TASHKENT UNIVERSITY OF TECHNOLOGY

Physics

Variant 2

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 motorcycle starts moving with a constant acceleration of $4\,\text{m/s}^2$. What speed will the motorcycle reach after 5 s of motion?

2. What mass should be suspended from a spring with a spring constant of 80 N/m so that it stretches by 5 cm?

3. A cylinder contains helium at a temperature of 320 K. The cylinder can safely withstand a pressure that is 1.5 times the current pressure. To what maximum temperature can the cylinder be safely heated?

4. A heat engine operates according to the Carnot cycle. The temperature of its hot reservoir is 127°C, and the temperature of its cold reservoir is 47°C. Find the efficiency of the engine.

5. A point charge $q = 5 \cdot 10^{-9}\,\text{C}$ is located in a vacuum. What is the electric potential at a point 5 m away from the charge?

6. In a DC circuit, two resistors with resistances $R_1 = 15\,\Omega$ and $R_2 = 25\,\Omega$ are connected in series. Find the total resistance of the circuit.

7. An aerial photograph of the sea surface was taken from a research drone. A coordinate grid is superimposed on the photograph. The x-axis is directed along the wave propagation and is measured in meters ($x = 0$ corresponds to the point directly below the drone). The y-axis shows the vertical displacement of the water surface from its equilibrium position, also in meters. The measurement results obtained from the photograph are given below. Determine the wavelength of the wave.

x, m	0	5	10	15	20	25
y, m	0	1.5	0	−1.5	0	1.5

8. During an optics experiment, a student placed a screen 36 cm from a thin converging lens. The focal length of the lens is 12 cm. At what distance from the lens should the object be placed to obtain a sharp image on the screen?

9. A hydrogen atom is excited to the $n = 6$ energy level. Determine the total number of different spectral lines that can be emitted.

10. A beam of photons with an energy of 15 eV ejects photoelectrons from a metal. The maximum kinetic energy of the emitted photoelectrons is equal to half the work function of the metal. Determine the maximum kinetic energy of the emitted photoelectrons.

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 200 g block rests on a horizontal table. The block begins to move only when the pulling force measured by a force meter reaches 0.4 N. Determine the coefficient of friction between the block and the table when the force meter reads 0.2 N.

12. (3 points) A sample of 0.2 mol of helium at 27°C is first cooled isochorically to 7°C, and then heated isobarically back to its initial temperature.
Determine:
1. The ratio of the magnitudes of the changes in the internal energy of the gas during the isobaric and isochoric processes.
2. The amount of heat supplied to the helium during the isobaric heating. Give your answer in joules.
3. Can it be stated that after these two processes the helium returned to its initial thermodynamic state? Explain your answer.

13. (2 points) An electric field in a DC circuit transfers a charge of 8 C through a heating element in 4 s. During this time, the electric field performs 240 J of work. Determine the electric power dissipated by the heating element.

14. (3 points) When investigating the mercury spectrum with a diffraction grating, it was found that the fourth-order maximum of the blue-violet spectral line with wavelength $\lambda = 435$ nm coincides with the third-order maximum of a yellow spectral line. Determine the wavelength of the yellow line.

TASHKENT UNIVERSITY OF TECHNOLOGY | Physics **Variant 2** | 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 motorcycle starts moving with a constant acceleration of $4\,\mathrm{m/s^2}$. What speed will the motorcycle reach after 5 s of motion?

Answer: 20 m/s

SOLUTION / PROOF :

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

$$v = v_0 + at.$$

Since the motorcycle starts from rest,

$$v_0 = 0.$$

Substitute the given values:

$$v = 0 + 4 \cdot 5 = 20\,\mathrm{m/s}.$$

$$v = 20\ \mathrm{m/s}$$

2. What mass should be suspended from a spring with a spring constant of 80 N/m so that it stretches by 5 cm?

Answer: 0.4 kg

SOLUTION / PROOF :

At equilibrium, the spring force is equal to the weight of the mass:

$$kx = mg.$$

Convert the extension to metres:

$$x = 5\,\mathrm{cm} = 0.05\,\mathrm{m}.$$

Express the mass:

$$m = \frac{kx}{g}.$$

Substitute the given values:

$$m = \frac{80 \cdot 0.05}{10} = \frac{4}{10} = 0.4\,\mathrm{kg}.$$

$$m = 0.4\ \mathrm{kg}$$

3. A cylinder contains helium at a temperature of 320 K. The cylinder can safely withstand a pressure that is 1.5 times the current pressure. To what maximum temperature can the cylinder be safely heated?

