IJSO 2021 Physics MCQ Solution

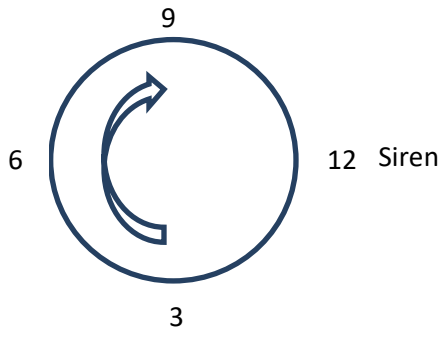
Constants

Acceleration due to gravity g = 9.8 ms^{-2}

Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and the density of water is 1000 kg m^{-3}

Mechanical equivalent of heat = 4.18 $Jcal^{-1}$

1. A siren goes on at a constant frequency in front of (outside) a merry-go-round. If the merry-go-round is rotating in the clockwise direction with the siren as shown in the figure. Following are some conditions at which maximum frequency, minimum frequency, and the original frequency are observed by a person sitting on the merry-go-round.
    1. Original pitch is heard at 12 O'clock and 6 O'clock positions.
    2. Original pitch is heard at 9 O'clock and 3 O'clock positions.
    3. Higher pitch is heard at 3 O'clock and lower pitch at 9 O'clock positions.
    4. Higher pitch is heard at 9 O'clock and lower pitch at 3 O'clock positions.



Select the correct statements

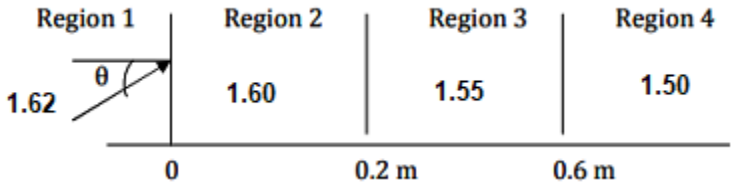
a) 1, 4 b) 2, 3 c) 1, 3 d) 2, 4

Answer: (a).

Explanation: At 12 and 6 O' clock positions, the velocity of the observer sitting on the merry-go-round with respect to the siren is zero, so no change in frequency.

At 9 O'clock position the observer is moving towards the source and 3 O'clock the observer is moving away from the source. So the observer gets higher pitch at 9 O'clock position and lower pitch at 3 O'clock position.

2. A light beam is travelling from vertically infinite region 1 to vertically infinite region 4 (refer to figure). The refractive indexes in regions 1, 2, 3, 4 are 1.62, 1.60, 1.55, and 1.50, respectively. The angle of incidence θ for which the beam just misses entering region 4 is



a) $\sin^{-1}\left(\frac{1.50}{1.55}\right)$
b) $\sin^{-1}\left(\frac{1.50}{1.62}\right)$
c) $\sin^{-1}\left(\frac{1.60}{1.62}\right)$
d) $\sin^{-1}\left(\frac{1.55}{1.60}\right)$

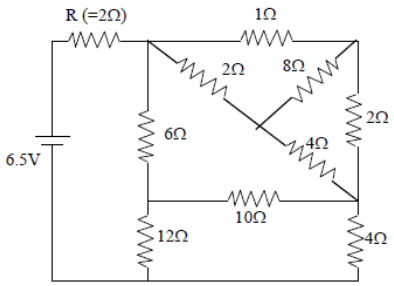
Ans.: (b)

Critical angle from region 3 to region 4: $\sin\theta_c = \frac{1.50}{1.55}$

Applying Snell's law in consecutive regions: $1.62\sin\theta = 1.60\sin\alpha = 1.55\sin\theta_c$

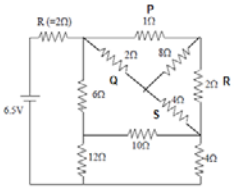
$1.62\sin\theta = 1.50$ $\theta = \sin^{-1}\frac{1.50}{1.62}$

3. In the following circuit, the current through the resistor R (=2 Ω) is I Amperes. The value of I is



a) 0.5 A
b) 1.0 A
c) 1.8 A
d) 2.0 A

Ans.: b)

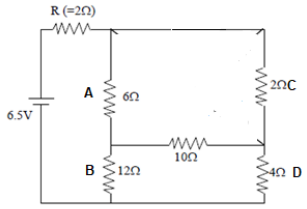


P/Q = R/S; So no current will pass through 8 ohms.

Hence P +R will be in parallel with Q+S.

The equivalent resistance of this combination will be 2 ohms.

