Motivation and Application

Why automate blackboard cleaning?

✅ Saves time during lectures
✅ Minimizes chalk dust exposure
✅ Promotes cleaner and healthier classrooms
✅ Enhances teaching experience

📌 **Real-world applications:**

- Classrooms & lecture halls
- Coaching centers
- Remote learning setups

Originality beyond class assignments or teaching notes

More than a class project — a real-world solution

🚫 Not just an assignment — it’s engineered for practicality
🧩 Unique sliding + wiping mechanism
🔩 Retrofit-friendly for existing blackboards
🔄 Combines mechanical design with automation logic

Kinematic Analysis

How does it move?

🔧 **2 DOF Mechanism:** Horizontal slide + vertical wiper

🧮 Coverage path length : 53 m

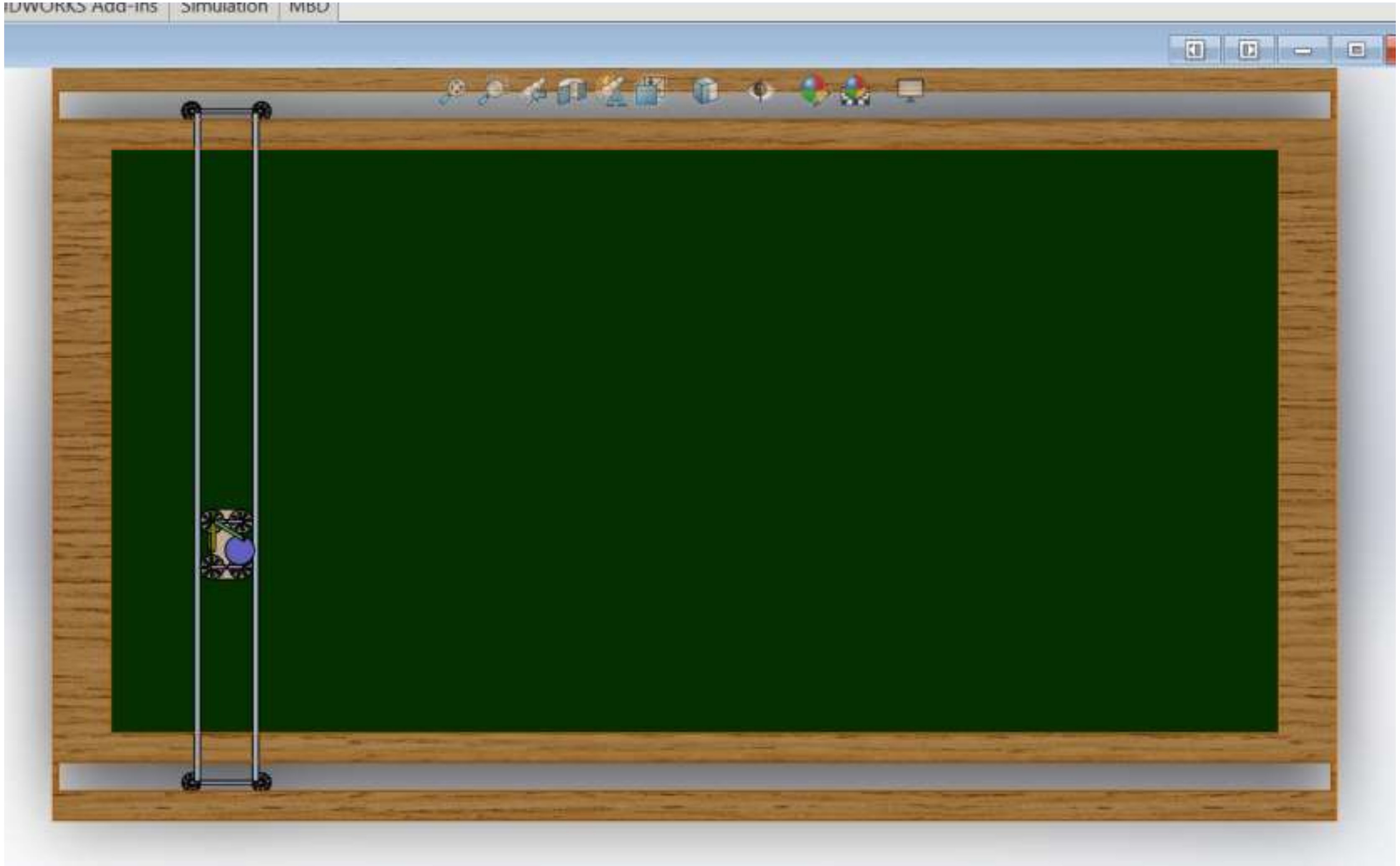
🕒 **Cycle time** (at 0.10 m/s): 530.00 s (≈ 8 min 50 s)

🛠️ Based on 4-bar and slider linkages

Kinematic Synthesis

- **Dimensional Synthesis:**
  - Optimized dimensions for coverage and minimal overlap.
- **Type Synthesis:**
  - Linear actuator and rotary motor hybrid system.
- **Motion Planning:**
  - Combines vertical and horizontal sweeps using timing wheels and duster attached with four bar mechanism will oscillates and clean the board.

