Homework Set: HW4
Momentum, Impulse, and 2D Collisions

Problem 1: Perfectly Inelastic 2D Collision + Impulse + Post-Collision Motion

Two low-friction carts collide on a horizontal air table and stick together (perfectly inelastic collision). Take +x to be east and +y to be north. External horizontal forces during the collision are negligible.

Cart A has mass $m_A = 0.45\,\text{kg}$ and moves at speed $6.2\,\text{m/s}$ at an angle of 25° *north of east* just before impact.

Cart B has mass $m_B = 0.70\,\text{kg}$ and moves at speed $4.5\,\text{m/s}$ at an angle of 40° *south of east* just before impact.

After they stick, the combined carts slide off the air table onto a rough surface and come to rest after traveling a distance of $3.5\,\text{m}$. Assume the rough surface provides a kinetic friction force with coefficient μ_k (unknown). Use $g = 9.81\,\text{m/s}^2$.

(a) **Vector momentum setup.** Write the initial velocity vectors $\vec{v}_A$ and $\vec{v}_B$ in component form (x- and y-components).

(b) **Post-collision velocity (2D).** Use conservation of momentum in x and y to find the combined velocity vector $\vec{v}_f$ immediately after the collision. Report:

(i) v_{fx} and v_{fy},

(ii) the speed v_f,

(iii) the direction as an angle measured from +x (east), with correct quadrant.

(c) **Kinetic energy change.** Calculate the total kinetic energy before the collision and just after the collision, then determine:

(i) the kinetic energy lost in the collision, $\Delta K = K_i - K_f$,

(ii) the fraction of kinetic energy lost, $\Delta K/K_i$.

(d) **Impulse and average collision force.** The sticking collision lasts $\Delta t = 0.035\,\text{s}$.

(i) Find the impulse vector on cart A, $\vec{J}_A$. Note $J = \Delta p = F\Delta t$.

(ii) Find the impulse vector on cart B, $\vec{J}_B$.

(iii) Hence find the average force on each cart during the collision, $\vec{F}_{\text{avg}} = \vec{J}/\Delta t$ (give components).

(e) **Friction estimate from stopping distance.** After the collision, the combined carts (mass $m_A + m_B$) enter the rough surface with initial speed v_f (from part b) and stop after 3.5 m. Assuming kinetic friction is the only horizontal force on the rough surface, determine μ_k.

(f) **Direction reasoning (short explanation).** In 1–2 sentences, explain why the final direction in part (b) must lie between the initial directions of A and B.