Collision detection and response in the assignment

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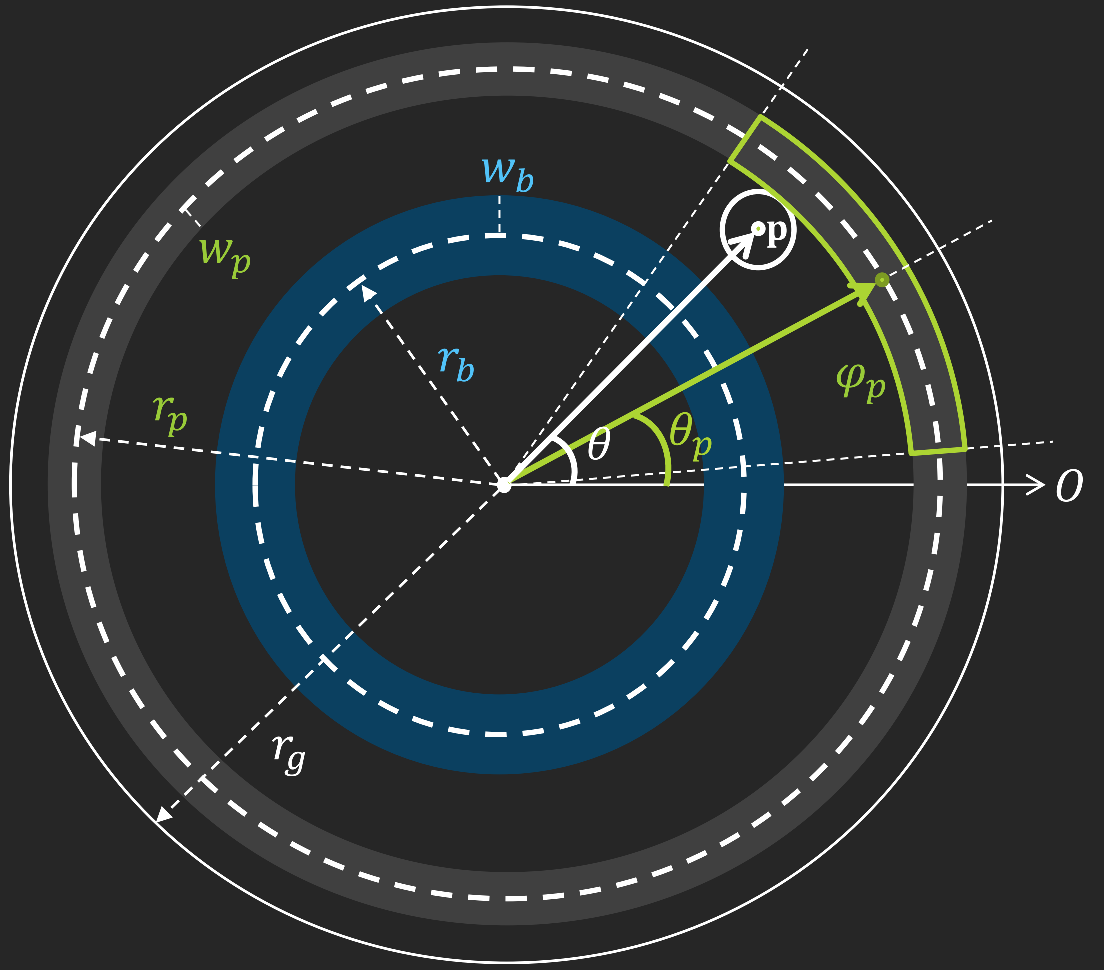
PA199

Collision detection: Broad phase

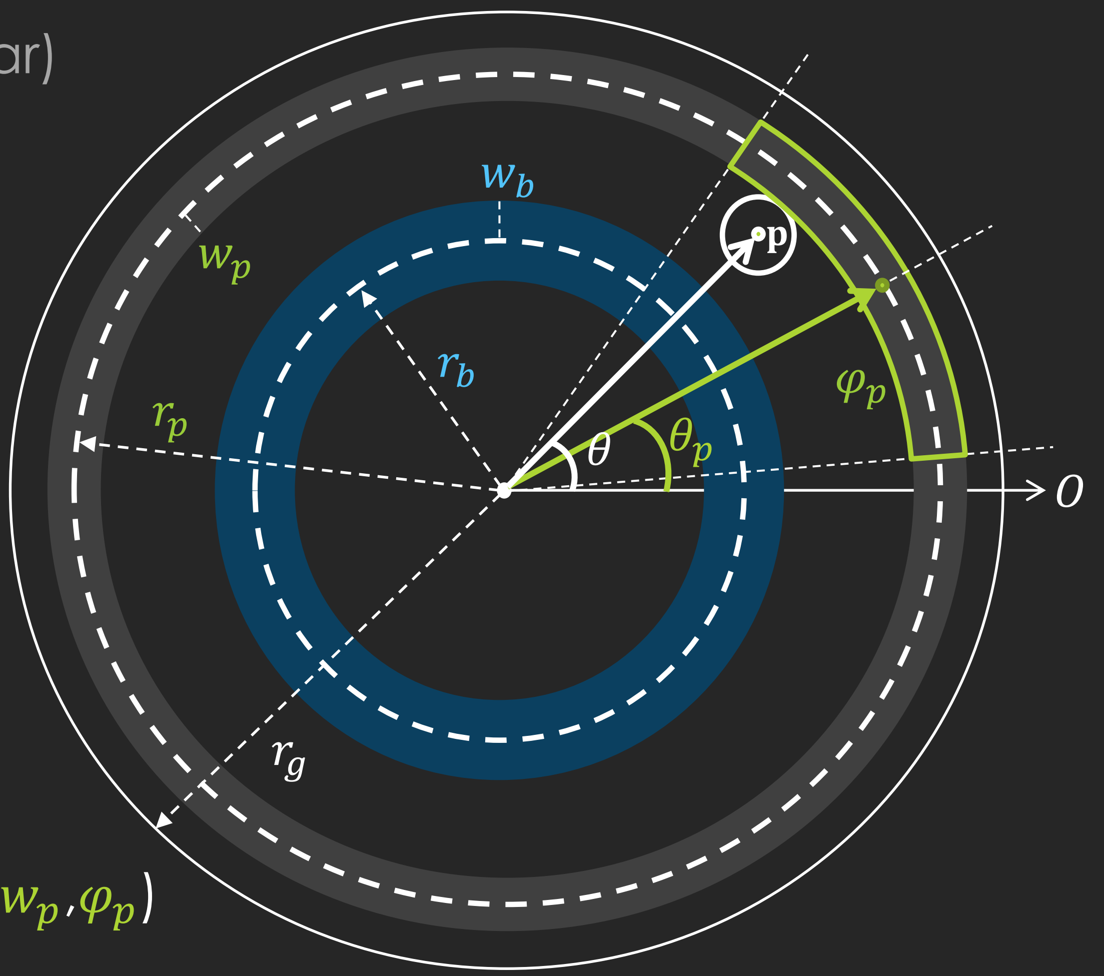
- Position of the ball: $\mathbf{p} = (\mathbf{p}_x, \mathbf{p}_y, r)^\mathsf{T}$, where r is the radius of the sphere.

- If $|\mathbf{p}| - r > r_g$ then GAME OVER.
- If $|\mathbf{p}| + r \geq r_p - w_p \wedge |\mathbf{p}| - r \leq r_p + w_p$ then "broad phase with paddles".
- If $|\mathbf{p}| + r \geq r_b - w_b \wedge |\mathbf{p}| - r \leq r_b + w_b$ then "broad phase with bricks".
- Otherwise, no collision.



Collision detection: Broad phase

```
# Colliding with Paddles (brick wall case is similar)
def broad_phase(positions,w_p,φ_p):
    r_p, θ_p = positions[0]
    for r'_p, θ'_p in positions[1:]:
        if min_difference(θ, θ'_p)
                < min_ difference(θ, θ_p):
            r_p, θ_p = r'_p, θ'_p
    if min_difference(θ, θ_p) ≤ φ_p:
        return narrow_phase_case_1(p, r_p)
    else
        return narrow_phase_case_2(p,r,θ,r_p,θ_p,w_p,φ_p)
```



Collision detection: Narrow phase

- Case 1: "min_difference$(\theta, \theta_p) \leq \varphi_p$".

