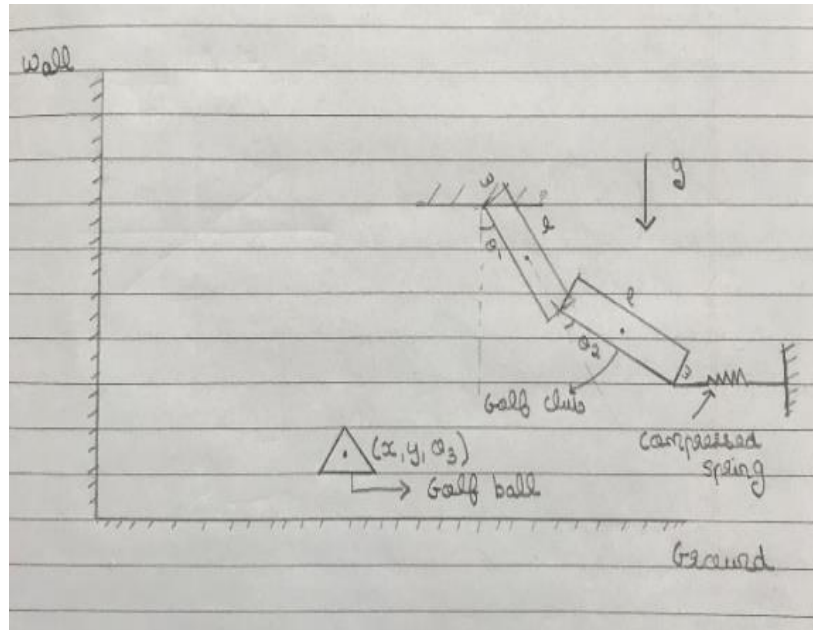


PROJECT



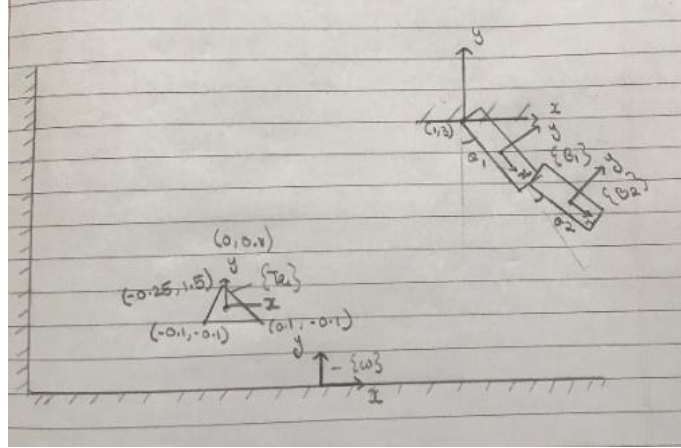
As shown in the above figure, the arm and the golf club are modelled like a double pendulum.

Assume a horizontal compressed spring which gives the club required energy to hit the ball. The ball is situated as shown. The animation I generated shows the impact of club and the ball initially and later the impacts of the ball with the wall (situated at -10m) and the ground. Initial configuration of golf ball is -0.25 in X direction and 1.5 in Y direction and orientation of golf ball is 0 and initial configuration of arm is 90° and that of golf club is 0° and initially all the objects are at rest.

Dimensions of Arm and Club: - Length (L) =1; Width (W) =0.25

Dimensions of Triangle: - Point 1 (0,0.1); Point 2 (-0.1, -0.1); Point 3 (0.1, -0.1)

Note: - Dimension of Triangle are with respect to center of Triangle



Frame of Triangle is achieved by translating World frame by $\{X, Y, 0\}$ where X and Y are coordinates of the system. After translation, frame is rotated by θ_3 which is also coordinate of the system.

$\text{Tri} = T(w, 0, [X, Y, 0]) * T(w, \theta_3, [0, 0, 0])$ where w is indicating rotation about Z -direction

Frame of Arm is achieved by translating World frame by $\{1, 3, 0\}$. So, by doing that frame of fixed point to which arm is attached is achieved. After translation, frame is rotated by 90° in clockwise direction. As, arm angle θ_1 is with respect to vertical line. Now frame is translated to center of arm by translating it by $\{L/2, 0, 0\}$. Finally, it is rotated by angle θ_1 where θ_1 is coordinate of the system.

$\text{B1} = T(w, 0, [0, 3, 0]) * T(w, \pi/2, [0, 0, 0]) * T(w, \theta_1, [0, 0, 0]) * T(w, 0, [L/2, 0, 0])$

Frame of Golf Club is achieved by translating Frame of arm by $\{L/2, 0, 0\}$ and then rotating by θ_2 . Finally, frame is translated to center of Golf Club by translating it by $\{L/2, 0, 0\}$.