Computer Aided Design



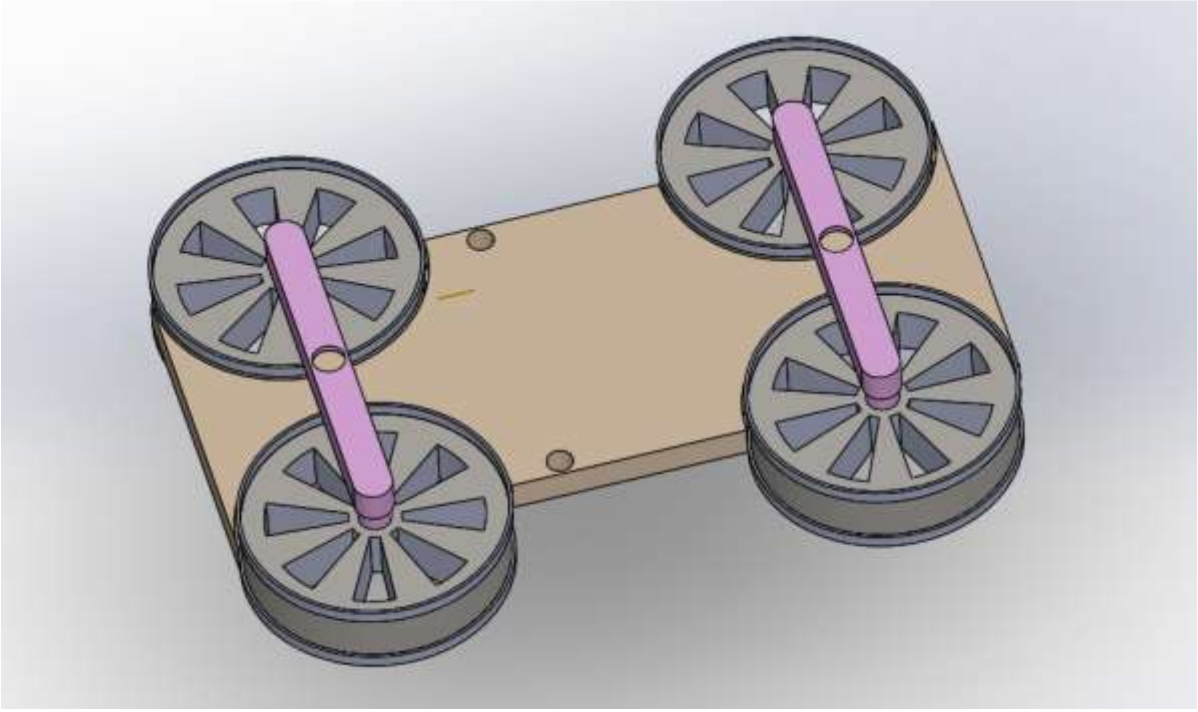
Overview of whole assembled cad.

Computer Aided Design

Vertical Rectangular Frame

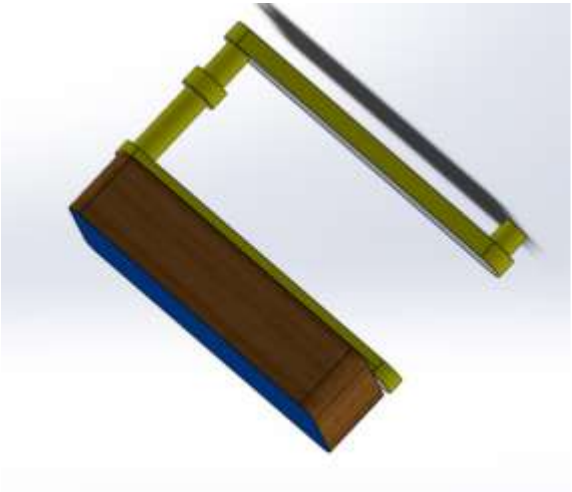
Frame that moves horizontally guided on base frame and provide cleaning in horizontal direction.

Quad- wheel Base platform

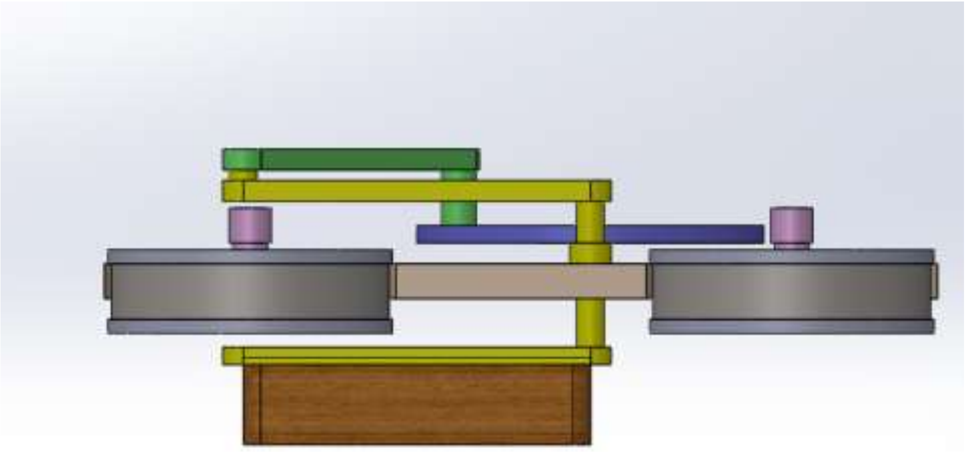


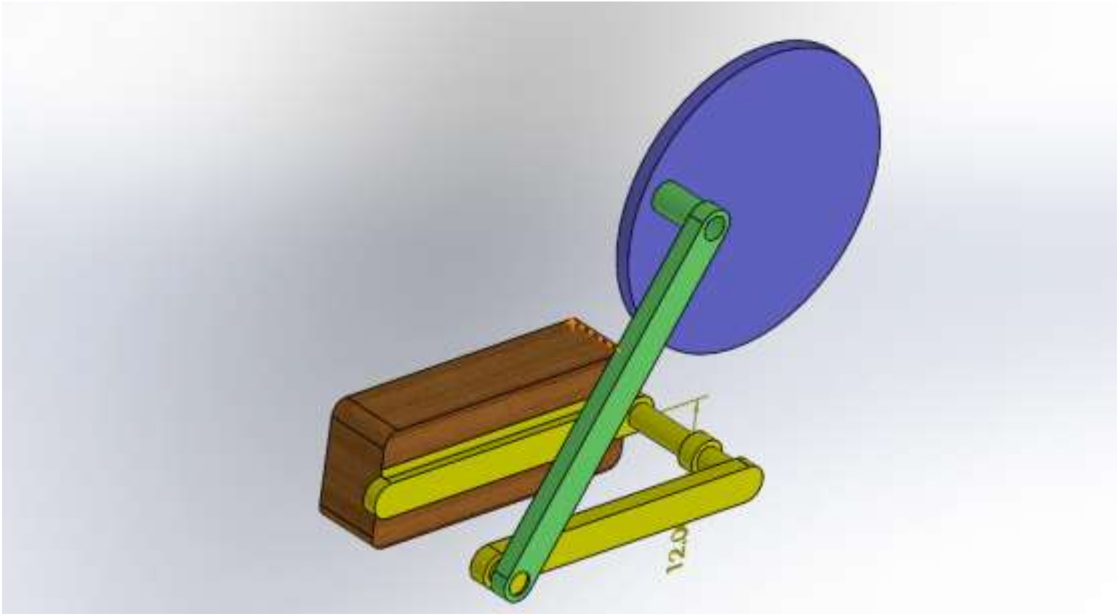
This frame will move vertically upwards and downwards and provide the cleaning in vertical direction.

