KamaChallenge 2020
Physics

A 4-member team must solve the theoretical problems within 105 minutes: 16 easy problems marked 1 point each, 8 intermediate problems marked 3 points each and 4 advanced problems marked 7 points each. Only answers are checked and marked.

The Winner in Physics nomination is recognized to be the team scored the highest points. If the scores are equal, the Winner is the team which is the quickest among the other teams to give the answers.

Basic problems marked 1 point each

1. A car drives at 40 km/h for the first 30 km and at 80 km/h for the next 50 km. Calculate an average car speed for the whole distance.

2. Two cyclists ride their bikes along mutually perpendicular roads at 20 km/h and 15 km/h and get to the intersection. What is the speed of the first cyclist with respect to the second cyclist?

3. A stone was thrown from 20 meter height above the ground at a horizontal speed of 10 m/s. Find a displacement module for the stone when it hits the ground.

4. A mathematical pendulum is displaced to 40° angle from its equilibrium position and freed with no initial velocity. What is the horizon angle for the pendulum acceleration vector at the initial moment of time?

5. A 200 kg air balloon is going down at a constant rate under 1.8 kN buoyancy force. What mass of ballast should be removed to make the air balloon go up at the same rate?

6. 1 kg point mass is moving along a 5 m flat slope with 45° horizon slope angle. Find the resultant force acting on the bead.

7. A perfectly inelastic collision of two similar modeling clay balls, one of them being in a resting position before the collision, gives the 4 kg·m/s momentum of balls stuck together. What is the momentum for each of the balls before the collision?

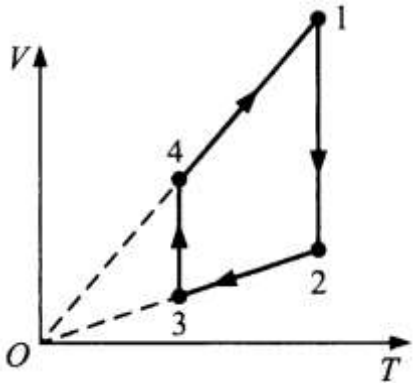
8. When the spring deformation is increased three times, the external force equals 100 J. What is the spring elastic force if the initial spring deformation is doubled?

9. A body with no resistance and initial velocity falls from the height of 20 m. At what height is its kinetic energy three times lower than its potential energy?

10. How many times does the full pressure (including the atmospheric one) at the lake bottom exceed the full pressure at the depth of 5 meters? The atmospheric pressure is 10^5 Pa, the lake depth is 30 m.

11. Find the ratio between the pressures of two gases (oxygen and hydrogen) if their concentration and mean-square velocities are equal.

12. The image shows a diagram (with the coordinates of temperature and volume) of the cycle process over a constant mass of perfect gas. Name the isoprocesses this gas is involved into.



13. A 1 м^3 heat insulated vessel is divided into two equal parts with a heat insulating wall. One part of the vessel is filled with 1 mole of helium at 300 K, while the other part is filled with 1 mole of nitrogen at 400 K. What temperature is reached after the wall is removed?

14. A perfect gas emitted 200 kJ of heat, at the same time the external forces applied 60 kJ to the gas. How did the internal energy of this gas change?

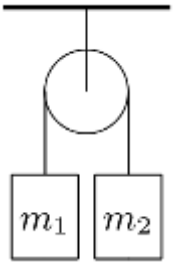
15. Air humidity in a closed vessel is 50%. How much should vessel volume be changed to see the condensed water inside the vessel? The temperature remains constant during the process.

16. A Carnot heat engine operates on a cycle. The temperature of a furnace and a refrigerator is reduced by 1.3. How much will the efficiency of the heat engine change?

Intermediate problems marked 3 points each

17. A mathematical pendulum swings freely in a vertical plane. When it goes through its equilibrium position, funicular force is 1.5 times higher than the stretching force with a resting bob. Find oscillation amplitude of the pendulum deviation angle.

18. The ideal Atwood machine consists of two objects connected by an inextensible, massless string over an ideal massless pulley. Gravitation force acts on the heavy object $m_1 = 2$ kg and it accelerates downwards, while the light one $m_2 = 1$ kg accelerates upwards. Find the pulley pressure force on the shaft if this machine is placed in an elevator accelerating upwards at 2 m/s^2.

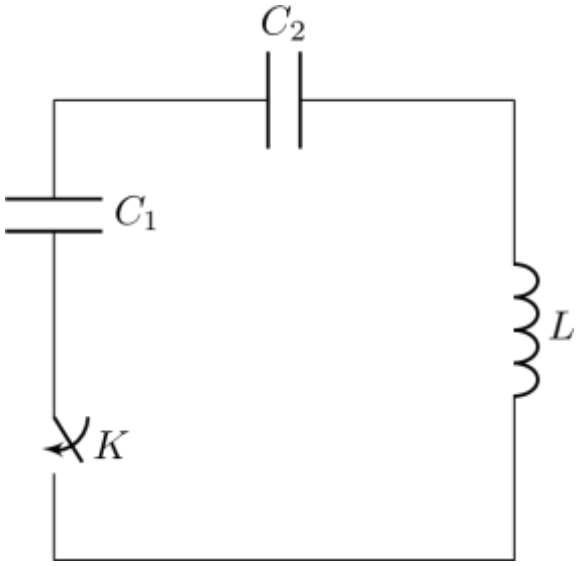


19. 100 g block slides over the horizontal surface and collides elastically with an immovable 200 g block. Find the distance between these bodies after the collision if the velocity of the first block before the collision was 1 m/s, while the friction coefficient between the blocks and the surface was 0.1.

