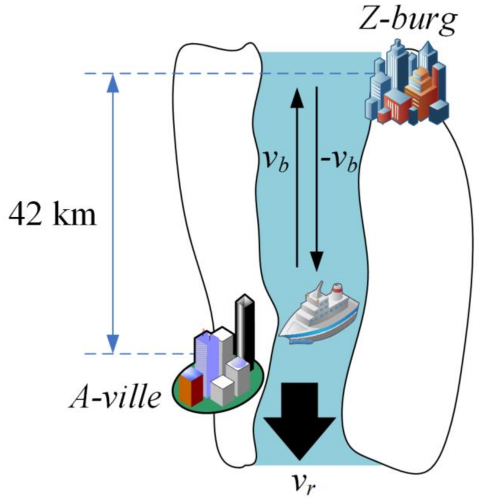
Mechanics: Kinematics

Block 1. One-Dimensional Motion

Question №1

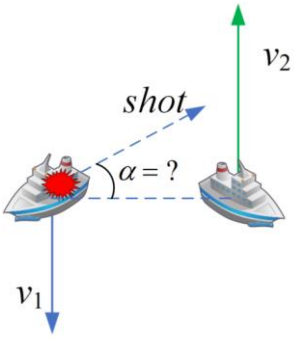
A boat travels up and down a straight part of a river between the cities A-ville and Z-burg at a constant speed of v_b = 10 km/h. The distance between the cities is 42 km. **What is the river speed** v_r if the boat completes the **roundtrip** between the cities in 10 hours?



Answer:

Question №2

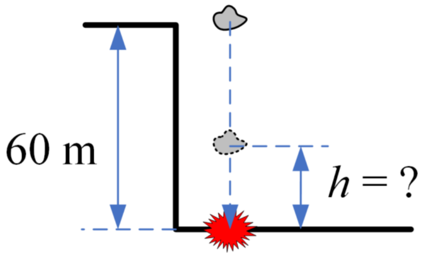
Two ships are moving parallel to each other in the opposite directions with speeds v_1 and v_2, respectively (Figure 2, left). The first ship shoots at the second. **Find the aiming angle** α required to hit the target if the shot is made when the distance between the ships is the shortest (shown in the figure). Assume the **speed of the projectile** v_0 **is constant**.



Answer:

Question №3

A rock is dropped (from rest) from the top of a 60-m-tall building (Figure 2, left). **How far above the ground** is the rock 1.5 s **before** it reaches the ground?

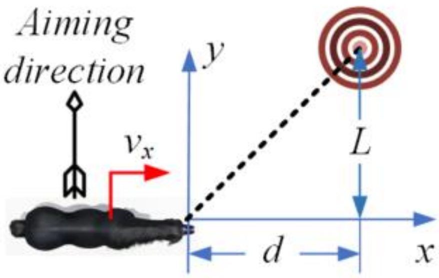


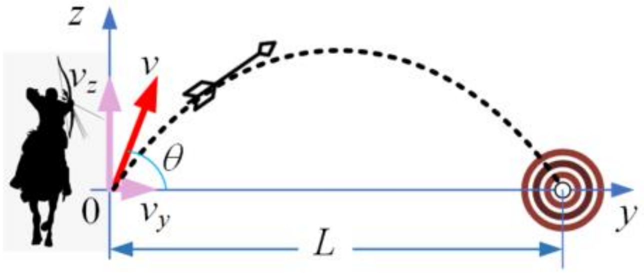
Answer:

Block 2. Three-Dimensional Motion

Question №4

A horse archer is moving with the speed of v_x = 36 km/h along the x axis, as shown below. At some point she aims in the direction perpendicular to v_x and shoots an arrow at angle θ to the horizon (right figure) at a target located at L = 100 m from the x axis. The speed of the arrow with respect to the archer is v = 121.1 km/h. **At what angle** θ to the horizon must she shoot to hit the target? Assume zero air resistance

