage source.
Two parallel plates are connected across the resistor. The electric field between the plates is uniform with a field strength of $E = 400\,\mathrm{V/m}$. The distance between the plates is $d = 0.03\,\mathrm{m}$. Determine the current flowing through the resistor.

14. (3 points) Monochromatic light with wavelength $\lambda = 400\,\mathrm{nm}$ is incident normally on a diffraction grating with spacing $d = 2.0\,\mu m$. Determine the highest diffraction order that can be observed.

Variant 3

Part 1

Physics. Questions 1–10

Write your answer on Answer Sheet No. 1 to the right of the corresponding question number. Where applicable, include the units of measurement. If you need to correct an answer, cross out the incorrect one, enter the question number in the table below, and write the correct answer in the field to the right.

1. A football rolling off the pitch began to decelerate at a constant rate of $4\,\mathrm{m/s^2}$ due to friction with the grass and came to a stop after 4 s. Find the speed of the ball the moment it rolled onto the grass.

.... ***Answer:*** 16 m/s

SOLUTION / PROOF :

The speed of a body moving with constant acceleration is given by

$$v = v_0 + at.$$

Since the ball comes to a stop,

$$v = 0.$$

The acceleration is opposite to the direction of motion:

$$a = -4\,\mathrm{m/s^2}.$$

Substitute the given values:

$$0 = v_0 - 4 \cdot 4.$$

Hence,

$$v_0 = 16\,\mathrm{m/s}.$$

$$v_0 = 16\ \mathrm{m/s}$$

2. A go-kart moves at a constant speed of 36 km/h under the action of a driving force of 100 N. Find the power of the go-kart.

.... ***Answer:*** 1000 W

SOLUTION / PROOF :

Power is given by

$$P = Fv.$$

Convert the speed to SI units:

$$36\,\mathrm{km/h} = 10\,\mathrm{m/s}.$$

Substitute the given values:

$$P = 100 \cdot 10 = 1000\,\mathrm{W}.$$

$$P = 1000\ \mathrm{W}$$

3. A gas occupies a volume of 4 L at a temperature of 300 K. The gas is heated at constant pressure until its volume becomes 6 L. Find the final temperature of the gas.

.... ***Answer:*** 450 K *or* 177°C

SOLUTION / PROOF :

At constant pressure,

$$\frac{V}{T} = \mathrm{const}.$$

Therefore,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}.$$

Express the final temperature:

$$T_2 = T_1 \frac{V_2}{V_1}.$$

Substitute the given values:

$$T_2 = 300 \cdot \frac{6}{4} = 450\,\mathrm{K}.$$

Convert the result to degrees Celsius:

$$t_2 = T_2 - 273 = 450 - 273 = 177^\circ\mathrm{C}.$$

$$T_2 = 450\ \mathrm{K} = 177^\circ\mathrm{C}$$

4. A gas receives 20 J of heat. At the same time, 20 J of positive work is done on the gas. By how many joules does the internal energy of the gas increase?

.... ***Answer:*** 40 J

SOLUTION / PROOF :

According to the first law of thermodynamics,

$$\Delta U = Q + A,$$

where A is the work done on the gas.
Substitute the given values:

$$\Delta U = 20 + 20 = 40\,\mathrm{J}.$$

$$\Delta U = 40\ \mathrm{J}$$

5. Two point charges, $q_1 = 3 \cdot 10^{-6}\,\mathrm{C}$ and $q_2 = 4 \cdot 10^{-6}\,\mathrm{C}$, are placed in a vacuum 2 cm apart. Find the magnitude of the Coulomb force between the charges.

.... ***Answer:*** *270 N*

SOLUTION / PROOF :

According to Coulomb's law,

$$F = k \cdot \frac{q_1 q_2}{r^2},$$

where

$$k = 9 \cdot 10^9\,\mathrm{N \cdot m^2/C^2}.$$

Convert the distance to SI units:

$$r = 2\,\mathrm{cm} = 0.02\,\mathrm{m} = 2 \cdot 10^{-2}\,\mathrm{m}.$$

Substitute the given values:

$$F = 9 \cdot 10^9 \cdot \frac{3 \cdot 10^{-6} \cdot 4 \cdot 10^{-6}}{(2 \cdot 10^{-2})^2}.$$

$$F = 9 \cdot 10^9 \cdot \frac{12 \cdot 10^{-12}}{4 \cdot 10^{-4}} = 9 \cdot 10^9 \cdot 3 \cdot 10^{-8} = 27 \cdot 10 = 270\,\mathrm{N}.$$

$$F = 270\ \mathrm{N}$$

6. When a charge of $q = 4\,\mathrm{C}$ moves through a section of an electric circuit, the electric field performs $A = 36\,\mathrm{J}$ of work. Find the voltage across this section of the circuit.

.... ***Answer:*** *9 V*

SOLUTION / PROOF :

Voltage is related to work and charge by

$$U = \frac{A}{q}.$$

Substitute the given values:

$$U = \frac{36}{4} = 9\,\mathrm{V}.$$

$$U = 9\ \mathrm{V}$$

7. The table below shows the dependence of the current I on time t in an oscillating LC circuit. Using these data, determine the period of the current oscillations in the circuit.

t, ms	0	4	8	12	16	20	24
I, mA	0	4	0	−4	0	4	0

.... ***Answer:*** *16 ms*

SOLUTION / PROOF :

The period is the time interval after which the current repeats its value and direction.
From the table,

$$I(4\,\mathrm{ms}) = 4\,\mathrm{mA},$$

and the same value occurs again at

$$I(20\,\mathrm{ms}) = 4\,\mathrm{mA}.$$

Therefore,

$$T = 20 - 4 = 16\,\mathrm{ms}.$$

$$T = 16\ \mathrm{ms}$$

8. A diffraction grating has a period of $d = 2{\cdot}10^{-6}\,\mathrm{m}$. The first-order maximum is observed at an angle $\sin\theta = 0.30$. Determine the wavelength of the light.