Computer Aided Design



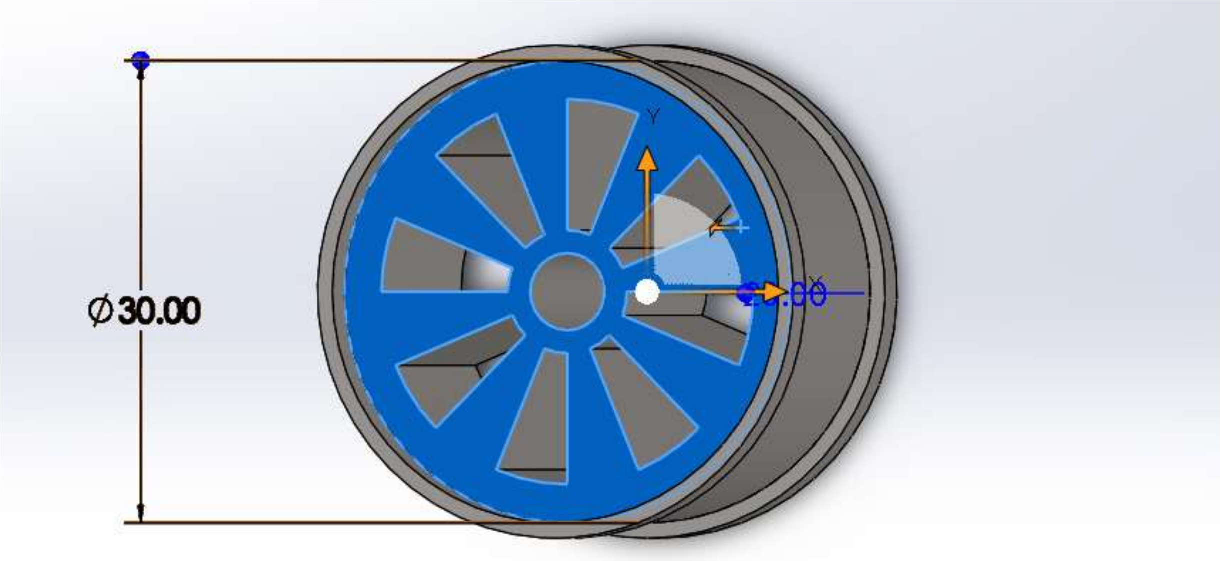
Duster



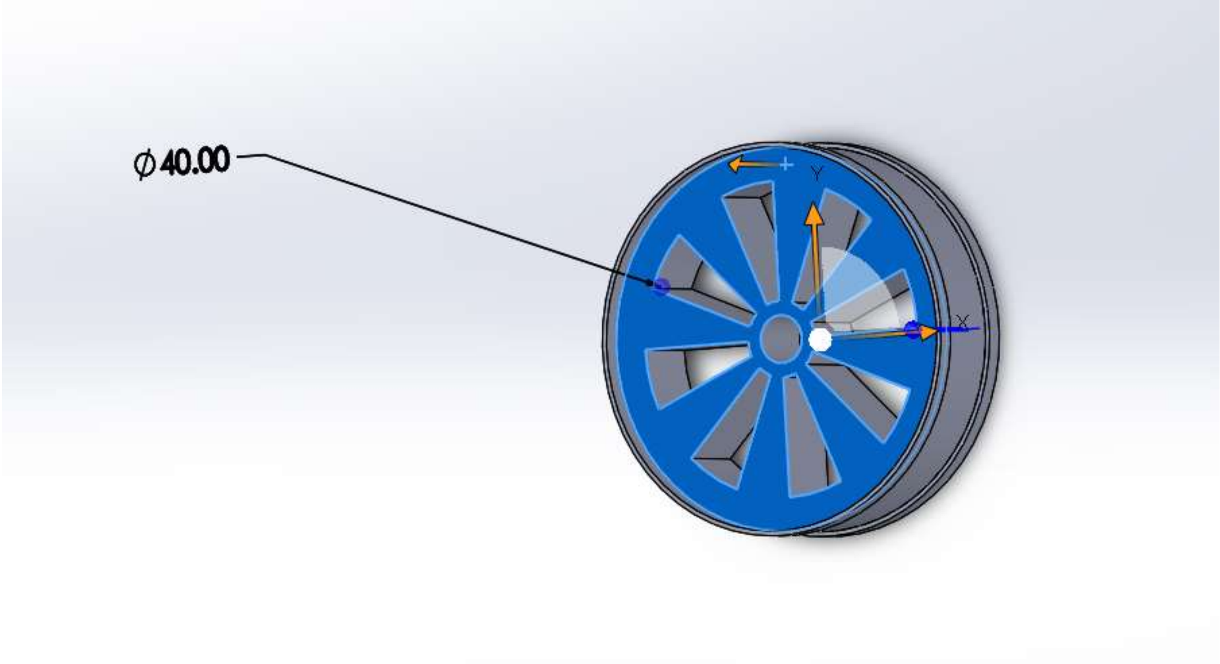


Duster attached with the mechanism (Four-bar mechanism)

