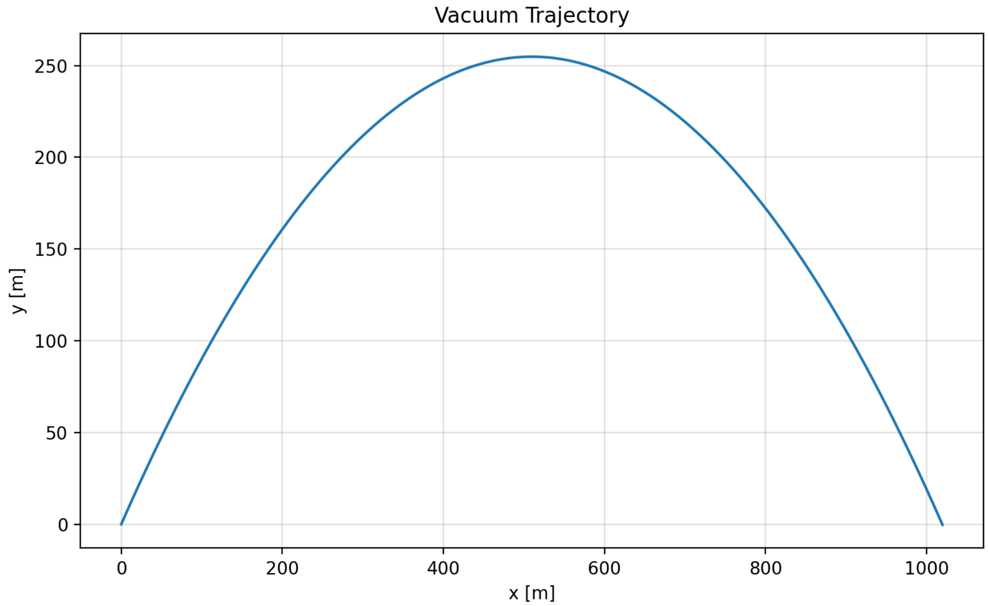
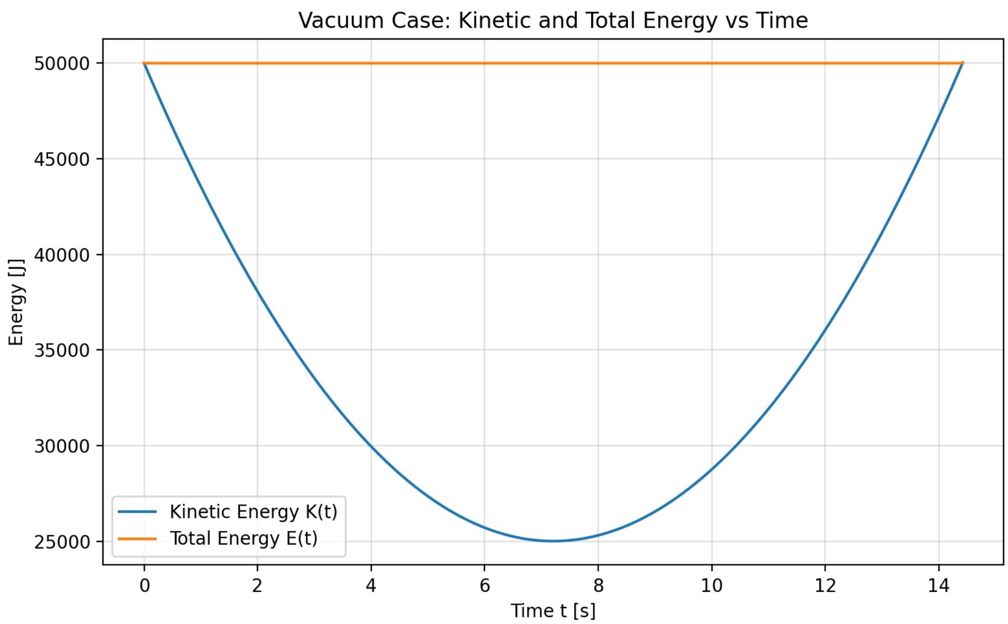
Vacuum Case