$\text{B2} = \text{B1} * T(w, 0, [L/2, 0, 0]) * T(w, \theta_2, [0, 0, 0]) * T(w, 0, [L/2, 0, 0])$

Before Impact of Golf club and Golf Ball: -

Lagrangian = (Linear Kinetic Energy_{Arm} + Rotational Kinetic Energy_{Arm} +

Linear Kinetic Energy_{Golf Club} + Rotational Kinetic Energy_{Golf Club} + Linear Kinetic Energy_{Ball} +

Rotational Kinetic Energy_{Ball} - Potential Energy of Arm - Potential Energy of Golf Club - Potential Energy of Ball - Potential Energy of Spring).

Linear Kinetic Energy of each body except the ball's is calculated as $(0.5 * \text{Mass} * \dot{p} \cdot \dot{p})$

where \dot{p} is differentiation of position center of mass of body in world frame with respect to

time. Rotational Kinetic Energy of each body is calculated (as $0.5 * \text{Rotation Inertia about Z axis}$

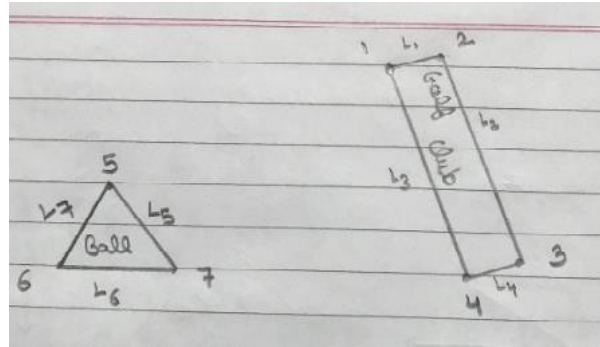
$* \text{rate of change of orientation of a body}$). Potential Energy is calculated as $(m * g (9.81) * y \text{ co-ordinate of center of mass in world frame})$.

Initially the golf ball is at rest at a certain height above the ground which implies the zero-energy condition. I modelled it to be at rest only at one point in the space (for initial condition).

Potential energy of spring is calculated as $0.5 * \text{spring constant (K=850)} * \text{difference of square of Golf club bottom line center x co-ordinate in world frame and its initial condition which is } \theta_1 \text{ and } \theta_2 \text{ equal to 0.}$

After the first impact, I performed dynamics of only Golf Ball whose initially velocities are obtained from final conditions of first impact. I placed the club back at initial position.

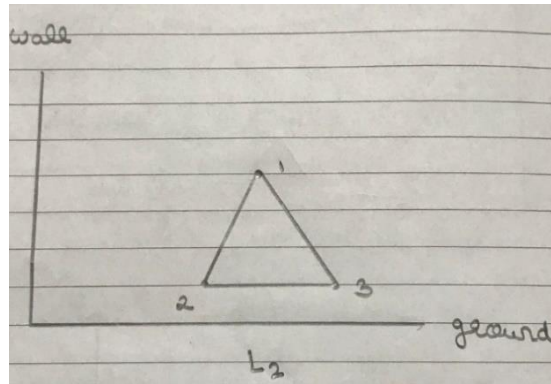
Impact Equation: -



There would be 24 possible impact but, only 6 of them are possible for this case. As, Golf Club could only hit line L5 and L6 as ball is stationary.

6 Impacts:

- a.) Point 7 inside Line L3
- b.) Point 5 inside Line L3
- c.) Point 1 inside Line L5
- d.) Point 4 inside Line L5
- e.) Point 1 inside Line L6
- f.) Point 4 inside Line L6



There would be total of 6 possible impact for ball either hitting ground or wall.

- a.) Point 1 inside Line Wall
- b.) Point 2 inside Line Wall
- c.) Point 3 inside Line Wall
- d.) Point 1 inside Line Ground
- e.) Point 2 inside Line Ground
- f.) Point 3 inside Line Ground

I consider this impact to be Inelastic impact with coefficient of restitution equal to 0.8 for all components of velocity.

Last step of this Project is simply to combine two matrix and animate a system.

Results:

My code is working properly. Golf Club hit one of triangle point and it receives velocity in negative X- Direction whereas negative in Y-direction as well as very large angular velocity. It is correct according to me as in real world also Golf Club hit bottom part of Ball and Ball tend to move in similar way. My entire code takes 3 minutes and 30 seconds to run