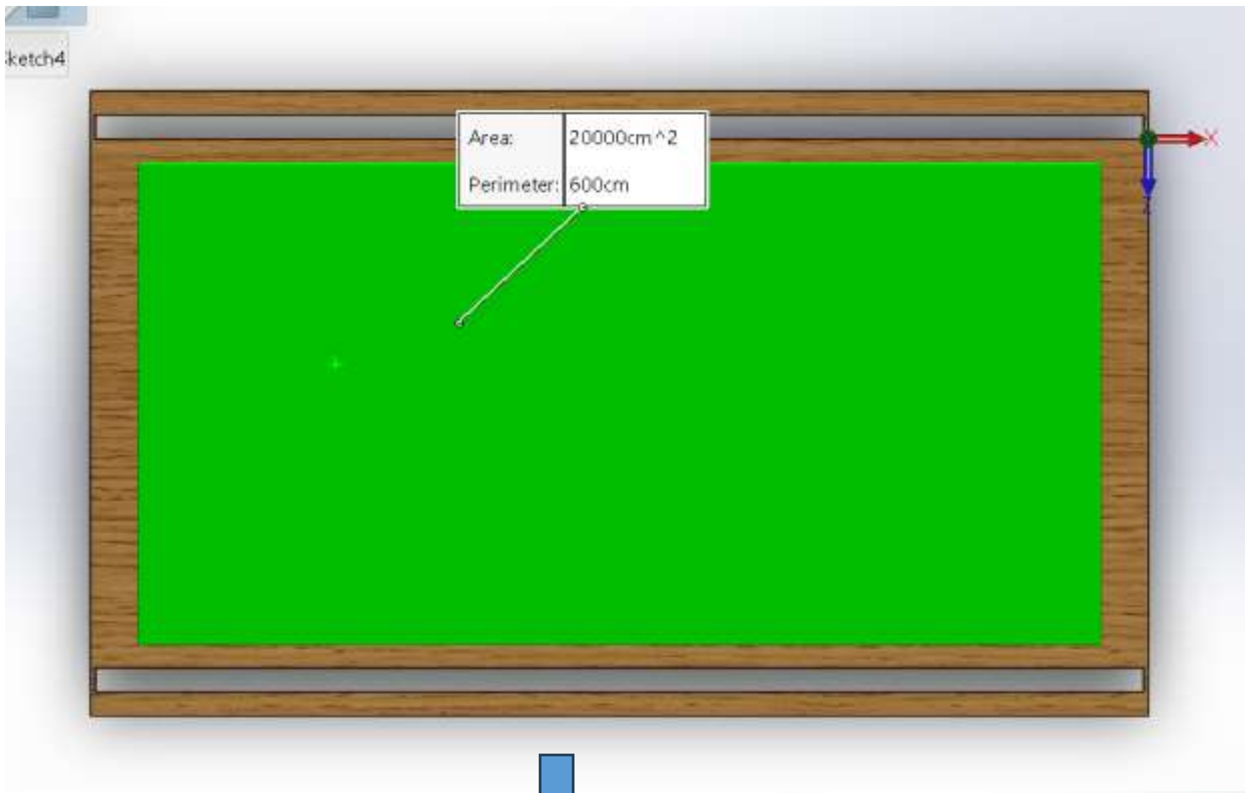
Side view of duster attached with mechanism, showing there is sufficient clearance

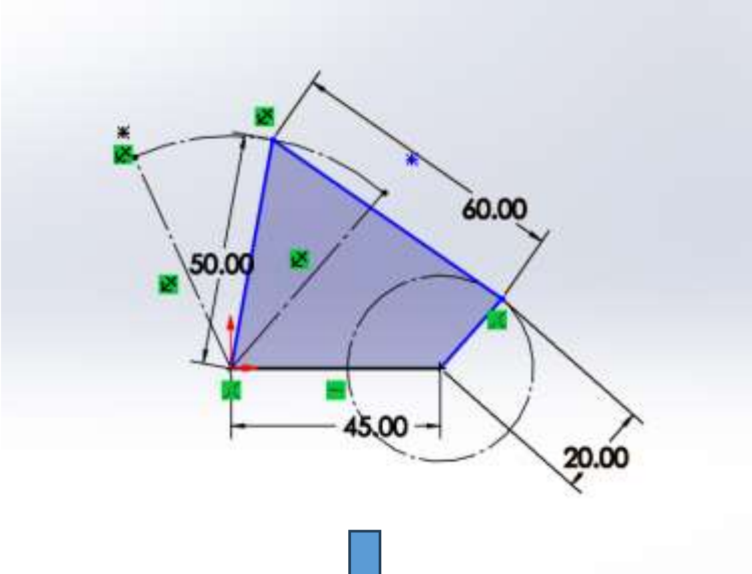


This is the wheel attached with the vertical frame for horizontal movement of wiper assembly.



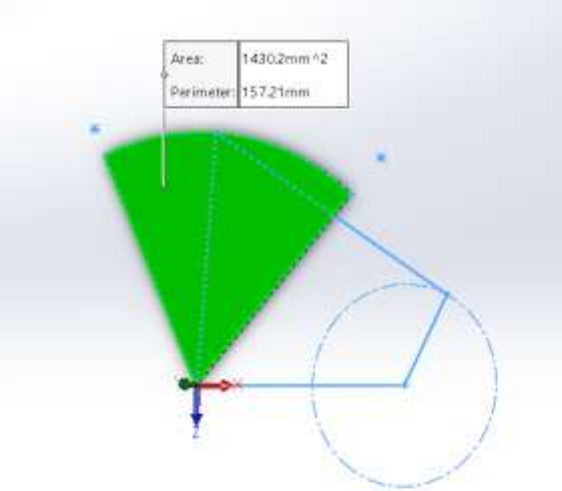
This is the wheel attached with Quad- wheel base platform for vertical cleaning.