So now circuit can be rearranged as given below



A/B = C/D; So no current will pass through 10 ohms.

Hence A +B will be in parallel with C+D.

The equivalent resistance of this combination will be 4.5ohms.

So now total resistance of the ciecuit will be 6.5 ohmsn Hence current will be 1 A.

4. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg of water by 40 K when connected to a line voltage source. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter 2d. Which of the following options is correct regarding the time taken for heating the same amount of water through the same temperature difference?
   a) 4 minutes if wires are in series.
   b) 2 minutes if wires are in parallel.
   c) 1 minute if wires are in series.
   d) 0.5 minute if wires are in parallel.

Ans.: d)

Initial Resistance is $R = \frac{\rho L}{\pi r^2} = \frac{4\rho L}{\pi d^2}$

When wires are changed resistance will be $R' = \frac{\rho L}{\pi (2r)^2} = \frac{\rho L}{\pi d^2} = \frac{R}{4}$

When wires are connected in series the resistance will be 2R' = R/2

When wires are connected in parallel the resistance will be R' /2= R/8

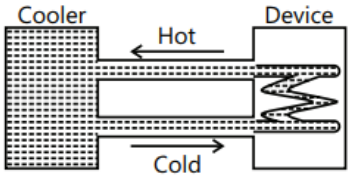
$E = Power \times time = \frac{V^2}{R} t$ $\qquad \frac{E}{V^2} = \frac{4}{R}$

When wires are connected in series the time required will be t = 2 minutes

When wires are connected in parallel the time required will be t = 0.5 minutes

5. A water cooler of storage capacity 120 litres can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3000 W of heat (thermal load). The temperature of water fed into the device cannot exceed 30°C and the entire stored 120 litres of water is initially cooled to 10°C. The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is

a) 4220
b) 2067
c) 3533
d) 3933



1. **Ans.:** b)

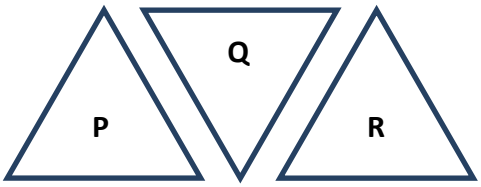
Device generates constantly 3 kW of heat which is fed to the cooler

$$Power\ of\ cooler\ = 3000\ -\ mass \times\ sp.Heat \times\ change\ in\ temperature\ /time$$

$$Power\ of\ coo = 3000\ - density \times\ volume \times\ sp.Heat \times\ change\ in\ temperature\ /time$$

=2067 watt

6. A given ray of light suffers minimum deviation in an equilateral prism P. Additional prisms Q and R of identical shape and of the same material as P are now added as shown in the figure. The ray will now suffer



a) Greater deviation.
b) Same deviation as before.
c) Total internal reflection.
d) No deviation.

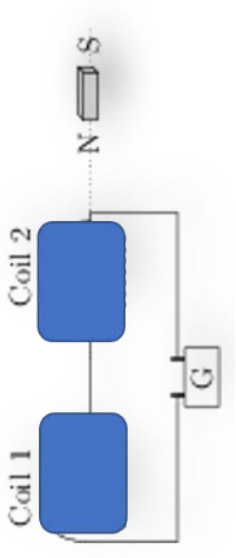
Ans.: b)
As the incident ray is suffering minimum deviation, angle of incidence is equal to the angle of emergence which should be the angle of incidence for the second prism as the refracting surfaces are parallel.
Hence the ray will suffer minimum deviation in each prism and the final angle of emergence will be equal to the initial angle of incidence.
Thus the ray will suffer same deviation as the case for a single prism.

7. When two mechanical waves meet in a small region of space, superposition of the two waves takes place. This is known as interference of waves. Which of the following statements is false?

a) The resultant displacement of the two waves can be obtained by adding their individual displacements.
b) The waves leaving the region carry less energy than the waves had before interference.
c) The frequency of each wave does not change after interference.
d) After leaving the region, the characteristics of the waves remain same as before interference.

Ans.: b)

8. While doing an experiment in physics laboratory, Mustafa connected two coils (say coil 1 and coil 2) in series with a galvanometer and dropped a magnet through the coils, as shown in the figure. He noticed that there was no deflection in the galvanometer when the magnet passed through coil 2 and observed a large deflection when it passed through coil 1. He noticed that both coils are identical in shape, size and material. Both had same number of turns and the speed with which the magnet passed through each coil was nearly the same. He concluded that



A. The net magnetic flux through coil 2 must be zero.
B. When passing through coil 2, induced emf across coils 1 and 2 must be in the opposite directions.
C. The galvanometer would show deflection for coil 2 if the poles of the bar magnet were reversed.
D. Coil 2 must have different pattern of windings than that of coil 1.