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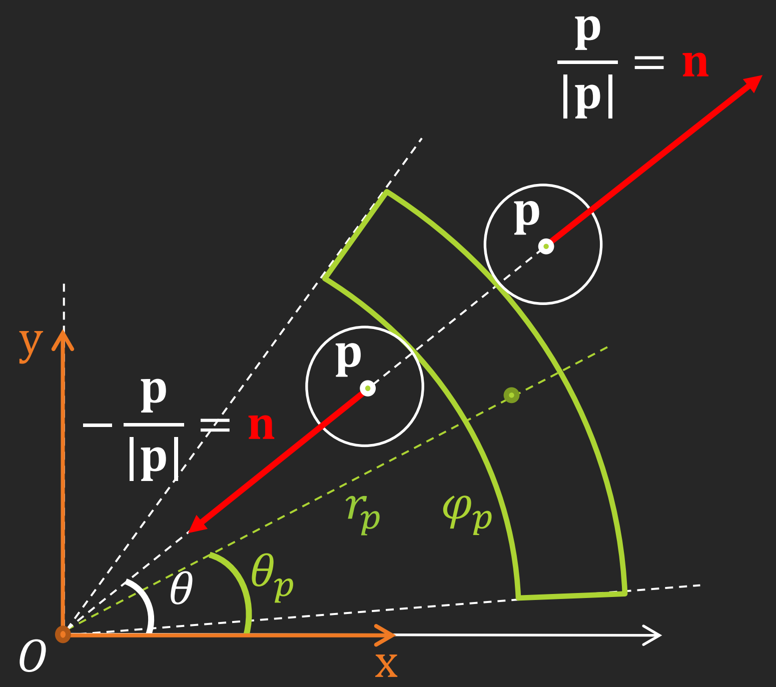
def narrow_phase_case_1(p, r_p):
    n = p / |p|
    return -n if |p| < r_p else n
```



Collision detection: Narrow phase

- Case 2: “min_difference$(\theta, \theta_p) > \varphi_p$”.

  def narrow_phase_case_2($\mathbf{p}$,r,θ,r_p,θ_p,w_p,φ_p):

  sign = 1 if on_left(θ, $\theta_p + \varphi_p$) else -1

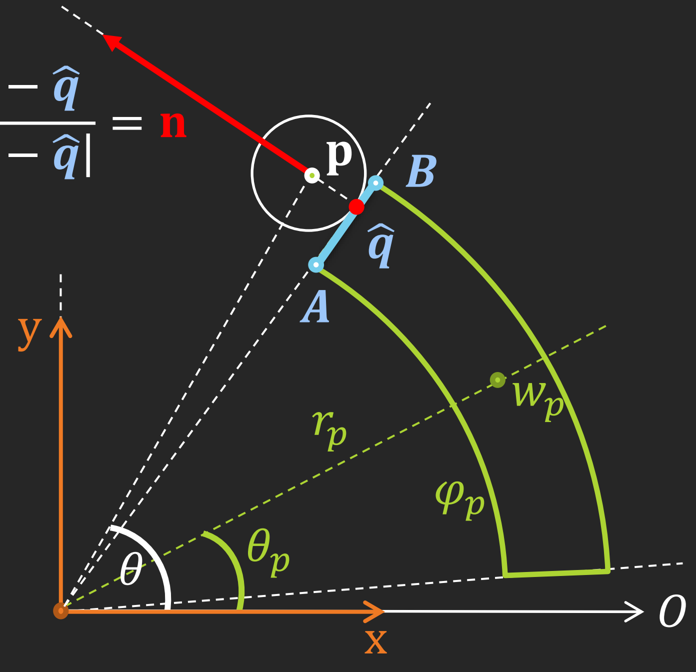
  A = to_cartesian(r_p-w_p, θ_p + sign*φ_p)

  B = to_cartesian(r_p+w_p, θ_p + sign*φ_p)

  $\hat{q}$ = closest_point_on_line(AB, $\mathbf{p}$)

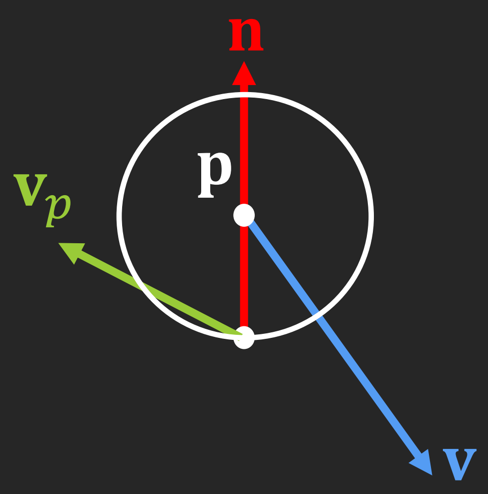
  return ($\mathbf{p} - \hat{q}$) / $|\mathbf{p} - \hat{q}|$ if $|\mathbf{p} - \hat{q}| \in \langle 0, r\rangle$ else None

$$\frac{\mathbf{p} - \hat{q}}{|\mathbf{p} - \hat{q}|} = \mathbf{n}$$

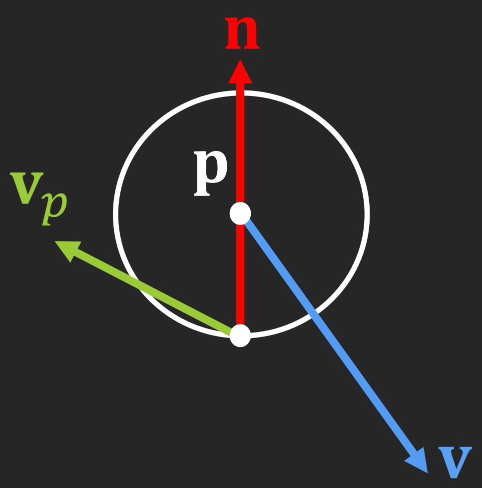


Collision response

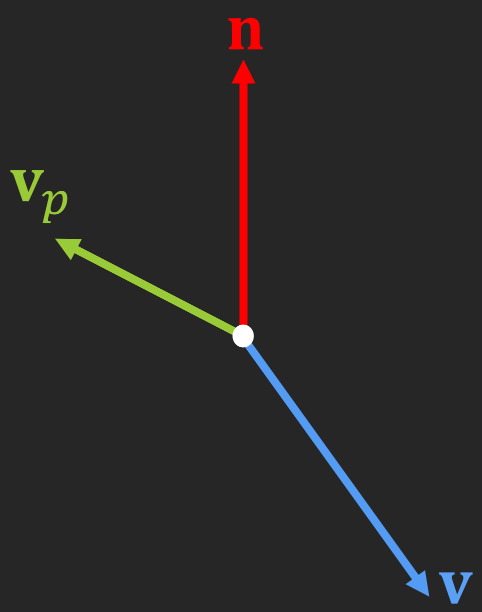
- Ball's velocity: $\mathbf{v} = (v_x, 0, v_z)^\top$, $|\mathbf{v}| = v_0$, where v_0 is the fixed speed.
- We have the **unit collision normal** $\mathbf{n} = (n_x, n_y, 0), |\mathbf{n}| = 1$ from the collision detection.
