SOLUTIONS TO THE PROBLEMS OF THE THEORETICAL COMPETITION

Problem 1 (10 points)

Problem 1A (3 points)

Boiling occurs in the first stage at a constant pressure , hence at a constant temperature. Likewise , the third condensation stage takes place at constant pressure and temperature. The second and fourth stages can be considered as adiabatic . Cycle steam engine is shown in Fig . Since this loop is composed of two isotherms and two adiabatic , then this cycle is the Carnot cycle . Therefore, its efficiency is calculated by the formula

(1)

where - the boiling point of the first phase - condensation temperature in the third stage of the cycle.

Temperatures can be found from the condition shown in vapor pressure depending on temperature

The first stage of the cycle occurs at constant pressure

(2)

Steam temperature is the temperature of the boiling point and is equal to

. (3)

The temperature difference in the formula (1) which is calculated by the formula

. (4)

Thus, the efficiency of the machine is

Problem 1B (5 points)

The first solution

Consider the left part of the scheme. Its load characteristic (dependence U (I)) - line corresponding to an equivalent source with parameters.

For the equivalent circuit

the heat generated power. In resistor R stood

The second solution

Kirchhoff system of equations has the form

Eliminating I1 and I2, we obtain the equation

,

From which I get the multiplication by

hence

and

Substituting, we get

Problem 1C (2 points)

The beam passing through the focus lens , after refractive index is parallel to the optical axis. Therefore, all the items shown in the figure give the image the same size, ie increase inversely with the distance from the object to focus.

Fig . Figure 1 . 2

From Fig. 2 shows that in the case of the diverging lens is impossible to get the same image size at different positions of the object , so the lens is necessarily going .

Fig . 3

Provisions object A and B , the image giving the same size, are arranged symmetrically with respect to the focus of the lens (Fig. 3). If the object to push another 5 cm, then he will be in position C, in which the image of the same size would have given three times larger object , so the same thing will give three times the smaller image .

Response 1/3 cm

Problem 2 Jet propulsion (10 points)

decision

1. Consider the motion of the missile in the comoving frame - the inertial reference frame , which moves relative to the laboratory frame with the speed of the rocket itself , ie in the frame in which the rocket at any given time at rest. Let rocket having a lot of time , a lot of throws with velocity , and its speed will change to . Then the law of conservation of momentum can be written as

. (1)

In classical mechanics, the change in velocity missiles in the laboratory frame must coincide with a change in velocity of the rocket in the comoving frame by virtue of the Galilean transformations . Therefore , solving the equation (1) with the initial condition at , we obtain Tsiolkovsky

. (2)

2 . It is known that the escape velocity at the Earth's surface is

(3)

then from (2) we find that the initial mass of the rocket

kg. (4)

3 . If a rocket external force , the associated coordinate system the total momentum of the system will change , and the equation (1) can be rewritten as

(5)

or , using the notation , we obtain

. (6)
By virtue of the principle of relativity , this equation does not change its form in any inertial frame of reference and is called the equation Meshcherskij .
Substituting , we finally obtain
. (7)
4 . To hang the rocket at a constant height , you need to . Substituting in equation (7) and using the fact that the mass of the rocket decreases by law
(8)
find
. (9)
5 . Substituting equation (8) to (7), we find
(10)
(11)
. (12)
6. Maximum speed achieved missile if the fuel burns almost instantly , and at the same time and the work force of gravity is the lowest possible . Thus optimal fuel consumption is
. (13)
Then , from the law of conservation of momentum
(14)
determine the velocity of the rocket
. (15)
Hence , the maximum height of the rocket is
. (16)
7. Suppose that in the reference frame moving with the speed , the particle moves with speed. Then its speed in the stationary reference frame is given by the relativistic velocity addition formula
. (17)
Hence, we find the relationship between changes in velocity corresponding reference systems
. (18)
In accordance with the Lorentz transformations
(19)
changes in two time frames are related
. (20)
Dividing equation (16) and (18) and setting , we finally obtain
. (21)
8. In comoving coordinates movement of the rocket is a classic , and its acceleration is given by
. (22)
Now we use the acceleration of transformation (19) and time (18) for , we obtain
. (23)
Hence we find that
. (24)
9. Calculations by the formula given
kg. (25)
10 . Calculations by the formula given
kg. (26)

Problem 3 Metamaterials (10 points)

decision
1. Consider conductor layer disposed radially at the interval. Its conductivity is
(1)
and hence the total conductivity
. (2)

Thus, the impedance of the conductor can be written as
. (3)
2 . The amount of heat generated in the conductor per unit time is determined by law Joule
. (4)
In steady state, the same amount of heat must be removed through the surface of the conductor in the environment , so Newton's law - Richman
(5)
whence
. (6)
3 . Consider a cylinder of radius . We find the amount of heat generated per unit time inside the cylinder . To do this, we first define the electric field . According to Ohm's law, the current density is
(7)
therefore the total current can be written as
. (8)
hence
. (9)
Power is determined by the law of heat Joule in differential form
. (10)
It is evident that the power dissipated inside the cylinder must be guided through the surface , so
. (11)
Solving the differential equation (11) using (10) and using an initial condition
(12)
obtain a solution in the form
. (13)
Thus, the temperature in the center of the conductor is
. (14)
4 . Changing the radius of the conductor is determined by the law of thermal expansion of solids and can be written as
. (15)
5 . The magnetic field is determined by the theorem on the circulation, which in this case is written as
. (16)
Using the expression (9) , we finally obtain
. (17)
6. The energy density of the magnetic field is given by
(18)
where the energy of the magnetic field inside the conductor
. (19)
7. We write the equilibrium condition conductor layer disposed on the distance to . Full Ampere force acting on this layer is
. (20)
Hence, the pressure
. (21)
8. As a result of the mechanical pressure in the crystal lattice of the supply voltage , the density of the mechanical energy which is determined by the expression
(22)
where the total energy of mechanical deformations
. (23)
9. Changing the wire radius is determined by Hooke's law , which in this case can be written in the form

(24)
where - relative change in radius.
Thus, the change in the radius due to mechanical deformations
. (25)
10 . Equating the expressions (15) and (25) we obtain
. (26)