.... ***Answer:*** *600 nm*

SOLUTION / PROOF :

The diffraction grating equation is

$$d \sin\theta = k\lambda.$$

For the first-order maximum,

$$k = 1.$$

Therefore,

$$\lambda = d \sin\theta = 2 \cdot 10^{-6} \cdot 0.30 = 6 \cdot 10^{-7}\,\mathrm{m} = 600\,\mathrm{nm}.$$

$$\lambda = 600\ \mathrm{nm}$$

9. The wavelength of a photon is 500 nm. Determine the frequency of the photon.

.... ***Answer:*** 6.0×10^{14} Hz

SOLUTION / PROOF :

The frequency of a photon is given by

$$\nu = \frac{c}{\lambda}.$$

Convert the wavelength to meters:

$$\lambda = 500\,\mathrm{nm} = 5.0 \times 10^{-7}\,\mathrm{m}.$$

Substitute the given values:

$$\nu = \frac{3.0 \times 10^8}{5.0 \times 10^{-7}} = 6.0 \times 10^{14}\,\mathrm{Hz}.$$

$$\nu = 6.0 \times 10^{14}\ \mathrm{Hz}$$

10. The half-life of a radioactive bismuth isotope is 19 min. How long will it take for 75% of the nuclei in a sample to decay?

.... ***Answer:*** *38 min*

SOLUTION / PROOF :

If 75% of the nuclei have decayed, then

$$25\%$$

of the original nuclei remain.
After one half-life:

$$100\% \to 50\%.$$

After two half-lives:

$$50\% \to 25\%.$$

Therefore, the required time is

$$t = 2T_{1/2} = 2 \cdot 19 = 38\,\mathrm{min}.$$

$$t = 38\ \mathrm{min}$$

Physics. Questions 11–14

Use Answer Sheets No. 2 to write your solutions and answers to questions 11–14. Write your solution as completely and in as much detail as possible. Remember that even if you are unable to solve the problem completely, you may still receive some points for significant progress according to the marking criteria.

11. (2 points) A spring is stretched by 4 cm when a force of 20 N is applied. Determine the spring constant if the spring is stretched by 8 cm.

.... ***Answer:*** *500 N/m*

SOLUTION / PROOF :

According to Hooke's law,

$$F = kx.$$

Using the initial data,

$$x = 4\,\mathrm{cm} = 0.04\,\mathrm{m},$$

we obtain

$$k = \frac{F}{x} = \frac{20}{0.04} = 500\,\mathrm{N/m}.$$

The spring constant depends only on the properties of the spring and does not change when the extension changes.

$$k = 500\ \mathrm{N/m}$$

12. (3 points) A sample of 0.2 mol of helium is initially at a temperature of 22°C. During heating, the internal energy of the gas increases by 49.86 J. The gas is then cooled isochorically back to its initial temperature.
Determine:
1. To what temperature was the helium heated?
2. How much heat was released during the isochoric cooling?
3. Did the helium return to its initial thermodynamic state? Explain your answer.

.... ***Answer:*** 42°C; 49.86 J; *Yes*

SOLUTION / PROOF :

For a monatomic ideal gas,

$$\Delta U = \frac{3}{2} nR\Delta T.$$

Therefore,

$$\Delta T = \frac{49.86}{1.5 \cdot 0.2 \cdot 8.31} = 20\,\mathrm{K}.$$

Hence,

$$t_2 = 22 + 20 = 42^\circ\mathrm{C}.$$

During an isochoric process,

$$A = 0,$$

therefore

$$Q = \Delta U.$$

Since the gas is cooled,

$$Q = -49.86\,\mathrm{J}.$$

Thus, the amount of heat released is

$$49.86\,\mathrm{J}.$$

After cooling, the temperature returns to its initial value. Since the volume remained constant during the cooling, it is also equal to its initial value. Therefore, the pressure also returns to its initial value, and the helium returns to the same thermodynamic state.

$$42^\circ\mathrm{C}, \qquad 49.86\ \mathrm{J}, \qquad \text{Yes}$$

13. (2 points) A resistor with resistance $R = 6\,\Omega$ is connected to a DC voltage source.
Two parallel plates are connected across the resistor. The electric field between the plates is uniform with a field strength of $E = 400\,\mathrm{V/m}$. The distance between the plates is $d = 0.03\,\mathrm{m}$. Determine the current flowing through the resistor.

.... ***Answer:*** *2 A*

SOLUTION / PROOF :

The voltage across the plates is

$$U = Ed = 400 \cdot 0.03 = 12\,\mathrm{V}.$$

Since the plates are connected in parallel to the resistor, the voltage across the resistor is also 12 V.
By Ohm's law,

$$I = \frac{U}{R} = \frac{12}{6} = 2\,\mathrm{A}.$$

$$I = 2\ \mathrm{A}$$

14. (3 points) Monochromatic light with wavelength $\lambda = 400\,\mathrm{nm}$ is incident normally on a diffraction grating with spacing $d = 2.0\,\mu m$. Determine the highest diffraction order that can be observed.

.... ***Answer:*** *5*

SOLUTION / PROOF :

The highest possible diffraction order is

$$k_{\max} = \left\lfloor \frac{d}{\lambda} \right\rfloor.$$

Since

$$\frac{2.0\,\mu\mathrm{m}}{0.40\,\mu\mathrm{m}} = 5,$$

we obtain

$$k_{\max} = 5.$$

$$k_{\max} = 5$$