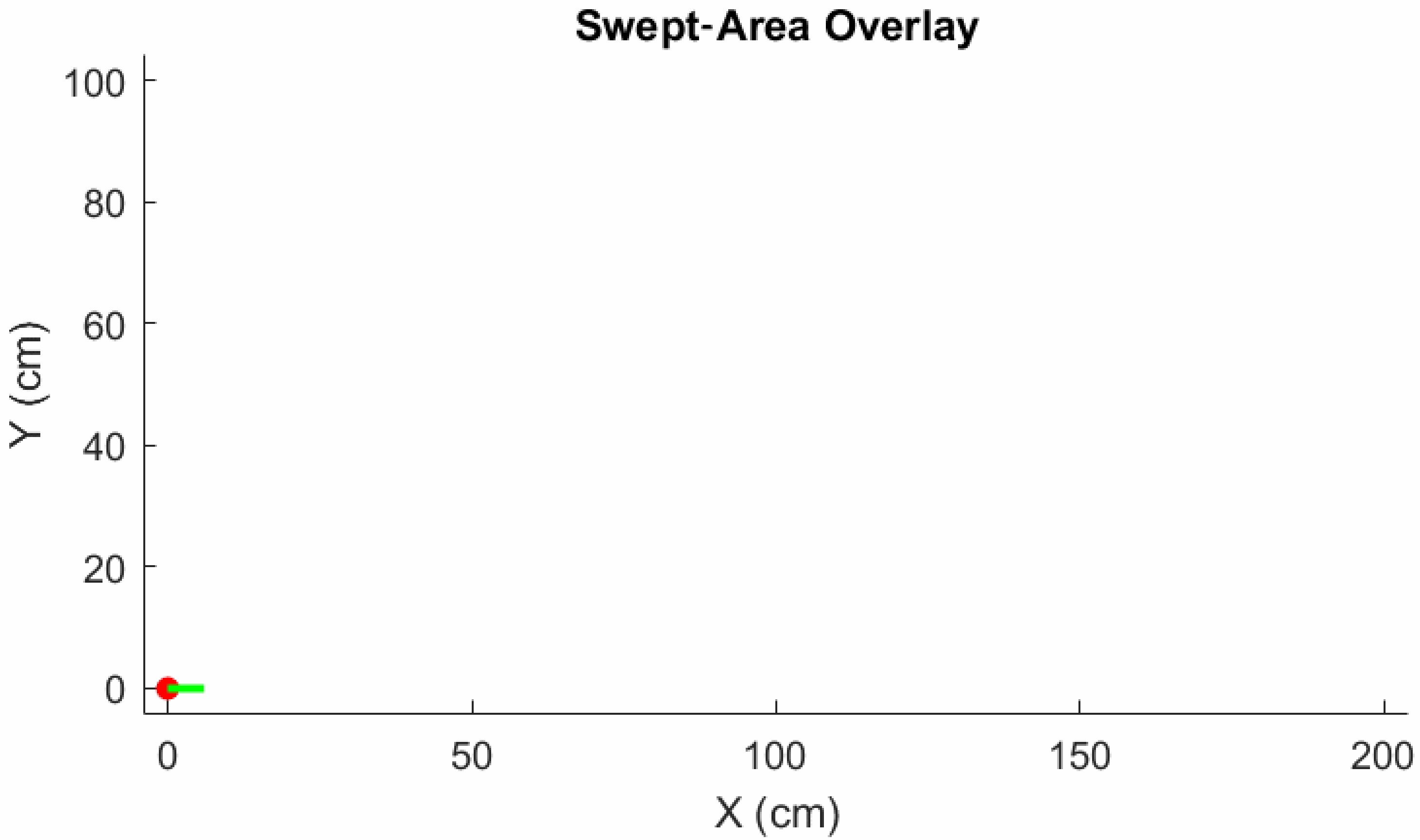
Schematic representation of four-bar mechanism on which rocker which is 50 mm in length oscillates in the range specified by black lines

Area of board where cleaning will be done.