Which of the above statements are correct?

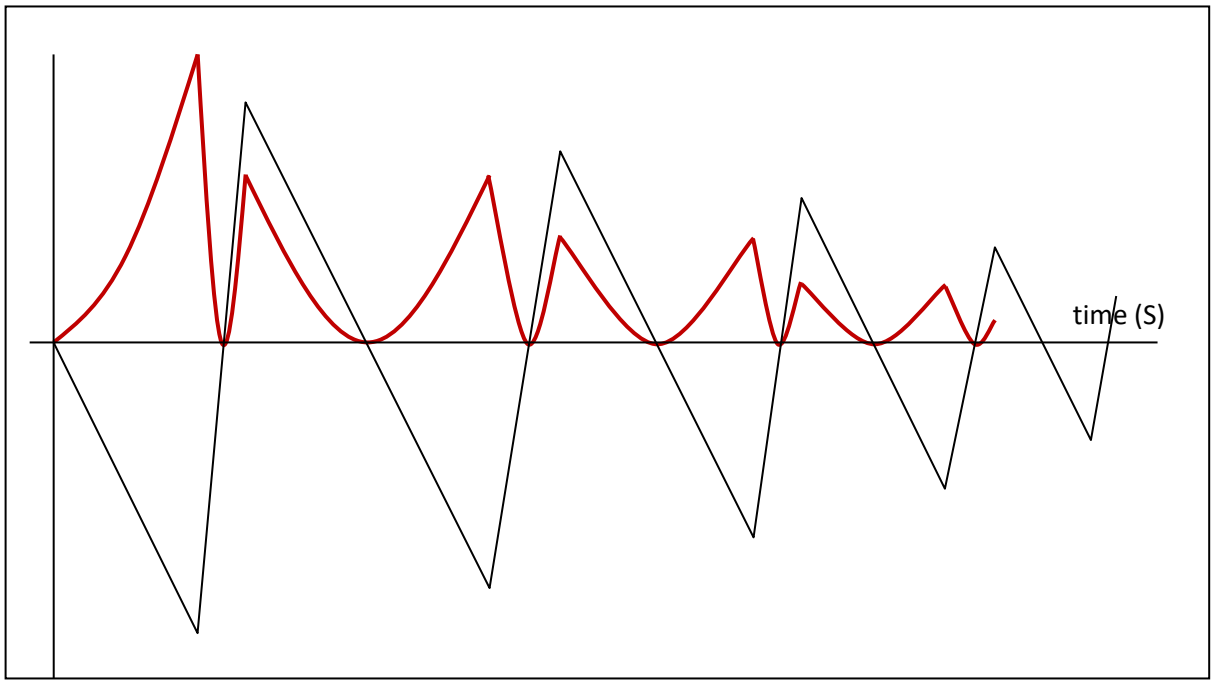
a) A, B
b) B, C
c) B, D
d) A, D

Ans.: d)

Windings in the coil B has been done in both the directions such that the no of turns in clockwise direction is equal to the no. of turns in the anticlockwise direction.

Thus, the induced emfs produced in coil 2 are in opposite direction because of which galvanometer does not show any deflection.

9. A typical ping pong ball is dropped from a height of 1 m above a marble floor. The ball bounces several times before it comes to rest. For every successive bounce, it loses 20% of its maximum height. Fatima plotted two quantities that she observed in this phenomenon vs time and the graphs are shown below. Identify the two quantities plotted on vertical axis vs time along the horizontal axis.



a) Height and velocity,
b) Velocity and kinetic energy .
c) Potential energy and kinetic energy
d) Velocity and potential energy

Ans.: b)

The velocity keeps on increasing linearly (-gt) with time until the ball hits the ground then it reverses within a short time.

Kinetic energy is always positive and increases quadratic with velocity.

Time taken for each bounce is progressively shorter.

10. Mercury is the fastest planet in the solar system moving with an average orbital speed of 47 km/s. The earth moves slower with an average orbital speed of 30 km/s. What is the radius of mercury's orbit around the Sun in astronomical units (nearly equal to the orbital radius of earth)?

(a) 0.25 (b) 0.40 (c) 0.50 (d) 0.70

Solution (b)

$T \propto R^{3/2}$ and also $T = 2\pi R/v \Rightarrow v \propto (1/R^{1/2}) \Rightarrow v_1/v_2 = (R_2/R_1)^{1/2}$