Answer: 480 K *or* 207°C

SOLUTION / PROOF :

Since the volume of the cylinder is constant,

$$\frac{P}{T} = \text{const}.$$

Therefore,

$$\frac{P_2}{P_1} = \frac{T_2}{T_1}.$$

The maximum allowable pressure is

$$P_2 = 1.5P_1.$$

Hence,

$$T_2 = 1.5T_1.$$

Substitute the given values:

$$T_2 = 1.5 \cdot 320 = 480\,\mathrm{K}.$$

Convert the result to degrees Celsius:

$$t_2 = T_2 - 273 = 480 - 273 = 207^\circ\mathrm{C}.$$

$$T_2 = 480\ \mathrm{K} = 207^\circ\mathrm{C}$$

4. A heat engine operates according to the Carnot cycle. The temperature of its hot reservoir is 127°C, and the temperature of its cold reservoir is 47°C. Find the efficiency of the engine.

Answer: 20%

SOLUTION / PROOF :

The efficiency of a Carnot engine is

$$\eta = 1 - \frac{T_c}{T_h},$$

where the temperatures are measured in kelvins.
Convert the temperatures:

$$T_h = 127 + 273 = 400\,\mathrm{K},$$

$$T_c = 47 + 273 = 320\,\mathrm{K}.$$

Substitute the given values:

$$\eta = 1 - \frac{320}{400} = 0.20.$$

Express the result as a percentage:

$$\eta = 20\%.$$

$$\eta = 20\%$$

5. A point charge $q = 5 \cdot 10^{-9}\,\mathrm{C}$ is located in a vacuum. What is the electric potential at a point 5 m away from the charge?

Answer: 9 V

SOLUTION / PROOF :

The electric potential of a point charge is given by

$$\varphi = k \cdot \frac{q}{r},$$

where

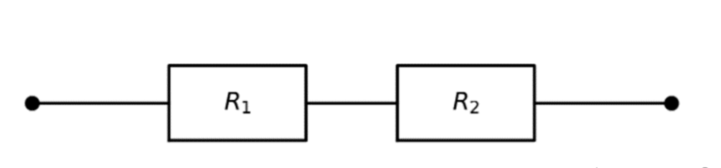
$$k = 9 \cdot 10^9\,\mathrm{N \cdot m^2/C^2}.$$

Substitute the given values:

$$\varphi = 9 \cdot 10^9 \cdot \frac{5 \cdot 10^{-9}}{5} = 9\,\mathrm{V}.$$

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

6. In a DC circuit, two resistors with resistances $R_1 = 15\,\Omega$ and $R_2 = 25\,\Omega$ are connected in series. Find the total resistance of the circuit.



Answer: 40 Ω

SOLUTION / PROOF :

For resistors connected in series, the total resistance is equal to the sum of the individual resistances:

$$R_{\text{total}} = R_1 + R_2.$$

Substitute the given values:

$$R_{\text{total}} = 15 + 25 = 40\,\Omega.$$

$$R_{\text{total}} = 40\ \Omega$$

7. An aerial photograph of the sea surface was taken from a research drone. A coordinate grid is superimposed on the photograph. The x-axis is directed along the wave propagation and is measured in meters ($x = 0$ corresponds to the point directly below the drone). The y-axis shows the vertical displacement of the water surface from its equilibrium position, also in meters. The measurement results obtained from the photograph are given below. Determine the wavelength of the wave.

x, m	0	5	10	15	20	25
y, m	0	1.5	0	−1.5	0	1.5

Answer: 20 m

SOLUTION / PROOF :

The wavelength is the distance between two nearest points oscillating in the same phase, for example, between two adjacent wave crests.
From the table, the crests are located at

$$x_1 = 5\,\mathrm{m}, \qquad x_2 = 25\,\mathrm{m}.$$

Therefore,

$$\lambda = x_2 - x_1 = 25 - 5 = 20\,\mathrm{m}.$$

$$\lambda = 20\ \mathrm{m}$$

8. During an optics experiment, a student placed a screen 36 cm from a thin converging lens. The focal length of the lens is 12 cm. At what distance from the lens should the object be placed to obtain a sharp image on the screen?

Answer: 18 cm

SOLUTION / PROOF :

For a thin lens,

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b},$$

where

$$f = 12\,\mathrm{cm}, \qquad b = 36\,\mathrm{cm}.$$

Substitute the given values:

$$\frac{1}{a} = \frac{1}{12} - \frac{1}{36} = \frac{3-1}{36} = \frac{2}{36} = \frac{1}{18}.$$

Therefore,

$$a = 18\,\mathrm{cm}.$$

$$a = 18\ \mathrm{cm}$$

9. A hydrogen atom is excited to the $n = 6$ energy level. Determine the total number of different spectral lines that can be emitted.

Answer: 15

SOLUTION / PROOF :

The total number of possible spectral lines emitted during transitions between energy levels is

$$N = \frac{n(n-1)}{2},$$

where n is the highest excited energy level.
For

$$n = 6,$$

we obtain

$$N = \frac{6(6-1)}{2} = \frac{6 \cdot 5}{2} = 15.$$

$$N = 15$$

10. A beam of photons with an energy of 15 eV ejects photoelectrons from a metal. The maximum kinetic energy of the emitted photoelectrons is equal to half the work function of the metal. Determine the maximum kinetic energy of the emitted photoelectrons.

Answer: 5 eV

SOLUTION / PROOF :

According to Einstein's photoelectric equation,

$$E_\gamma = A + K_{\max},$$

where A is the work function and $K_{\max}$ is the maximum kinetic energy of the photoelectrons.
Since

$$K_{\max} = \frac{A}{2},$$

we have

$$15 = A + \frac{A}{2} = \frac{3A}{2}.$$

Therefore,

$$A = 10\,\mathrm{eV},$$

and

$$K_{\max} = \frac{10}{2} = 5\,\mathrm{eV}.$$

$$K_{\max} = 5\ \mathrm{eV}$$

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 200 g block rests on a horizontal table. The block begins to move only when the pulling force measured by a force meter reaches 0.4 N. Determine the coefficient of friction between the block and the table when the force meter reads 0.2 N.

Answer: 0.2

SOLUTION / PROOF :

When the block just begins to move, the pulling force is equal to the maximum static friction force:

$$F_{\text{fr,max}} = 0.4\,\mathrm{N}.$$

The normal force is

$$N = mg = 0.2 \cdot 10 = 2.0\,\mathrm{N}.$$

Therefore,

$$\mu = \frac{F_{\text{fr,max}}}{N} = \frac{0.4}{2.0} = 0.2.$$

When the force meter reads 0.2 N, the block remains at rest because the static friction force is equal to the applied force. The coefficient of friction depends only on the contacting surfaces and therefore remains unchanged.

$$\mu = 0.2$$

12. (3 points) A sample of 0.2 mol of helium at 27°C is first cooled isochorically to 7°C, and then heated isobarically back to its initial temperature.
Determine:
1. The ratio of the magnitudes of the changes in the internal energy of the gas during the isobaric and isochoric processes.
2. The amount of heat supplied to the helium during the isobaric heating. Give your answer in joules.
3. Can it be stated that after these two processes the helium returned to its initial thermodynamic state? Explain your answer.

Answer: 1; 83.1 J; No

SOLUTION / PROOF :

The internal energy of a monatomic ideal gas is

$$U = \frac{3}{2}nRT.$$

Therefore,

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

Since the temperature change is the same in magnitude for both processes,

$$|\Delta U_{\text{isobaric}}| = |\Delta U_{\text{isochoric}}|.$$

Hence,

$$\frac{|\Delta U_{\text{isobaric}}|}{|\Delta U_{\text{isochoric}}|} = 1.$$

During the isobaric heating,

$$Q = nC_p\Delta T,$$

where

$$C_p = \frac{5}{2}R.$$

Since

$$n = 0.2\,\mathrm{mol}, \qquad \Delta T = 20\,\mathrm{K},$$

we obtain

$$Q = 0.2 \cdot \frac{5}{2} \cdot 8.31 \cdot 20 = 10 \cdot 8.31 = 83.1\,\mathrm{J}.$$

The helium does not return to its initial thermodynamic state. Although the temperature becomes the same as initially, the gas expands during the isobaric heating, so its volume is greater than at the beginning of the process.

$$1, \qquad 83.1\ \mathrm{J}, \qquad \text{No}$$

13. (2 points) An electric field in a DC circuit transfers a charge of 8 C through a heating element in 4 s. During this time, the electric field performs 240 J of work. Determine the electric power dissipated by the heating element.

Answer: 60 W

SOLUTION / PROOF :

Electric power is equal to the work done per unit time:

$$P = \frac{A}{t} = \frac{240}{4} = 60\,\mathrm{W}.$$

$$P = 60\ \mathrm{W}$$

14. (3 points) When investigating the mercury spectrum with a diffraction grating, it was found that the fourth-order maximum of the blue-violet spectral line with wavelength $\lambda = 435\,\mathrm{nm}$ coincides with the third-order maximum of a yellow spectral line. Determine the wavelength of the yellow line.

Answer: 580 nm

SOLUTION / PROOF :

The diffraction maxima satisfy $k_1\lambda_1 = k_2\lambda_2$. Therefore,
$4 \cdot 435 = 3\lambda$. Hence, $\lambda = \frac{1740}{3} = 580\,\mathrm{nm}$.

$$\lambda = 580\ \mathrm{nm}$$