Edward Auttonberry

**Lab 1**

12/10/2019

PHYS 262 – 001

With:

Jacob Sennett

and

Anna Weeks

**Objective**

The objective of this lab is to verify the linear relationship between the speed of an induced wave traveling through a string versus the wavelength and frequency of that wave.

**Theory**

The theory being tested is that the total momentum within a system is conserved in the absence of external forces, which is Newton’s First Law. Newton’s Third Law then states that forces inside the system have counterforces that are equivalent in magnitude but opposite in polarity. Momentum is a conserved quantity defined found by p=mv. Applying the laws discussed above, the conservation of momentum after the collision of objects in the system can be expresses as

The theory being tested is that a wave can be described by

Eq. 7-1

in a two-body system with a total mass *M* equivalent to *m1+m2* and individual velocities *v1* and *v2*. Because the total momentum in a system cannot change, and the mass does not change in these two-body collisions, the velocity of the center of mass of the system, *vcm*, will also not change, even after the events of collision where new individual velocities, *v’1* and *v’2*, are in place. Thus, we can rewrite Eq. 7-1 to the new velocities:

Eq. 7-2

Combining Eq. 7-1 and Eq. 7-2 produces:

Eq. 7-3

This is the primary equation for analysis of the collisions, whether elastic or inelastic.

Additionally, in the case of elastic collisions, the kinetic energy must also be conserved:

Eq. 7-4

In these experiments, the momentum cannot be entirely conserved due to the interference of frictional forces. Measures are taken to minimize the effect of frictional forces in this experiment, such as a low-friction track and magnetic repulsion for the elastic collisions.

**Procedure**

The achievement of this experiment’s goal was extruded into three scenarios. Each scenario involved a string, a pulley, a wave-inducing modulator, and one or more weights of varying mass. The string was tied to the output prong of the wave modulator, laid over the pulley, and attached to by the weights for each scenario’s iterations. Measurements taken would be the mass of the collective weights, the current output frequency, and the distance between nodes of the standing waves.

**Scenario 1**

For the first set of iterations, the mass at the end of the string was kept at a constant 100 grams to impart a steady 0.98 Newtons of tension.

**Data**

Shown below is the table of all the readings for the procedures defined in Table 7-1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Procedure | Trial # | v1 (m/s) | v2 (m/s) | v'1 (m/s) | v'2 (m/s) |
| A | 1 | 0.271 | 0 | 0.016 | 0.217 |
| 2 | 0.15 | 0 | 0.117 | 0.000 |
| 3 | 0.2513 | 0 | 0.000 | 0.202 |
|  |  |  |  |  |  |
| B | 1 | 0.1601 | 0 | 0.028 | 0.190 |
| 2 | 0.1632 | 0 | 0.029 | 0.183 |
| 3 | 0.1999 | 0 | 0.049 | 0.252 |
|  |  |  |  |  |  |
| C | 1 | 0.2421 | 0 | 0.062 | 0.137 |
| 2 | 0.3028 | 0 | 0.043 | 0.160 |
| 3 | 0.2044 | 0 | 0.060 | 0.121 |
|  |  |  |  |  |  |
| D | 1 | 0.3459 | 0 | 0.141 | 0.136 |
| 2 | 0.3144 | 0 | 0.127 | 0.135 |
| 3 | 0.2402 | 0 | 0.104 | 0.104 |
|  |  |  |  |  |  |
| E | 1 | 0.2054 | 0 | 0.108 | 0.107 |
| 2 | 0.2704 | 0 | 0.164 | 0.165 |
| 3 | 0.2484 | 0 | 0.157 | 0.152 |
|  |  |  |  |  |  |
| F | 1 | 0.3738 | 0 | 0.108 | 0.109 |
| 2 | 0.3043 | 0 | 0.094 | 0.095 |
| 3 | 0.3886 | 0 | 0.120 | 0.120 |

**Table 7-2.** The table of the velocity readings for each trial from all the procedures.

**Analysis**

Using the information compiled in Table 7-2 and the equation for momentum, we can derive the net momentum for each trial run in the experiment. Seeing the momentum of the system before and after collision will allow us to see how the momentum was conserved.

The momentum calculations for each procedure are given below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | m1 (kg) | 0.5072 |  |
|  | m2 (kg) | 0.5102 |  |
| Procedure | pnet (N·s) | p'net (N·s) | %lossp |
| A | 0.137 | 0.119 | 13.660 |
| 0.076 | 0.060 | 21.733 |
| 0.127 | 0.103 | 19.143 |
|  |  |  |  |
| B | 0.081 | 0.111 | 36.492 |
| 0.083 | 0.108 | 30.750 |
| 0.101 | 0.153 | 51.336 |
|  |  |  |  |
| C | 0.123 | 0.101 | 17.551 |
| 0.154 | 0.103 | 32.813 |
| 0.104 | 0.092 | 10.804 |
|  |  |  |  |
| D | 0.175 | 0.141 | 19.628 |
| 0.159 | 0.133 | 16.476 |
| 0.122 | 0.106 | 13.107 |
|  |  |  |  |
| E | 0.104 | 0.109 | 5.079 |
| 0.137 | 0.167 | 22.032 |
| 0.126 | 0.157 | 24.799 |
|  |  |  |  |
| F | 0.190 | 0.110 | 41.829 |
| 0.154 | 0.096 | 37.871 |
| 0.197 | 0.122 | 38.212 |

**Table 7-3.** The table containing the derived net momenta before and after collision and the percentage of the momentum lost in the process.