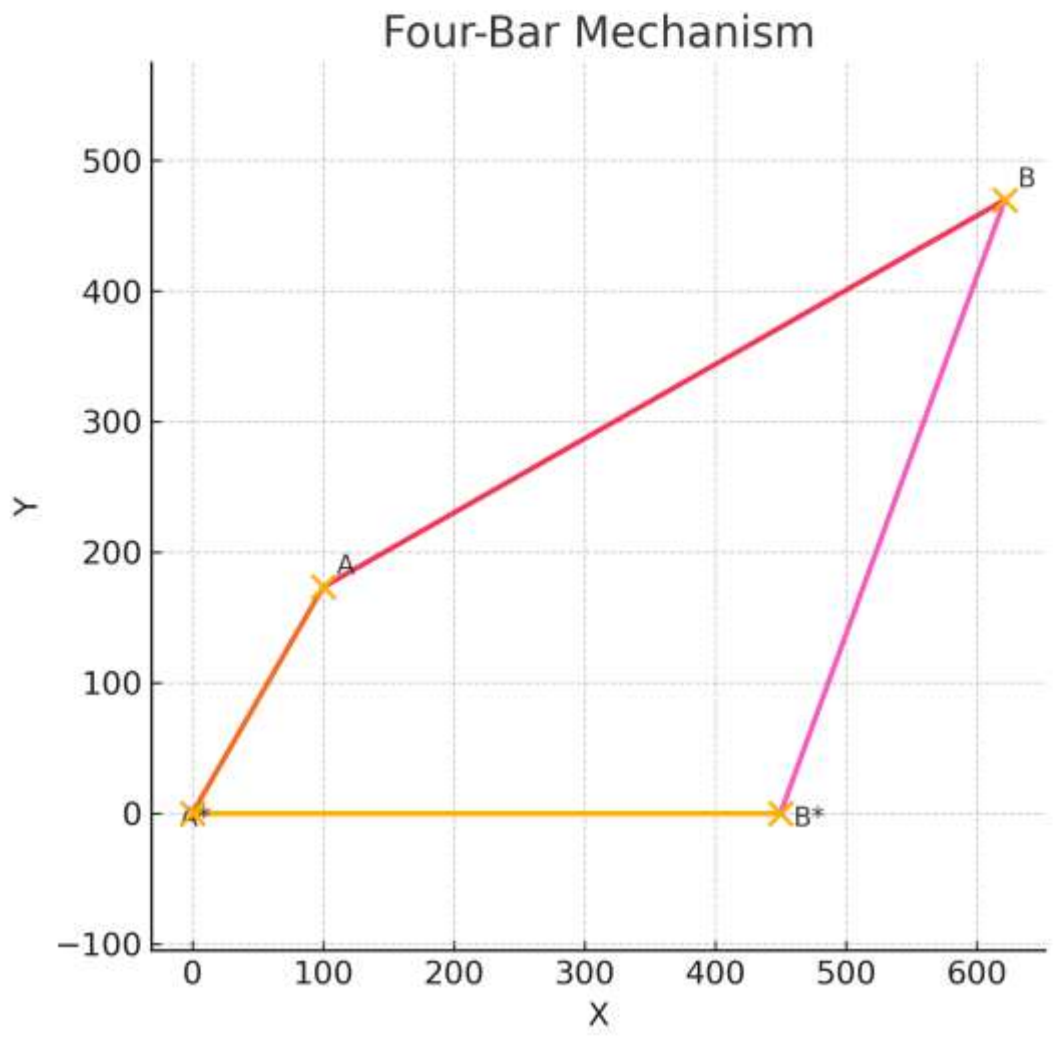


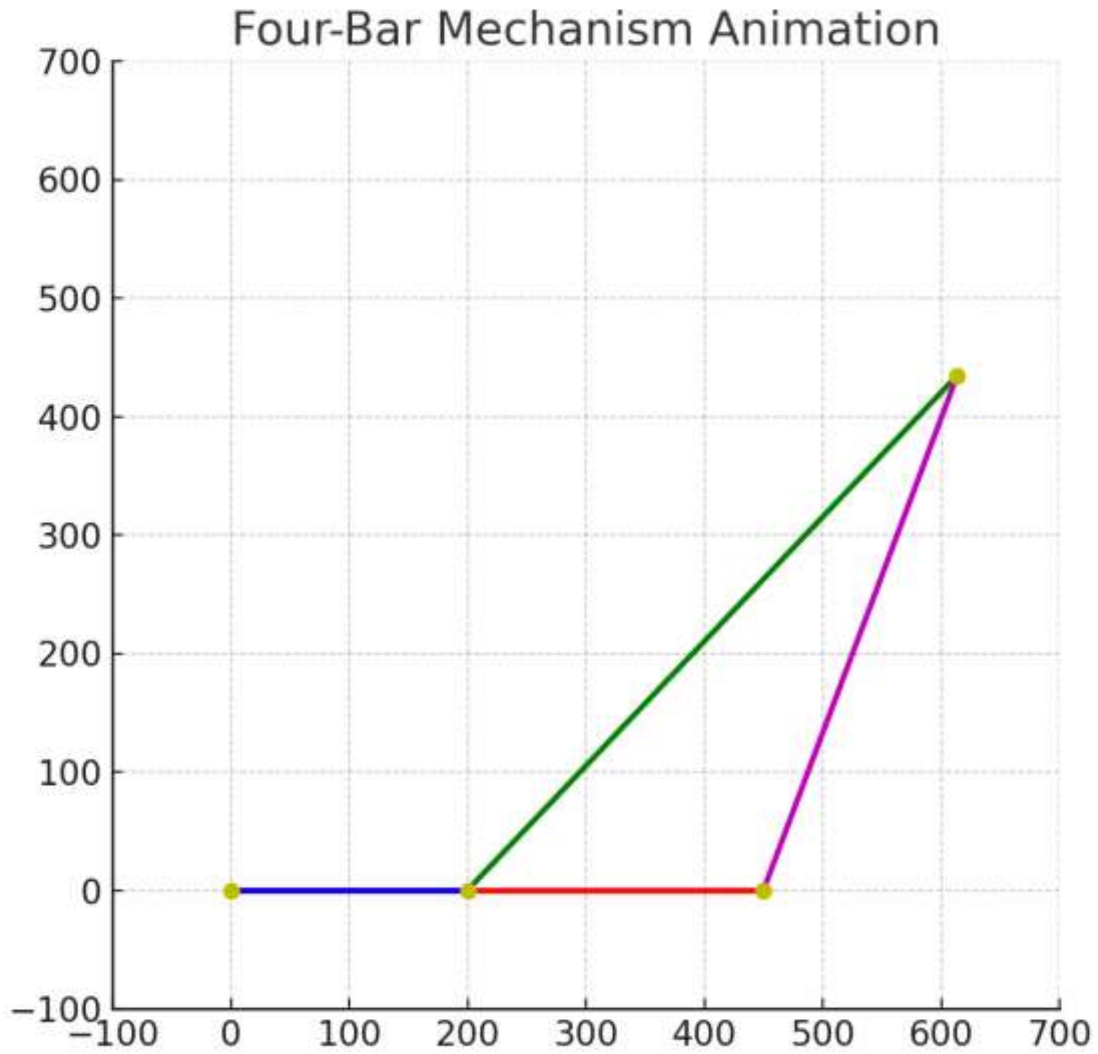
Area cleaned in one revolution of crank

Motion Analysis / Study



Motion Analysis / Study





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```
clc
clear all


% ##Position Analysis##
syms theta_3 theta_4

%input
l1 = 450;
l2 = 200;
l3 = 600;
l4 = 500;
theta_2 = 60;
theta_1 = 0;

%initial solution
angle_3=20;
angle_4=70;
iter=0;
sol = [angle_3;angle_4];

% using the Newton-Raphson method
      % Xn+1 = Xn - f(Xn)/f'(Xn) ; f'(Xn)*(delX)= - f(Xn)

%while loop
while iter <1000
         f = [(-l1*cosd(theta_1) +l2*cosd(theta_2) +l3*cosd(sol(1)) -l4*cosd(sol(2)));
    (-l1*sind(theta_1) +l2*sind(theta_2) +l3*sind(sol(1)) -l4*sind(sol(2)))];
df = [-l3*sind(sol(1)), l4*sind(sol(2));
    l3*cosd(sol(1)), -l4*cosd(sol(2))];
sol = sol - (df\f);
iter = iter + 1;
```

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```


end

%solution
theta_3=sol(1);
theta_4 = sol(2);


%plotting the four bar mechanism

%calculating coordinates of points
A_star_x = 0;
A_star_y = 0;
B_star_x = l1*cosd(theta_1);
B_star_y = l1*sind(theta_1);
A_x = l2*cosd(theta_2);
A_y = l2*sind(theta_2);
B_x = A_x + l3*cosd(theta_3);
B_y = A_y + l3*sind(theta_3);

%plot links
plot([A_star_x,B_star_x],[A_star_y,B_star_y], 'r-','Linewidth' ,2); %lin1 (ground)
hold on;
plot([A_star_x,A_x],[A_star_y,A_y], 'b-','Linewidth' ,2);
plot([A_x,B_x],[A_y,B_y], 'g-','Linewidth' ,2);
```

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```
% Set axis properties
axis equal;
grid on;
xlabel('X');
ylabel('Y');
title('Four-Bar Mechanism');
legend('Link 1 (Ground)', 'Link 2', 'Link 3', 'Link 4', 'Joints');

% Display results
fprintf('Converged in %d iterations\n', iter);
fprintf('theta_3 = %.2f degrees\n', theta_3);
fprintf('theta_4 = %.2f degrees\n', theta_4);


