Q- A cart (m_1 = 120 kg) is moving to the right along a track at v_{1i} = 15 m/s when it hits a stationary cart (m_2 = 360 kg) and rebounds with a speed of v_{1f} = 7 m/s in the opposite direction.

a. With what speed does the 360 kg cart move after the collision?
b. An observer moves in the same direction as the incoming cart with a speed of 12 m/s. (positive) Using the convention that the positive direction is to the right, what are the velocities of both bodies with respect to this observer before and after collision
c. What is the total momentum of the system before and after the collision as seen by this moving observer?
d. Discuss the results found in part(c)

Answer:

a) Here the two carts can be considered as a system and as there in no external force on the system in horizontal direction, the linear momentum in horizontal direction is conserved. Hence we get with the same law
Initial momentum of the system
$P_1 = m_1v_{1i} + m_2*0 = 120*15 = 1800$ kg m/s(in forward direction +)
{Second cart is at rest}

Now as after collision, the first cart rebounds, means it is going backward with speed 7 m/s and its momentum is 120*7 = 840 kg m/s. As the momentum of a body is a vector quantity and is in the direction of velocity which is backward direction hence it should be − 840 kg m/s. (- because of backward). Thus if the speed of the second cart after collision is v_{2f} (definitely forward) the final momentum of the system is given by

$P_2 = - 840 + 360*v_{2f}$

And according to law of conservation of momentum we have

$P_2 = P_1$

Or $-840 + 360*v_{2f} = 1800$

Or $v_{2f} = (1800 + 840)/360 = 7.333$ m/s

b) The velocity of body 2 relative to 1 is given by

$V_{21} = v_2 - v_1$ {keep direction in mind}
Using the convention that the positive direction is to the right, what are the following velocities with respect to this observer:

$v_{1i,\, ob} = v_{1i} - v_{ob} = 15 - 12 = 3.00$ m/s

$v_{2i,\, ob} = v_{2i} - v_{ob} = 0 - 12 = -12$ m/s

$v_{1f,\, ob} = v_{1f} - v_{ob} = - 7 - 12 = - 19$ m/s

$v_{2f,\, ob} = v_{2f} - v_{ob} = 7.333 - 12 = - 4.667$ m/s

c) The total momentum of the system before the collision as seen by this moving observer

$p_{tot,\ i} = m_1*(\ v_{1i} - v_{ob}) + m_2*(\ v_{2i} - v_{ob}) = 120*3.00 + 360*(-12.0) = -3960$ kg m/s

The total momentum of the system after the collision as seen by this same observer

$p_{tot,\ f} = m_1*(\ v_{1f} - v_{ob}) + m_2*(\ v_{2f} - v_{ob}) = 120*(-19) + 360*(-4.667) = -3960.12$ kg m/s

d) We see that the for the observer too the law of conservation of momentum holds good, as it is moving with constant velocity (Inertial frame of reference).

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