20. A horizontal tube with a uniform cross section contains 18 cm mercury column which is blocked by 40 cm air layer. If the tube is turned vertically with its open end up, then the mercury column is displaced by 8 cm. How much will the mercury column be displaced if the tube is turned vertically with its open end down.

21. Two metal balls with $r_1 = 2$ cm and $r_2 = 3$ cm which are separated by quite a large distance are like charged equally and repelled with 1 N force. What is the attractive force between these balls if they are connected for a short time with a wire?

22. An electric circuit consists of a sequence of an induced coil $L = 4$ mH and capacitors with the capacities $C_1 = 10^{-7}$ F, $C_2 = 4 \cdot 10^{-7}$ F, a capacitor C_1 is charged at the beginning before the voltage $U = 100$ V, while the second one is discharged. Find the maximum current force in the circuit after switch closure.

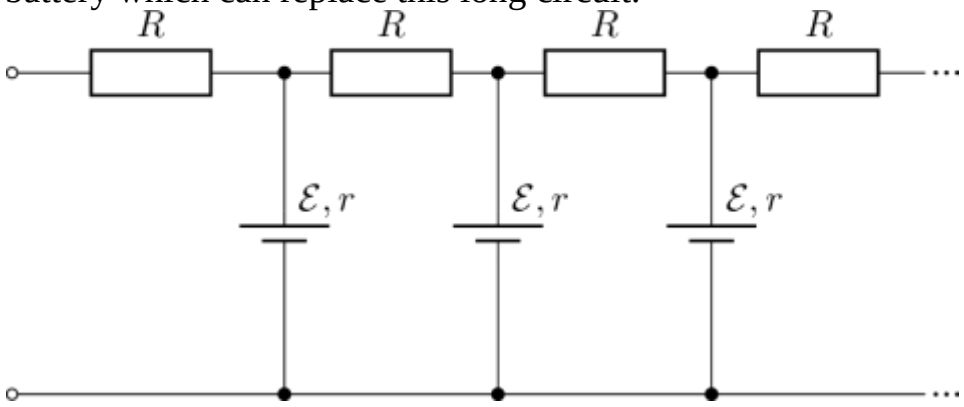


23. A charged particle – an electron – moves in a uniform magnetic field with $B = 1$ mt along the helix. Find the velocity of the particle if a lead of helix is $h = 20$ cm, and its radius is $R = 4$ cm.

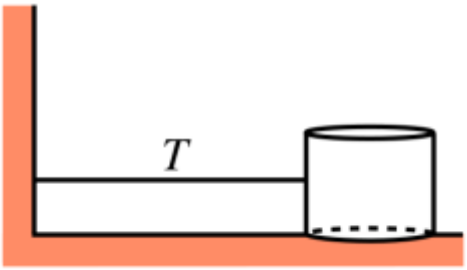
24. One mole of helium is inside a cylinder at the initial temperature of 500 K and pressure 3 atm. The gas is involved into a thermodynamic process, when the pressure is inversely as square of volume, and the finite volume is twice as larger as the initial one. Find the amount of heat emitted by the gas when expanding.

Advanced problems marked 7 points each

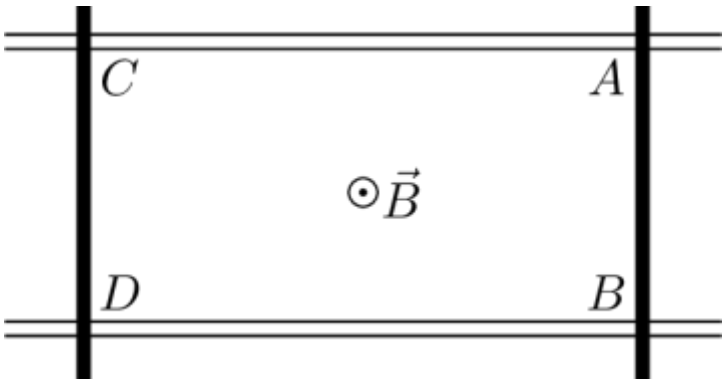
25. A very long electric circuit contains batteries with 15 V electromotive force and 2 Ohm inner resistance and resistors $R = 20$ Ohm. Find the inner resistance of the equivalent battery which can replace this long circuit.



26. At the initial moment of time, a massless vessel contains sand with the mass $M = 5$ kg. The vessel is connected with the vertical wall through a massless spring with a constant tension $T = 100$ N (in this case, tension force does not depend on the spring stretching). A horizontal surface is flat, the initial spring length is $L = 1$ m. When the vessel moves, x is the distance between this vessel and the vertical wall, m is the vessel mass. Along with that, the sand leaks through a hole in the bottom of the vessel so that the mass of the vessel with sand reduces with the change in the coordinate under the law $dm/dx = M/L$, where $dm < 0$, $dx < 0$. What is the maximum value of the kinetic energy of the vessel?



27. Two horizontal metal rail bars with 1 m between them hold conductive links AB and CD with the mass of 10 g and electric resistance of 1 Ohm each. The links slide with no tension in the uniform magnetic 0.04 T field perpendicular to the rail bar plane. Initially, the distance between the links is 40 cm, CD link is immovable, while AB link starts moving at 10 cm/s. What is the distance between the links in a long lapse of time?



28. Find the efficiency of the reversible heat engine, which diagram of cyclic process is shown in the picture and contains adiabats 1-2, 3-4 and isochors 2-3, 4-1. A mole of monoatomic perfect gas is the medium, while T_1 = 800 K, T_2 = 320 K.