% ##velocity analysis##
w2= 10; % in rad/s

% position vector
r1 =[l1*cosd(theta_1) l1*sind(theta_1)]./1000;
r2 =[l2*cosd(theta_2) l2*sind(theta_2) 0]./1000;
r3 =[l3*cosd(theta_3) l3*sind(theta_3) 0]./1000;
r4=[l4*cosd(theta_4) l4*sind(theta_4) 0]./1000;

k=[0 0 1];

v_A = w2*cross(k,r2);
```

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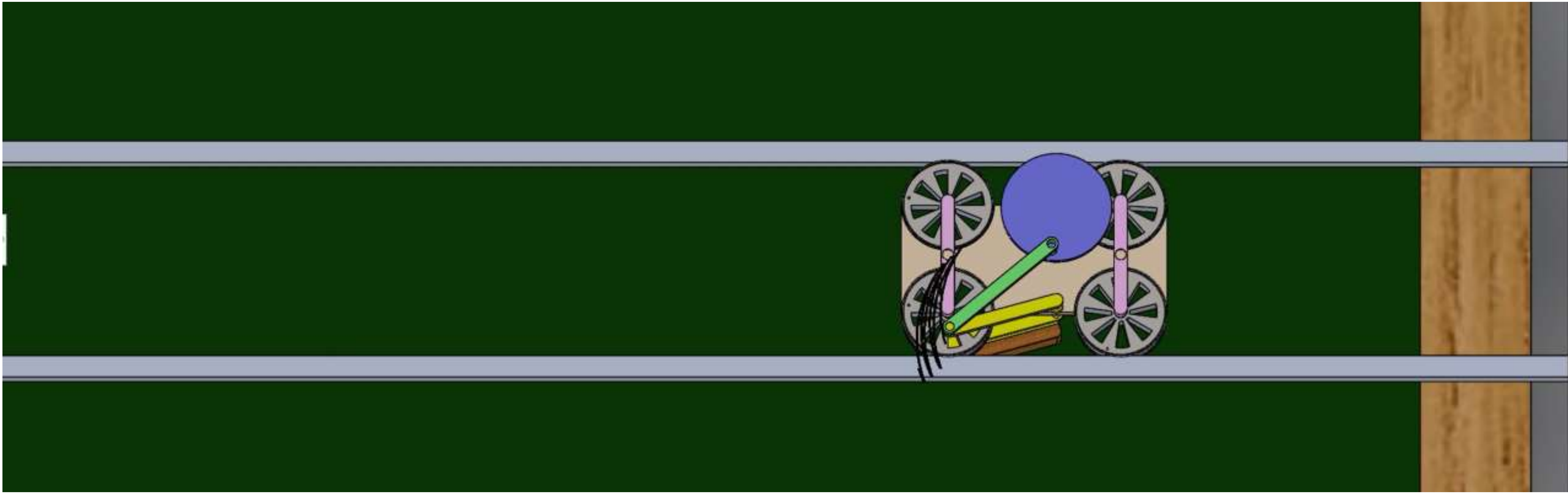
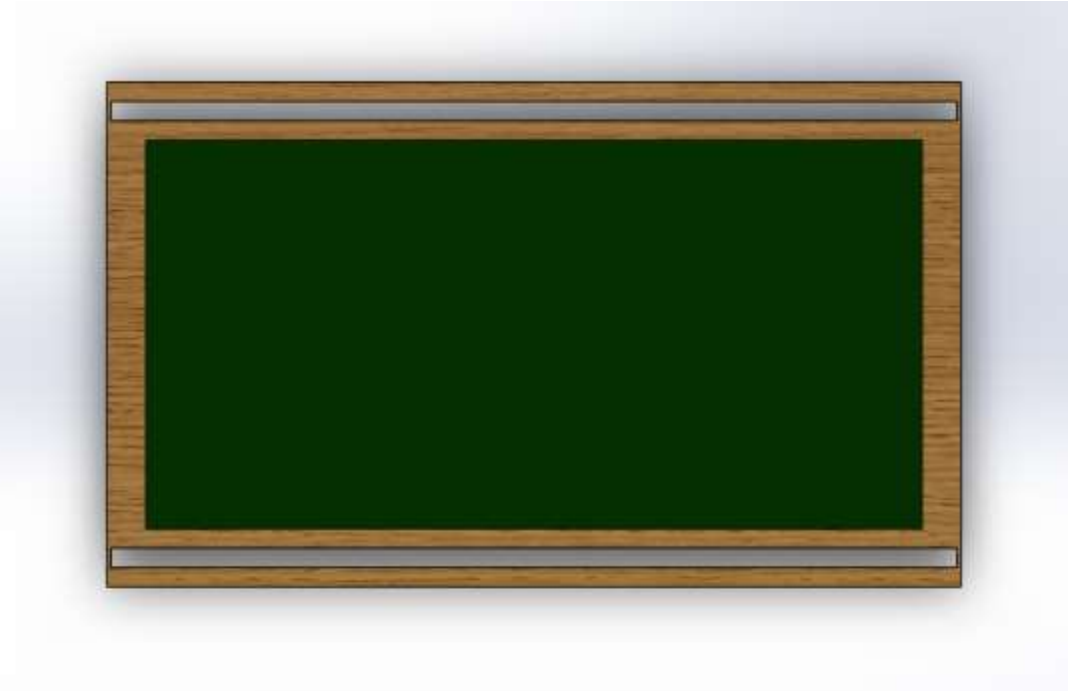
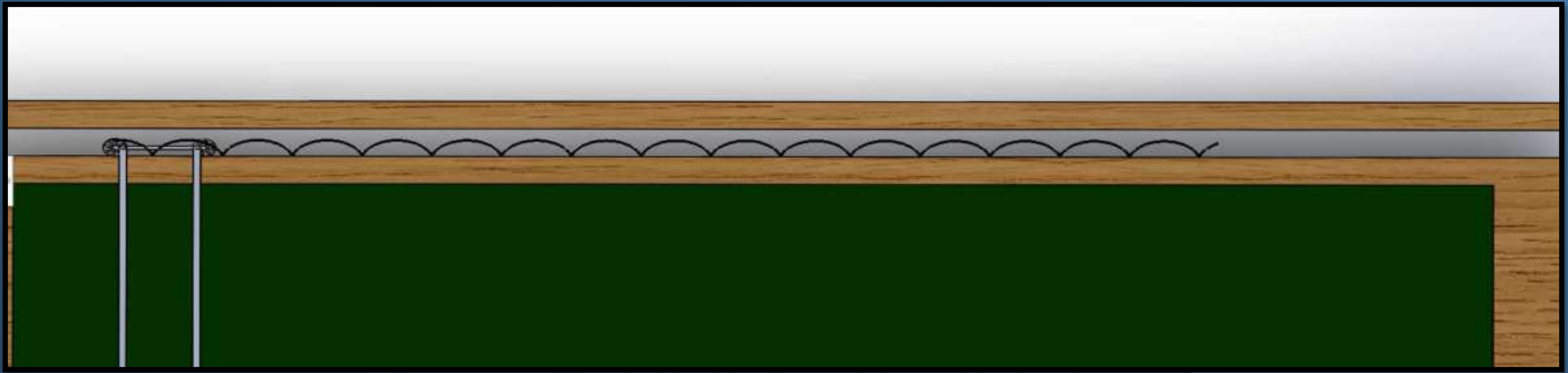
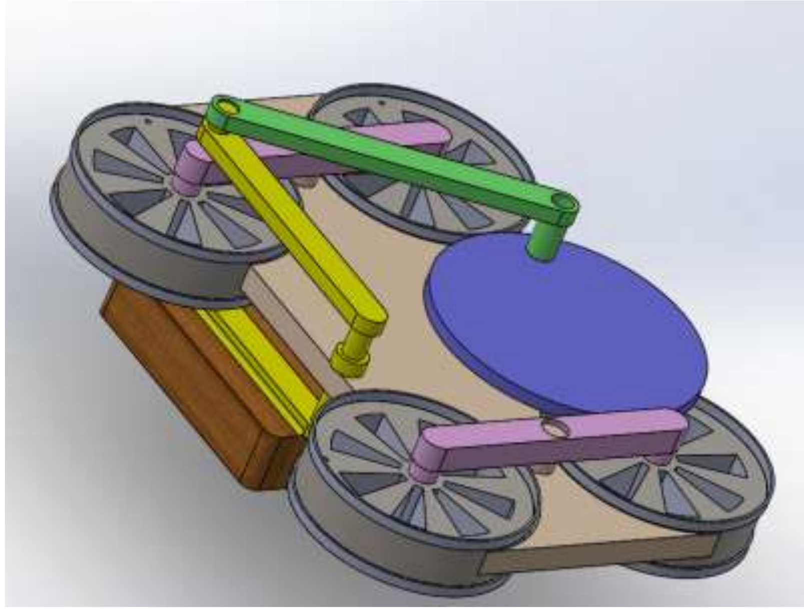
```
eqn_vel = v_B1 - v_B2 ==0;
s = solve(eqn_vel,[w3,w4]);