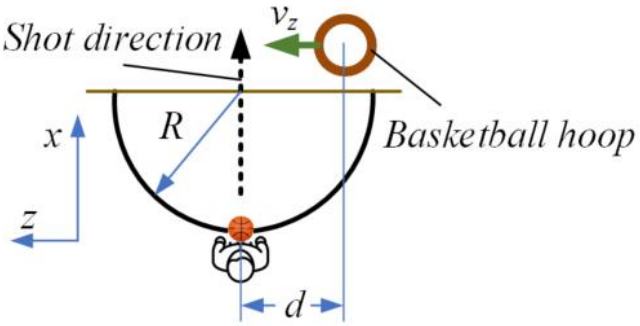


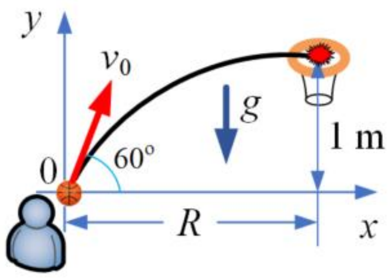


Answer:

Question №5

A player shoots a basketball at a hoop moving with constant speed v_z = 2 m/s along the z axis, as shown below. The hoop is 1 m above the ball at the time of the shot, and the player is R = 7.24 m away from the hoop. The player shoots the ball at the angle 60 degrees to the ground. **What must be the initial speed** of the ball v_0 with respect to the player to score? Assume zero air resistance.

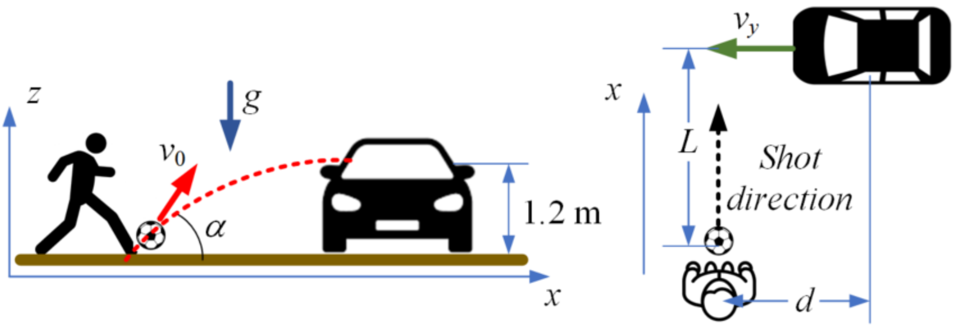




Answer:

Question №6

A footballer kicks the ball, trying to hit his friend in a driver's seat through the window of a passing car. The car is moving in the direction perpendicular to the shot with speed v_y = 36 km/h. The smallest distance between the guy and the car is L = 25 m and the car window is at the height of 1.2 m above ground. Initial speed of the ball after the kick is v_0 = 50 m/s with respect to the kicker, with no air drag. Find the angle α to the horizon at which the guy must kick the ball in order for it to fly through the car at the highest point of its trajectory.



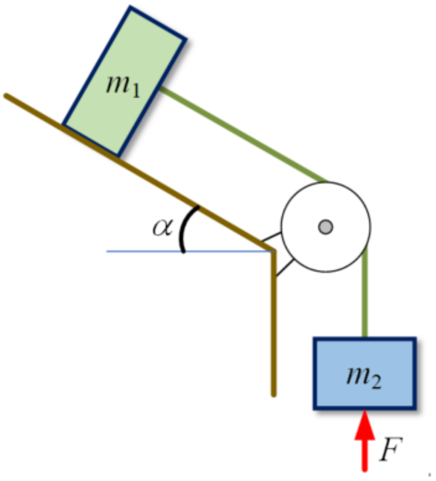
Answer:

Mechanics: Dynamics

Block 3. Forces and Motion 1

Question №7

A can of worms (m_2 = 2 kg) is suspended by a rope thrown over a rotational pulley with zero mass and friction. The rope has its other end connected to a can of biscuits (m_1 = 2 kg), which is placed on a frictionless surface at an angle α to the horizon. The can of worms is pushed up by the force F = 6 N and has a downward acceleration of 5.5 m/s^2. **How much is angle α?**



Answer:

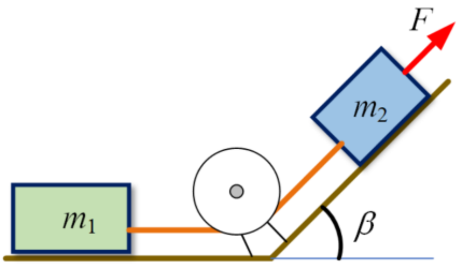
Question №8

During a race, the motorcyclist is going through a turn of constant radius R = 33 m with constant velocity v_0 = 18 m/s. **By how much does the racer have to lean** with respect to the vertical (angle θ) so that the bike remains at this angle during the cornering without tipping over?

