PHYSICS

BOOKS - HC VERMA

THE SPECIAL THEORY OF RELATIVITY

Example

1. A person in a train moving at a speed $3 \times 10^7 ms^{-1}$ sleeps at 10 .00 p.m. by his watch and gets up at 4.00 a.m. How long did

he sleep according to the clocks at the stations?

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2. The passenger of example slept with his head towards the engine and feet towards the guard's coach. If he measured 6 ft in the train frame, how tall is he in the ground frame ?

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3. Suppose the rest length of the box in figure is 30 light seconds. The train T_1 travels at a speed of $0.8c$. Find the time elapsed between opening of D_1 and D_2 in the frame of T_1.

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4. A particle is kept at rest at the origin. A constant force $\rightarrow$ F starts acting on it at $t = 0$. Find the speed of the particle at time t.

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5. If a mass of 3.6 g is fully converted into energy , how many kilowatt hour of electical energy will be obtained ?

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Worked Out Example

1. A hypothetical train moving with a speed of 0.6 c passes by the platform of a small station without being slowed down. The observes o

the platform note that the length of the train is just equal to the length of the platform which is 200 m . (a) Find the rest length of the train (b) Find the length of the platform as measured by the obsevers in the train .

A.

B.

C.

D.

Answer:

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2. Unstable pions are produced as a beam in a nuclear reaction experiment . The pions leave the target at a speed of 0.995c. The intensity of the beam reduces to half its original value as the beam travels a distance of 39 m . Find the half - life of pions (a) in the laboratory frame, (b) in their rest frame.

A.

B.

C.

D.

Answer:

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3. Two events A and B occur at places separated by $10^6 km$, B occuring 5s after A . (a) Find the velocity of a frame in which these events occur at the same place . (b)What is the

time interval between the events in this frame ?

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4. A satellite orbits the earth near its surface. By what amount does the satellite's clock fall behind the earth's clock in one revolution ? Assume that non-relativistic analysis can be made to compute the speed of the satellite and only the time dilation is to be taken into account for calculation of clock speeds.

A.

B.

C.

D.

Answer:

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5. The radius of our galaxy is about $3 \times 10^{20} m$ .With what speed should a person travel so

that he can reach from the centre of the galaxy to its edge in 20 years of his lifetime ?

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6. Find the speed at which the mass of an electron is double of its rest mass.

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7. Calcualte the increase in mass when a body of rest mass 1 kg is lifted up through 1 m near

the earth's surface.

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8. A body of rest mass m_0 collides perfectly inelastically at a speed of 0.8c with another body of equal rest mass kept at rest . Calculate the common speed of the bodies after the collision and the rest mass of the combined body .

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Short Answer

1. The speed of light in glass is $2.0 \times 10^8 ms^{-1}$. Does it violate the second postulate of special relativity ?

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2. A uniformly moving train passes by a long platform. Consider the events ' engine crossing the beginning of the platform' and the ' engine crossing the end of the platform '.

Which frame (train frame (train frame or the platform frame) is the proper frame for the pair of events ?

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3. An object may be regarded to be rest or in motion depending on the frame of reference chosen to view the object. Because of length contraction it would mean that the same rod may have two dfferent lenghts depending on the state of the observe. Is this true ?

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4. Mass of a particle depends on its speed . Does the attraction of the earth on the particle also depend on the paricle's speed ?

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5. A person travelling in a fast spaceship measures the distance between the earth and the moon. Is it the same, smaller or larger than the value quoted in this book?

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Objective

1. The magnitude of linear momentum of a particle moving at a relativistic speed v is proportional to

A. v

B. 1 - v^(2) / c^(2)

C. (sqrt 1 - v^(2) / c^(2)

D. none of these

Answer: D

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2. As the speed of a particle increases, its rest mass

A. increases

B. decreases

C. remains the same

D. changes

Answer: C

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3. An experimenter measure the length of a rod . Initially the experiment and the rod are at rest with respect to the lab. Consider the following statements.

A. A is true but B is false

B. B is true but A is false

C. Both A and B are true

D. Both A and B are false

Answer: C

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4. An experimenter measures the length of a rod. In the caese listed, all motions are with respect to the lab and parallel to the length will be minimum?

A. The rod and the experimenter move with the same speed v in the same direction .

B. The rod and the experimneter move with the same speed v in opposite directions

C. The rod moves at speed v but the exprimenter satsy at rest.

D. The rod stays at rest but the experimenter moves with the speed v but the experimenter moves with the speed v.

Answer: B

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5. If the speed of a particle moving at a relativistic speed is doubled, its linear momentum will

A. Become double

B. bocome more than double

C. remain equal

D. become less than double.

Answer: B

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6. If a constant force acts on a particle, its acceleration will

A. remain constant

B. gradually decrease

C. gradully increase

D. be undefined.

Answer: B

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7. A charged particle is projected at a very high speed perpendicular to a uniform magnetic field . The particle will

A. move along a circle

B. move along a curve with increasing radius of curvature

C. move along a curve with decreasing radius of curvature

D. move along a straight line .

Answer: B

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Objective 2

1. Mark the correct statements :

A. Equations of special relativity are not applicable for small speeds.

B. Equations of special relativity are applicable for all speeds

C. Nonrelativistic equation give exact result for small speeds.

D. Nonrelativistic equation never give exact result.

Answer: B::D

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2. If the speed of a rod moving at a relativistic speed is parllel , to its length is doubled,

A. the length will become half of the original value.

B. the mass will become double of the original value.

C. the length will decrease

D. the length will increase

Answer: C::D

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3. Two events take place simultaneously at points A and B as seen in the lab. Frame. They also occur simultaneously in a frame moving with respect to the lab in a direstion

A. parallel to AB

B. perpendicular to AB

C. making an angle of `45^@ with AB

D. making an angle of `135^@ with AB

Answer: B

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4. Which of the following qunatities related to an elcetron has a finite upper limit?

A. mass

B. momentum

C. speed

D. Kinetic energy

Answer: C

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5. A rod of rest length L moves at a relativistic speed. Let L' = L / γ . Its length

A. must be equal to L'

B. may be equal to L

C. may be more than L' but less than L

D. may be more than L

Answer: B::C

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6. When a rod moves at a relativistic speed v, its mass

A. must incrase by a factor of gamma

B. may remain unchanged

C. may increase by a factor other than gamma

D. may decrease

Answer: A

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Exercises

1. The guru of a yogi lives in a Himalyan cave, 1000 km away from the house of the yogi . The

yogi claims that whenever he thinks about his guru, the guru immediately knows about it. Calcualte the minimum possible tiem interval between the yogi thinking about the guru and the guru knowing about it.

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2. The length of a rod is exactly 1 m when measured at rest . What will be its length when it moves at a speed of (a) $3 \times 10^5 ms^{-1}$ (b) $3 \times 10^6 ms^{-1}$ and (c) $3 \times 10^7 ms^{-1}$?

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3. A person standing on a platform finds that a train moving with velocity, 0.6c takes one second to pass by him. Find (a) the length of the train as seen by the person and (b) the rest length fo the train .

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4. An aerplane travels over a rectangular field $100m \times 50m$ parallel to its length. What

should be the speed of the plane so that the field becomes square in the plane frame?

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5. The rest distance between patna and Delhi is 1000 km. A nonstop train travels at $360 kmh^{-1}$. (a) What is the distance between Patna and Delhi in the train frame ? (b) How much time elapses in the train frame between Patna and Delhi?

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6. A person travels by a car at a speed of $180 kmh^{-1}$. It takes exactly 10 hours by his wristwatch to go from the station A to the station B . (a) What is the rest distance between the two stations ? (b) How much is taken in the road frame by the car to go from the station A to the station B?

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7. A person travels on a spaceship moving at a speed of $5\frac{c}{13}$. (a) Find the train interval calculate by him between the consecutive birthday celbrations of his friend on the earth . (b) Find the time interval calculated by the friend on the earth between the consecutive birthday celebrations of the traveller.

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8. According to the station clocks, two babies are born at the same instant, one in Howrah and other in Delhi. (a) Who is elder in the frame of 2301 up Rajdhani Experess going from Howrah to Delhi? (b) Who is elder in the frame of 2302 Dn Rajdahni Express going from Delhi to Howrah .

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9. Two babies are born in a moving train, one in the compartment adjacent to the engine and other in the compartment adjacent to the guard. According to the train frame , the babies are born at the same instant of time. Who is elder according to the ground frame?

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10. Suppose Swrglok (heaven) is in constant motion at a speed of 0.9999c with respect to

the earth. According to the earth,s frame , how much time passes on the earth before one day passes on Swarglok?

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11. If a person lives on the average 100 years in his rest frame, how long does he live in the earth frame if he spends all his life in a spaceship going at 60% of the speed of light .

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12. An electric bulb, connected to a make and break power supply, switches off and on every second in its rest frame. What is the frequency of its switching off and on as seen from a spaceship travelling at a speed 0.8c?

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13. A person travelling by a car moving at $100 kmh^{-1}$ finds that his wristwatch agress with the clock in a tower A. By what amount will his wristwatch lag or lead the clock on

another tower B, 1000km (in the earth's frame) from the tower A when the car reaches there?

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14. At what speed the volume of an object shrinks to half its rest value ?

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15. A particular particle created in a nuclear reactor leaves a 1cm track before decaying. Assuming that the particle moved at $0.995c$, calculate the life of the particle (a) in the lab frame and (b) in the frame of the particle .

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16. By what fraction does the mass of a spring is 200 g at its natural lenth and the spring constant is `500 N m ^(-1)

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17. Find the increase in mass when 1 kg of water is heated from $0^\circ C$ to $100^\circ C$. Specific heat capacity of water $= 4200 Jkg^{-1}K^{-1}$.

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18. Find the loss in the mass of 1 mole of an ideal monatomic gas kept in a rigid container as it cools down by $10^\circ C$. The gas constant $R = 8.3 JK^{-1}mol^{-1}$.

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19. By what fraction does the mass of a boy increase when he starts running at a speed of `12 km h ^(-1)?

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20. A 100 W bulb together with its power supply is suspended from a sensitive balance.

Find the change in the mass recorded after the bulb remains on for 1 year .

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21. The energy from the sun reaches just outside the earth's atmoshphere at a rate of $1400 Wm^{-2}$. The distance between the sun and the earth is $1.5 \times 10^{11} m$. (a) Calculate the rate at which the sum is losing its mass. (b) How long will the sun last assuming a

constant decay at this rate? The present mass of the sun is $2 \times 10^{30} kg$

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22. An elcetron and a positron moving at small speeds collide and annihilate each other. Find the energy of the resulting gamma photon .

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23. Find the mass, the kinetic energy and the momentum of an electron moving at 0.8c.

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24. Through what potential difference should an electron be accelerated to give it a speed of (a) 0.6c, (b) 0.9c), and (0.99c)?

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25. Find the speed of an elctron with kinetic energy (a) 1 eV , (b) 10 KeV and (c) 10 MeV.

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26. What is the kinetic energy of an electron in electronvolts with mass equal to double its real mass?

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27. Find the speed at which the kinetic energy of a particle will differ by 1% from non-relativistic value $\frac{1}{2}m_0V^2$.

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Exercise

1. A suitcase kept on a shop's rack is measured $50cm \times 25cm \times 10cm \times bytheshop'sow \neq r$. A traveller takes this suitcase in a train

moving with velocity 0.6c . If the suitcase is placed with its length along the trains velocity , find the dimensions mesured by (a) the traveller and (b)a ground observe .

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