- Velocity of a paddle is $\mathbf{v}_p$.



Collision response

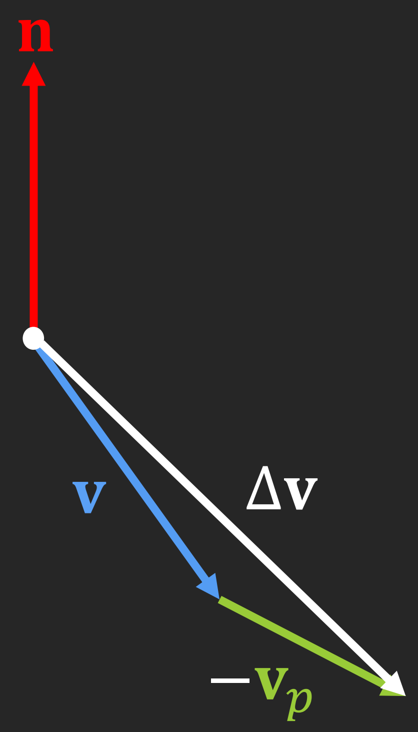


We can model the situation as



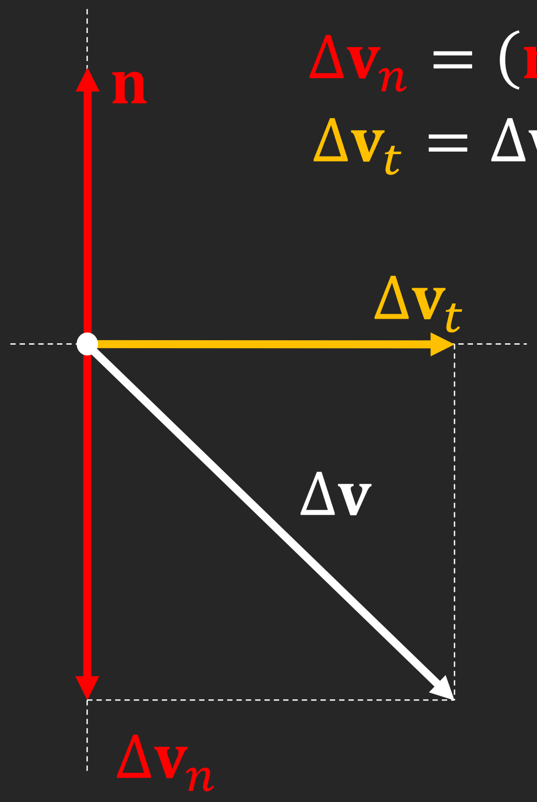
Compute the relative velocity

Collision response



Decompose $\Delta\mathbf{v}$

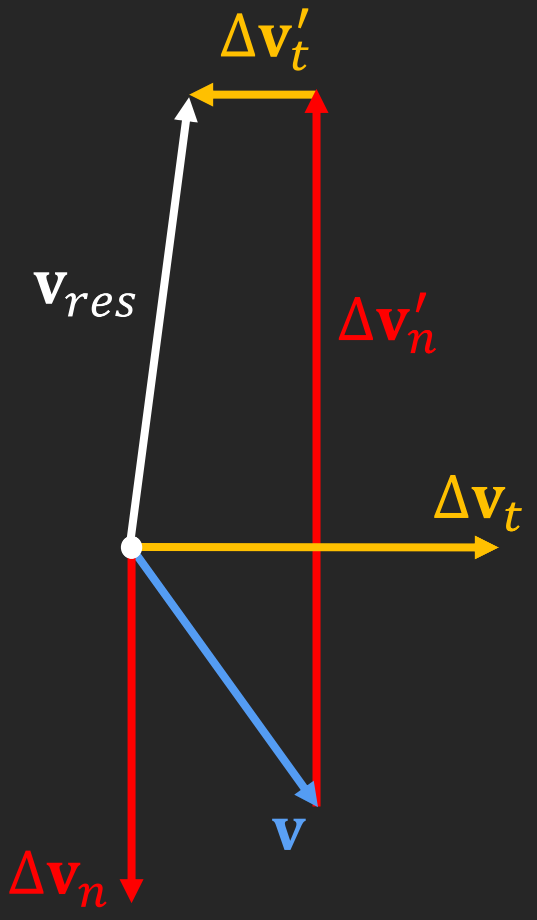
IMPORTANT
Continue only if
$\Delta\mathbf{v} \cdot \mathbf{n} < 0$



$$\Delta\mathbf{v}_n = (\mathbf{n} \cdot \Delta\mathbf{v})\mathbf{n}$$
$$\Delta\mathbf{v}_t = \Delta\mathbf{v} - \Delta\mathbf{v}_n$$

Collision response

- "Bounce of the paddle" velocity change:
$$\Delta\mathbf{v}_n' = -2\Delta\mathbf{v}_n$$
- "Match paddle's velocity" velocity change:
$$\Delta\mathbf{v}_t' = -\mu_p \min\{|\Delta\mathbf{v}_n|, |\Delta\mathbf{v}_t|\}\frac{\Delta\mathbf{v}_t}{|\Delta\mathbf{v}_t|}, \quad \text{if } |\Delta\mathbf{v}_t| > 0,$$
where $0 \le \mu_p \le 1$ is a "friction" coefficient.
- So, the collision response velocity is:
$$\mathbf{v}_{res} = \mathbf{v} + \Delta\mathbf{v}_n' + \Delta\mathbf{v}_t'$$
- The final velocity is then:
$$\mathbf{v} := v_0 \frac{\mathbf{v}_{res}}{|\mathbf{v}_{res}|}, \quad \text{NOTE: } |\mathbf{v}_{res}| > 0.$$



Implementation notes

- Polar coordinates:
  - Always normalize the angles to the range $\langle 0, 2\pi)$ before comparison.
  - Consider using normalization directly in:
    - Conversion from the Cartesian to polar coordinates.
    - Operators for addition and subtraction of angles.
      - Alternatively, in comparison operators.
  - Otherwise, assert angles are normalized before comparisons.
  - When implementing angle comparison algorithm, keep in mind the case of passing the polar axis (in CW or CCW direction).

Implementation notes

- Recommendations:
  - Build **tests** and **test scenes** for collision detection and response algorithms.
    => Do **not** build the complete scene of the game (all paddles all wall bricks).
    => Test function "closest_point_on_line" is different situations (configurations of line's points and the reference point).
    => Test all phases of the collision detection in separate test scenes.
    => Test collison response in separate test scenes (for different velocities of the ball and the paddle).