Answer:

Question №9

A Yandex Rover vehicle of mass m_2 = 50 kg is being pulled up a slippery hill (zero friction) by a force F = 1200 N. The slope of the hill is β = 35 degrees. The Rover is towing a box of pizza weighing m_1 = 10 kg. Assume the ground and pulley to be frictionless and masses of the rope and pulley negligible. What is the tension in the cord?

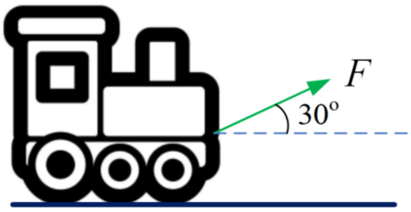


Answer:

Block 4. Forces and Motion 2

Question №10

A person is pulling on a rope attached to a locomotive of mass m = 100 tons (Fig. 1, right). The person is pulling with a constant force F that is **2 times greater than their body weight**, at an upward angle $\theta = 30°$ from the horizontal. The person's mass is 75 kg, and they moved the train by 1 m. Neglecting any friction on wheels and assuming the train was initially stationary, **find the speed of the train** v at the end of the pull. Assume g = 9.8 m/s^2.



Answer:

Question №11

A car moving at speed v = 60 km/h crashes into a streetlight. The driver's upper body of mass m = 40 kg hits the airbag and moves forward by 45 cm before coming to a full stop. **What is the magnitude of force** F acting on the body, assuming it is moving with constant deceleration?

Answer:

Question №12

A 500 kg rocket sled can be accelerated at a constant rate from rest to 1600 km/h in 1.8 s. What is the magnitude of the **required net force**?

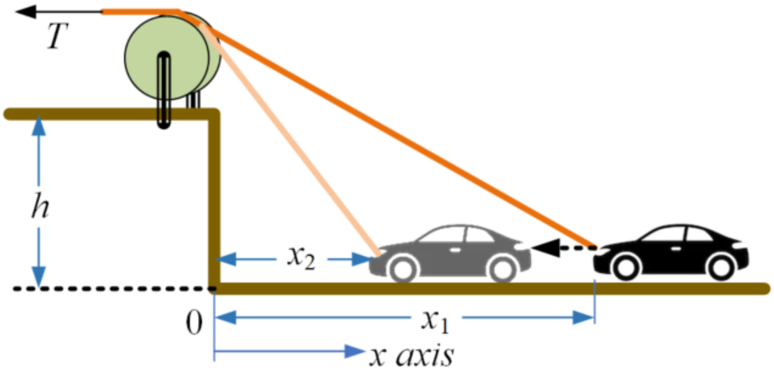
Answer:

Block 5. Energy

Question №13

Figure below shows a side view of a car towed by a rope on ice (zero friction) along an x axis. The left end of the rope is pulled over a pulley (negligible mass and friction) at the height h = 3 m, and the car slides from x_1 = 4 m to $x_2 = \sqrt{7}$ m. During towing the tension in the tow rope is always constant at T = 250 N, and the car's wheels never lose contact with the ground. **What is the change in the kinetic energy** of the car during towing?

Recall that $\int \frac{a}{\sqrt{a^2+b^2}} da = \sqrt{a^2+b^2}$.

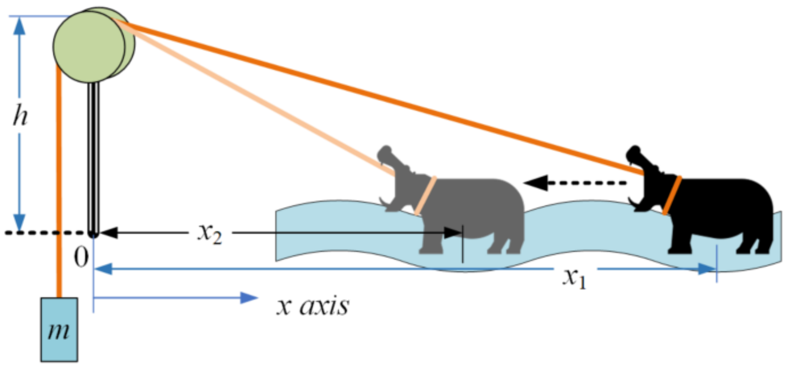


Answer:

Question №14

A team of National Geographic explorers is trying to pull a hippo (who is initially at rest) out of a swamp by tying a rope around its shoulders and attaching to the rope's other end a block with mass m = 100 kg, with the rope routed over a frictionless, massless pulley. The height of the pulley above the animal is h = 10 m. The friction between the swamp's bottom and hippo's feet suddenly becomes zero when it is located at distance x_1 = 50 m away from the pulley. **What will be the hippo's speed** once it reaches x_2 = 30 m? Assume hippo mass to be M = 300 kg and it was pulled by a constant force the whole time.

Recall that $\int \frac{a}{\sqrt{a^2+b^2}} da = \sqrt{a^2+b^2}$

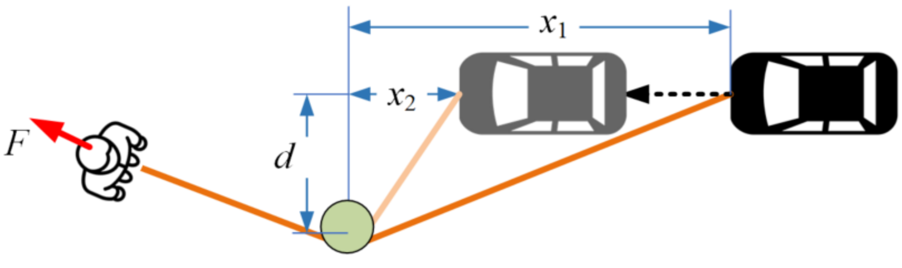


Answer:

Question №15

A guy is trying to pull out his car stuck (v_0 = 0 m/s) in the snow tracks by pulling on a tow rope wound around a frictionless massless pulley with constant force F = 300 N. The offset between the rope and the car's direction of motion is d = 3 m. Suddenly, when the car was x_1 = 20 m away from the driver, it broke free from the snow and got onto a patch of icy tracks because of which the friction between the tires and the ground dropped to zero. **What was the car's velocity** by the time the driver pulled his car to x_2 = 15 m, given that he was pulling with the same force the whole time? Car's mass is M = 1500 kg and **it can only move forward** (not sideways).

Recall that $\int \frac{a}{\sqrt{a^2+b^2}} da = \sqrt{a^2+b^2}$

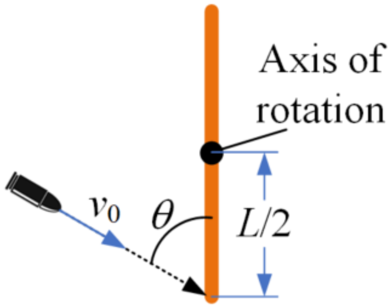


Answer:

Block 6. Rotation

Question №16

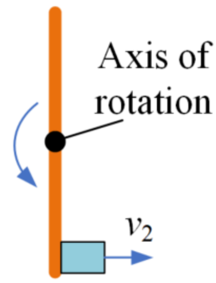
A sharpshooter hits an end of a uniform rod of mass M = 12 kg with a bullet of mass m = 8 grams, as shown on the overhead view below, after which the bullet drops on the floor. The length of the rod is L = 1 m. It is known that the bullet hits the rod at angle of θ = 60 degrees and after this the rod spins with the angular velocity $\omega = \sqrt{3}$ rad/s. **Find the initial velocity of the bullet** v_0. Recall that the rod's moment of inertia $I = 1/12ML^2$



Answer:

Question №17

A figure below shows an overhead view of a uniform bar of length L = 1 m and mass M rotating at angular speed 20 rad/s about an axis through its center. A particle of mass $M/3$ is initially attached to one end but at some point, is ejected from the rod and travels along a path that is perpendicular to the rod at the instant of ejection. If the particle's speed v_2 is 6 m/s greater than the speed of the rod end just after ejection, **what is the value** of v_2?