w3 = double(s.w3);
w4 = double(s.w4);

v_B = double(subs(v_B2,w4));
vel_mag_B = norm(v_B,2);


% ## Acceleration analysis##
alpha_2 = 0; % in rad/s^2

a_A = (alpha_2*cross(k,r2)) - ((w2)^2)*r2;
acc_mag_A = double(norm(a_A,2)); % magnitude of acceleration of B

syms alpha_3 alpha_4

a_B1 = a_A + (alpha_3*cross(k,r3)) - ((w3)^2)*r3;
a_B2 = (alpha_4*cross(k,r4));

eqn_acc = a_B1 - a_B2 == 0;
R = solve(eqn_acc,[alpha_3,alpha_4]);

alpha_3 = double(R.alpha_3);
alpha_4 = double(R.alpha_4);

a_B = double(subs(a_B2,alpha_4));
acc_mag_B = double(norm(a_B,2));
```



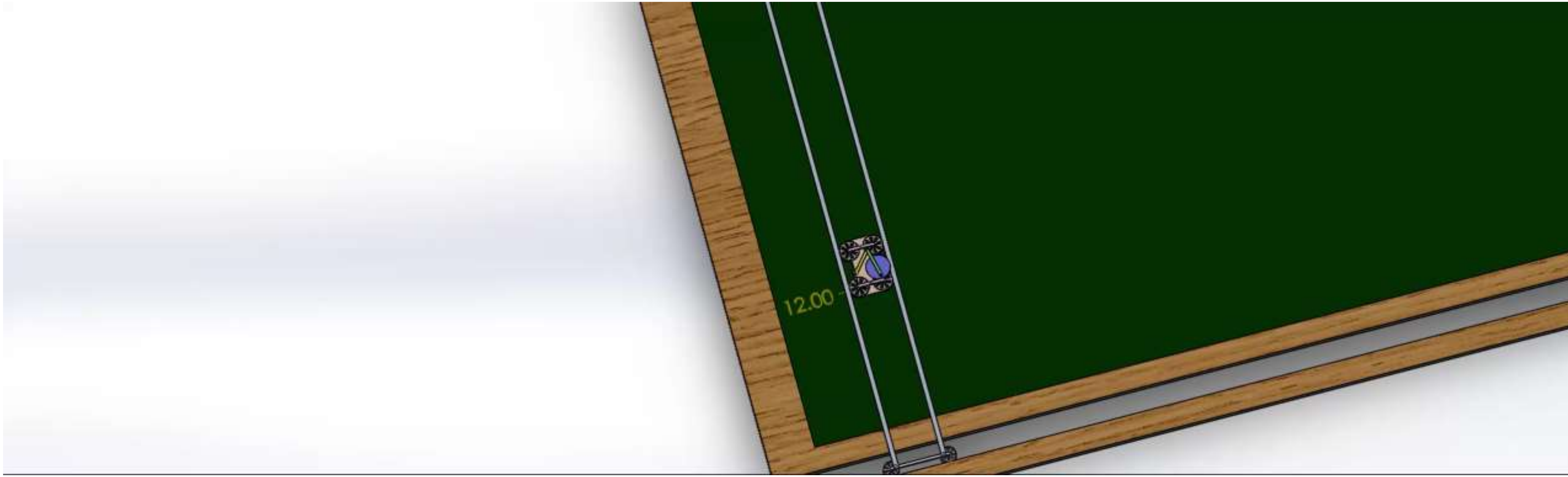


Vertical rectangular frame will run on the board (animation in next slide).





Duster attached with four-bar mechanism is fixed to the Quad-wheel platform, that will run on the tracks between the vertical rectangular frame (animation on next slide.)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Conclusions

- Efficient, cost-effective solution to a common classroom problem.

- Reduces manual effort and exposure to chalk dust.

- Can be scaled to large boards or touch screens.

- <u>Future Scope:</u>

- [ ] Dust collection system.
- [ ] App or voice-based control.
- [ ] Solar-powered version for rural use.

Thank You

"I sincerely thank you for your guidance, support, and encouragement throughout my work. Your leadership and feedback have been invaluable, and I've learned a lot under your supervision."

Supervisor:- *Prof. Santosha Kumar Dwivedy*
(Department of Mechanical Engineering)