In a similar fashion, we can calculate the total energies in the system before and after the collision. Because the system takes place on a level track with no vertical variation, we can ignore potential energy and focus solely on the kinetic energy exchange. The energy calculations are given on the next page.

|  |  |  |  |
| --- | --- | --- | --- |
|  | m1 (kg) | 0.5072 |  |
|  | m2 (kg) | 0.5102 |  |
| Procedure | E (J) | E' (J) | %lossE |
| A | 0.019 | 0.012 | 35.442 |
| 0.006 | 0.003 | 38.743 |
| 0.016 | 0.010 | 35.005 |
|  |  |  |  |
| B | 0.007 | 0.009 | 44.474 |
| 0.007 | 0.009 | 30.170 |
| 0.010 | 0.017 | 65.875 |
|  |  |  |  |
| C | 0.015 | 0.006 | 61.324 |
| 0.023 | 0.007 | 70.073 |
| 0.011 | 0.005 | 55.871 |
|  |  |  |  |
| D | 0.030 | 0.010 | 67.788 |
| 0.025 | 0.009 | 65.184 |
| 0.015 | 0.006 | 62.359 |
|  |  |  |  |
| E | 0.011 | 0.006 | 44.952 |
| 0.019 | 0.014 | 25.761 |
| 0.016 | 0.012 | 22.340 |
|  |  |  |  |
| F | 0.035 | 0.006 | 83.130 |
| 0.023 | 0.005 | 80.757 |
| 0.038 | 0.007 | 80.967 |

**Table 7-4.** The table of the net energies before and after collision of the carts, and the percentages of energy lost in the process of each trial.

**Extension of theory:**

Given Eq. 7-3, we can derive a formula to calculate the expected final velocities of the colliding bodies in an elastic collision.

We can eliminate the initial cart 2 momentum because it begins still.

Kinetic energies would be conserved because this is an elastic collision.

According to the second step:

We sub this back into step 4.

Which we expand and multiply by *m2*.

Then we factor out *v’1*.

This is a quadratic equation with an independent variable *v’1*, which we can solve for using the quadratic formula. Doing so results in the following:

Which simplifies to

However, it cannot be the positive solution because that would mean

Which is not true because there was a collision and cart 1 is not an unstoppable force, so to speak. Therefore, the only other solution is the other root:

Eq. 7-5a

If we take this known velocity and plug it into step 7, we can find *v’2*.

Eq. 7-5b

Using these two equations we can get what the expected velocities for the elastic trials were.

|  |  |  |  |
| --- | --- | --- | --- |
| Procedure | Trial # | v'1 (m/s) Expected | v'2 (m/s) Expected |
| A | 1 | -0.000799096 | 0.270200904 |
| 2 | -0.000442304 | 0.149557696 |
| 3 | -0.000741006 | 0.250558994 |
|  |  |  |  |
| B | 1 | 0.052438184 | 0.212538184 |
| 2 | 0.053453539 | 0.216653539 |
| 3 | 0.065474035 | 0.265374035 |
|  |  |  |  |
| C | 1 | -0.080253262 | 0.161846738 |
| 2 | -0.100374588 | 0.202425412 |
| 3 | -0.067756162 | 0.136643838 |

**Table 7-5.** The expected final velocities for each of the elastic trials.

These values do not match up very well with the experimental values. The transfer of kinetic energy followed the proportions, and the momentum seems to be conserved, but the raw velocities between this table and Table 7-2 simply do not match. One of the main discrepancies is the presence of negative velocities in this table. It is consistent, however. When the masses are the same it seems that most of the energy just gets handed to cart 2, but whenever one cart is more massive than the other, the larger one does not like to move as much, which is what Procedures B and C show here.

Everything just done for elastic collisions can also be done for the inelastic collision procedures.

We can start with Eq. 7-3.

But because the collision is inelastic, but cart one and cart 2 will have same final velocity *v’*. We can also take cart 2’s initial momentum out because again, it is motionless at the beginning.

Which gives us the result

Eq. 7-6

Applying this equation our results for the expected final velocities are as follows on the next page:

|  |  |  |
| --- | --- | --- |
| Procedure | Trial # | v' (m/s) expected |
| D | 1 | 0.172440024 |
| 2 | 0.156736466 |
| 3 | 0.119745862 |
|  |  |  |
| E | 1 | 0.136337736 |
| 2 | 0.179482589 |
| 3 | 0.164879715 |
|  |  |  |
| F | 1 | 0.124944879 |
| 2 | 0.10171409 |
| 3 | 0.129891868 |

**Table 7-6.** The expected final velocities for all the trials in the inelastic collision series of procedures.

This data is a little bit more consistent with the information from Table 7-2. Table 7-2’s final values show pretty close and, in some cases, perfect splits between the velocities of carts 1 and 2, and most of that data matches closely to the values shown here.

**Conclusions**

Based on all these results, it is hard for me to say with a clear conscience that the information presented supports the law of conservation of momentum. While the data given in the inelastic collisions portion matches up relatively well with the expected values, the actual values for the elastic collisions were way off from those of the expected calculations. Within the experiment, even though these trials were run on a frictionless track, we saw up to 50% loss of the net momentum within the system. There is no way we can say that this upholds the law. I disagree that the information presented here is a good case for the law of conservation of mass, and that it supports the theory presented, but the objective of the lab has still been achieved.