Answer:

Question №18

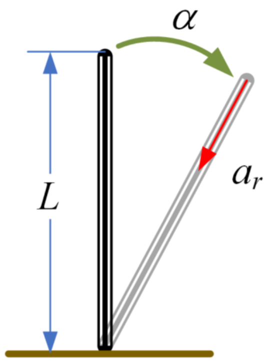
A uniform disk rotates on a frictionless bearing about a vertical axle through the center of the disk. The platform has a mass of 150 kg, a radius of 2 m, and a rotational inertia of 300 kg·m^2 about the axis of rotation. A 60 kg person starts walking slowly from the rim of the platform toward the center. If the angular speed of the system is 1.5 rad/s when the person starts moving, what is the angular speed when she is 0.5 m from the center?

Answer:

Block 7. Energy during Rotation

Question №19

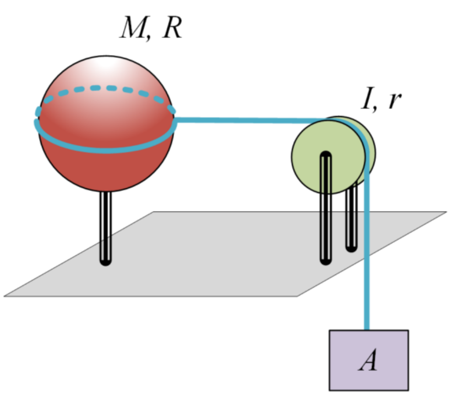
A thin rod of length L = 55 cm is falling down from its vertical-up position while pivoting about one of its ends, as shown on the right. **Find the radial acceleration a_r of the top point** when the rod makes an angle of α = 35 degrees with the vertical.



Answer:

Question №20

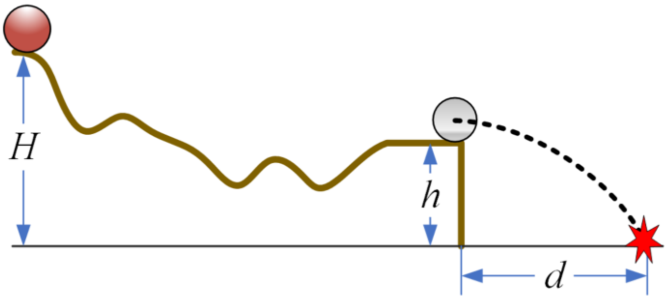
A sphere (moment of inertia $J = 2/3MR^2$, mass M = 4.5 kg, radius R = 8.5) cm can rotate about a vertical axis. A **massless** rope is connected at one of its ends to a block A of mass m = 0.60 kg, with its other end wrapped around the middle of the sphere. On the way to the sphere, the rope passes over a pulley of rotational inertia $I = 0.003\ \text{kg}\cdot\text{m}^2$ and radius r = 5.0 cm. There is zero friction everywhere and the rope does not slip on the pulley. **What is the speed of the object** v when it has fallen 82 cm after being released from rest? Use energy considerations.



Answer:

Question №21

A solid sphere of a given radius rolls smoothly from its original stationary position at height H = 6 m, as shown below. The sphere then falls from the horizontal section at the end of the track, at height h = 2 m. **How far** (d = ?) **from the edge** will the ball land on the floor? Assume there is no friction and no air resistance.



Answer:

Electrical Engineering

Block 8. Definitions

Question №22

Problem 1.

Which equations can be used to calculate **electrical power**? The terms V, I, R denote voltage, current and resistance, respectively. Multiple correct answers are possible.

A. $P = V/I$ **B**. $P = I^2R$ **C**. $P = VI$ **D**. $P = R/V^2$

Answer:

Question №23

Answer:

Problem 2.

What is **electrical impedance**? Multiple correct answers are possible.

A. Complex resistance

B. Amount of assistance that a circuit presents to current or voltage change

C. Sum of resistance and inductance

D. The inverse of capacitance

Question №24

Answer:

Which quantity among the ones listed below describes a fundamental property of a material that quantifies how easily an electric current passes through it:

A. Resistance

B. Electrical conductivity

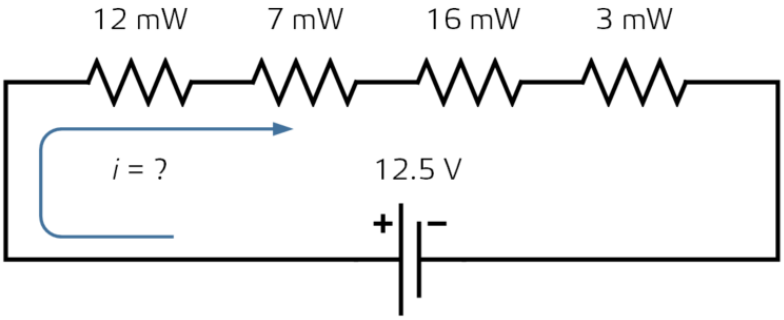
C. Electric resistivity

D. Conductance

Block 9. Electrical Power

Question №25

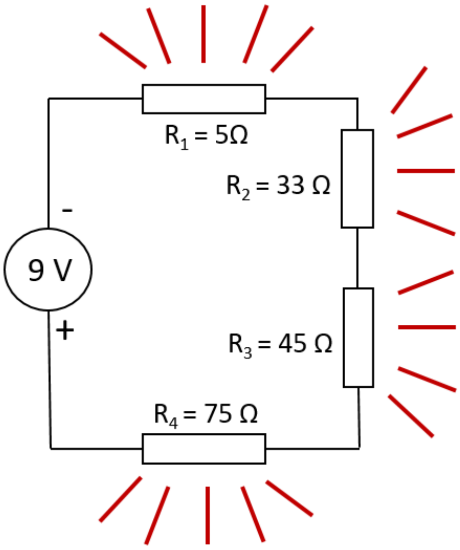
Find electric current in the circuit below for the given values of power spent on resistors.



Answer:

Question №26

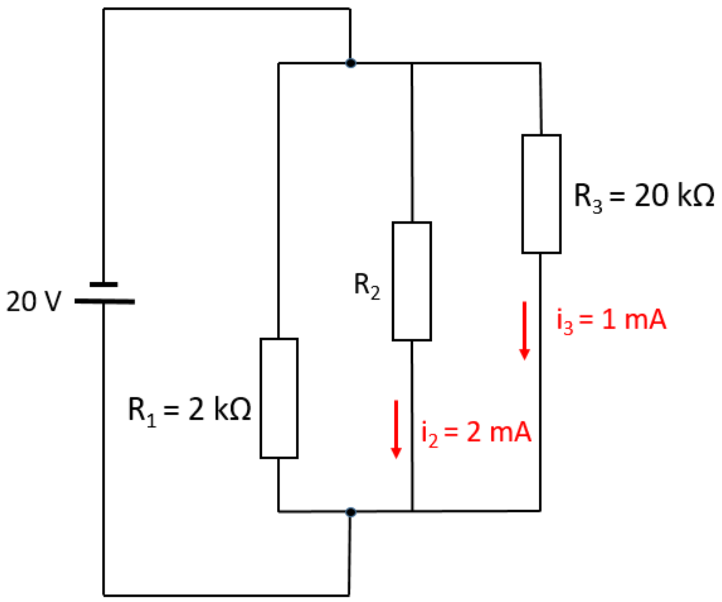
Find electric power on the 45-Ω resistor in the circuit below.



Answer:

Question №27

Find electric power on resistor R_1.

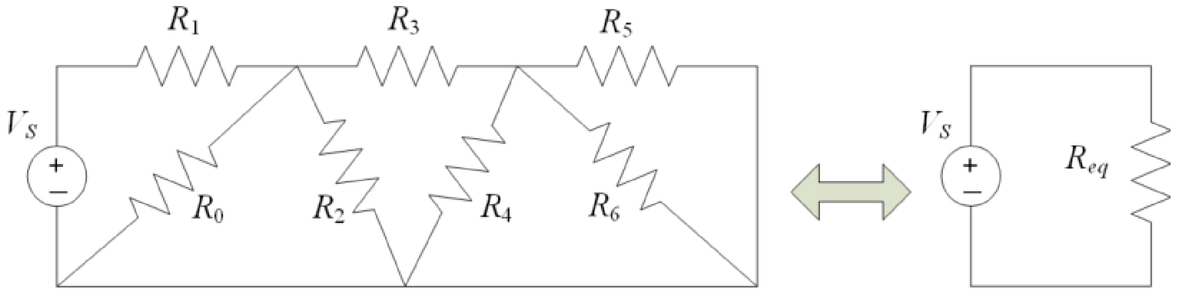


Answer:

Block 10. Equivalent Resistance

Question №28

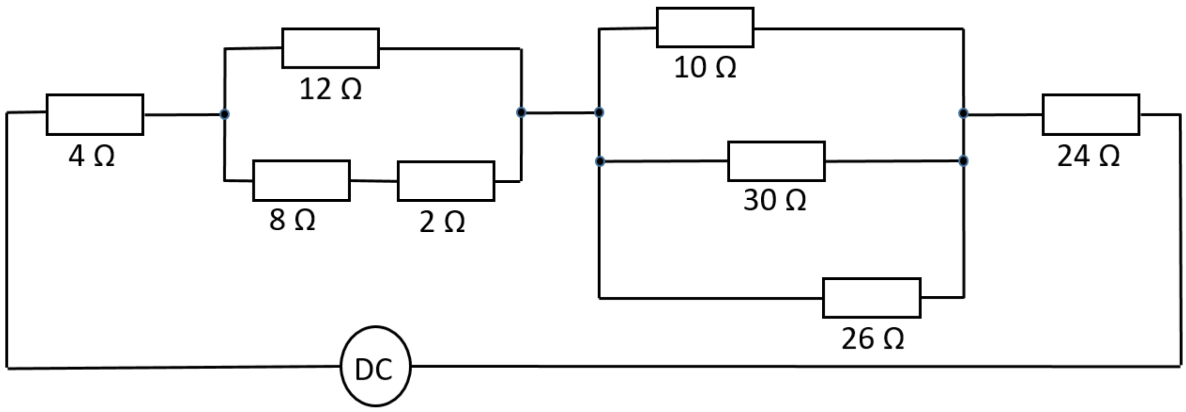
Find the equivalent resistance R_{eq} in the circuit below
Given: $V_S = 12$ V, $R_0 = 4\ \Omega$, $R_1 = 2\ \Omega$, $R_2 = 50\ \Omega$, $R_3 = 8\ \Omega$, $R_4 = 10\ \Omega$, $R_5 = 12\ \Omega$, $R_6 = 6\ \Omega$.



Answer:

Question №29

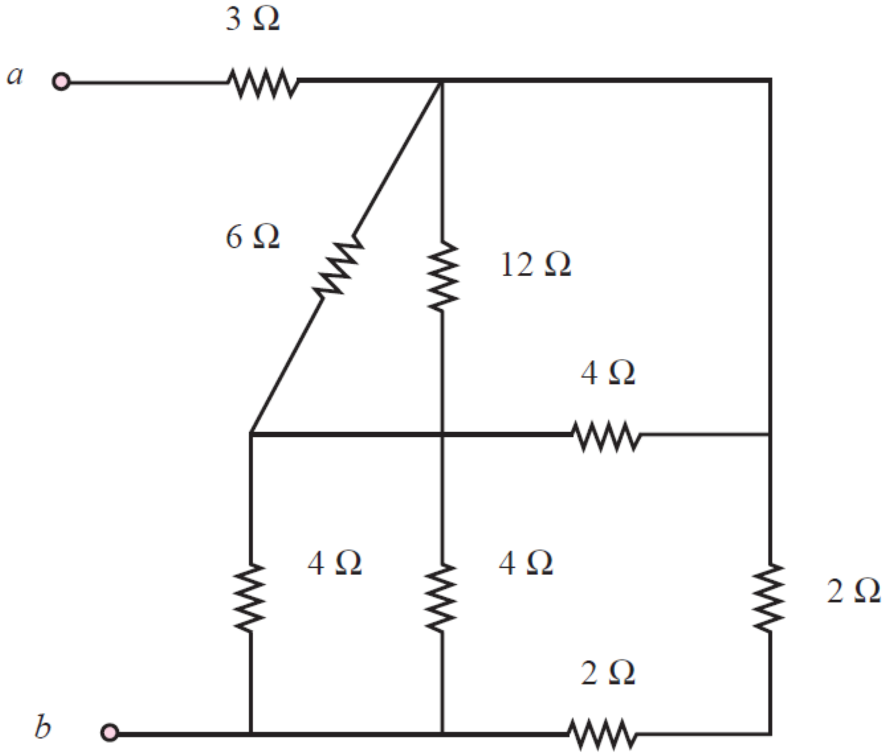
Find the equivalent resistance for the circuit below.



Answer:

Question №30

Find the equivalent resistance between terminals *a* and *b* in the circuit below.



Answer: