Collisions-I

PreLab submission with a pass grade is required to begin the lab.
Must be submitted no later than right before the lab starts.

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Section: H4
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Purpose

To understand the relationship of impulse to change of momentum.

Readings

You can explore the Wikipedia or your favorite mechanics textbook,
Elastic collision, Inelastic collision, Impulse

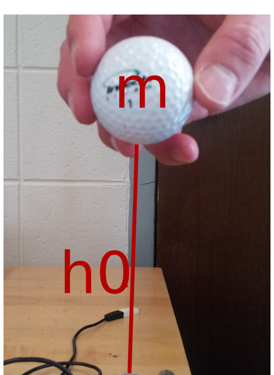
In a collision it is difficult to use Newton’s Second Law, **F** = m**a** because the force varies with time in some generally unknown manner. (Note: a bold letter for **F** means it is a vector unlike mass, m, which is a scalar.) We can rewrite the second law in a manner more useful for collisions by using the impulse **I** = $\int$ **F** dt.
Integrating both sides of the second law,

$$\mathbf{I} = \int \mathbf{F}\, dt = \int m\, \mathbf{a}\, dt = \int m\, (d\mathbf{v}/dt)\, dt = \int m\, d\mathbf{v} = m\, \mathbf{v}f - m\, \mathbf{v}i,$$

where **v**f and **v**i are the velocities of m after and before the collision, respectively. Note that **F** is the **total (net) force** acting on the mass.
We define the linear momentum of m as **P** = m**v**. Then the second law says that the change of momentum of a body during a collision equals the impulse it receives,

$$\mathbf{I} = \Delta \mathbf{P}.$$

Dialog:



Question 1.
We drop a golf ball of mass m from height h0 on a force probe which is facing upwards. The ball hits the force probe at t0, bounces off the force probe at t1, and hits the probe the 2nd time at t2. Assume we can neglect air friction.

In[7]:=
```
m = 0.050 (*kg*)
h0 = 0.150 (*m*)
t0 = -0.001 (*s*)
t1 = 0.012 (*s*)
t2 = 0.140 (*s*)
g = 9.81 (*m/s^2*)
```

Out[7]= 0.05

Out[8]= 0.15

Out[9]= -0.001

Out[10]= 0.012

Out[11]= 0.14

Out[12]= 9.81

1.1. What force(s) are acting on the ball before it hits the probe?

The force of Gravity.

1.2. What force(s) are acting on the ball during the first collision, i.e. between t0 and t1? What is their relative sign?

The force of Gravity and the Normal force from the force probe. They both point in the opposite direction. While gravity pulls the ball down (say -ve), the Normal Force pushes it up (+ve).

1.3. Use kinematic equations to calculate p0 (momentum of the ball at t0, right before the first collision) and p1 (momentum of the ball at t1, right after the first collision). [Hint: You can calculate p0 from the initial height h0 and p1 from the time between the two consecutive bounces, t1 and t2.]

v_0^2 - 0 = 2 gh_0
hence, v_0 = Sqrt(2 gh_0)
therefore, p_0 = mv_0 = m * Sqrt(2 gh_0) = 0.0858 $kgms^{-1}$ (IN THE DOWNWARD DIRECTION) (this is just the magnitude, the direction has been specified)

for the 2nd bounce,
0 = v_1t - $gt^2/2$
hence v_1= gt/2, t=t2-t1

therefore, p_1= mv_1= mg(t2-t1)/2 = 0.031392 kgms^{-1}(IN THE UPWARD DIRECTION)

In[17]:=
```
p0 = m * Sqrt[2 g * h0]
```
Out[17]=
```
0.0857759
```

In[18]:=
```
v1 = g * (t2 - t1) / 2
p1 = m * v1
```
Out[18]=
```
0.62784
```
Out[19]=
```
0.031392
```

1.4. What is the **total** impulse experienced by the golf ball during the first collision?

Impulse$_{total}$ = p2 (vector) - p1(vector) = 0.031392 - (-0.0857759) = 0.117168 kgms^{-1}

In[22]:=
```
Impulse = p1 + p0
```
Out[22]=
```
0.117168
```

1.5. By Newton's third law, the ball exerts an equal and opposite force on the force probe when its momentum changes.
F_P is what the force probe recorded between t0 and t1. What do you expect $\int_{t0}^{t1} F_P dt$ to be?
[Hint: Consider all the forces acting on the ball during the collision.]

I = $\int_{t0}^{t1} F_{total}dt = \int_{t0}^{t1} (F_{probe}+ F_{grav})dt = \int_{t0}^{t1} (F_P + (-mg))dt = \int_{t0}^{t1} F_P dt$ - mg(t2-t1) {I mean F_i=F due to i}

Hence, $\int_{t0}^{t1} F_{probe}dt$ = I + mg(t2-t1) = 0.179952 kgms^{-1}

Since the force ON probe would be Equal but opposite but for the same time bounds, $\int_{t0}^{t1} F_P dt$ = -0.179952 kgms^{-1} (Assuming This stands for Force ON probe)

In[23]:=
```
Impulse + m * g * (t2 - t1)
```
Out[23]=
```
0.179952
```

Question 2.
Next we drop a play-dough ball of the same mass m from the same height h0 on the force probe, and the ball sticks to the probe.

2.1. Is it an elastic or inelastic collision? What is the **total** impulse experienced by the play-dough ball during the collision?

In[40]:=
```
m = 0.050 (*kg*)
h0 = 0.150 (*m*)
Impulse = m * Sqrt[2 * g * h0]
m * g
```

Out[40]=
```
0.05
```
Out[41]=
```
0.15
```
Out[42]=
```
0.0857759
```
Out[43]=
```
0.4905
```

This time, it’s an inelastic collision.
Total impulse I = p1-p0, here p1 is 0 since the dough would be stationary and p1 would be the momentum of the dough just before collision
(I still consider up to be in +ve direction)
p0 = −mSqrt $(2\,gh_0)$
p1 = 0
Hence I = mSqrt$(2\,gh_0)$ = 0.0857759 kgms^{-1}

2.2. What is the force that the force probe will be reading after the play-dough ball sticks to it?

After the dough sticks to the probe, Net force on the dough would be 0. Hence, the normal force would then be mg and the force on probe would hence be -mg = -0.4905 ms^{-2}

2.3. If F_P is what the force probe recorded between t0 and t1 . What do you expect $\int_{t0}^{t1} F_P dt$ to be?

Again, the Net Impulse is the result of force due to probe as well as gravity (Impulse due to gravity would be -ve)

Hence, $\int_{t0}^{t1} F_{\text{probe}} dt$ = I + mg(t2-t1) = Which is why
$\int_{t0}^{t1} F_P dt$ (Impulse ON probe) would be -(I + mg(t2-t1))

It’s magnitude, would be higher than the Total Impulse on the dough again since it also counteracts the impulse that there would have been due to gravity.
(t2 and t1 not given in this case.)

Rutgers 275 Classical Physics Lab
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