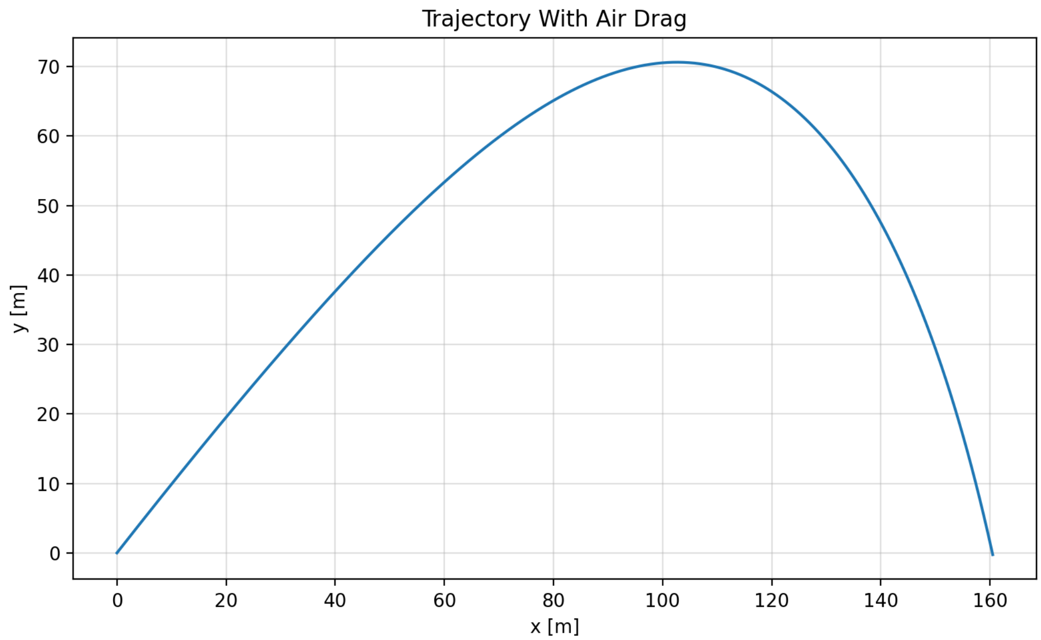
Vacuum Case — Energy Conservation
In the absence of air resistance (k = 0), total mechanical energy must remain constant.
The simulation confirms this: E(t) stays flat to numerical precision.
RK4 step size affects the drift: smaller steps improve conservation.

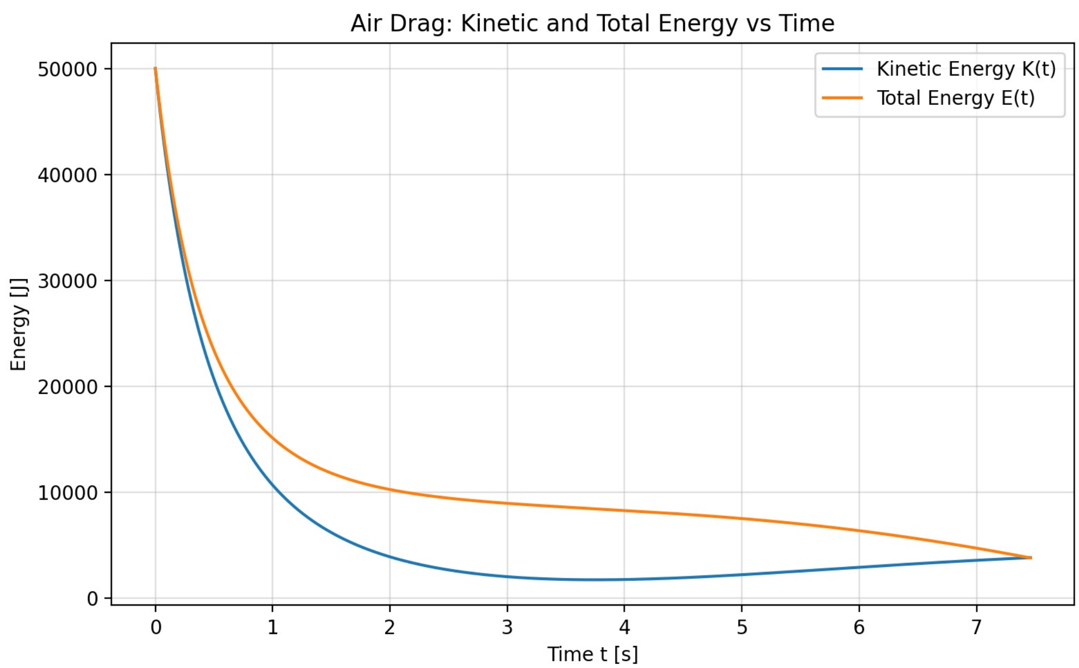




Drag Case

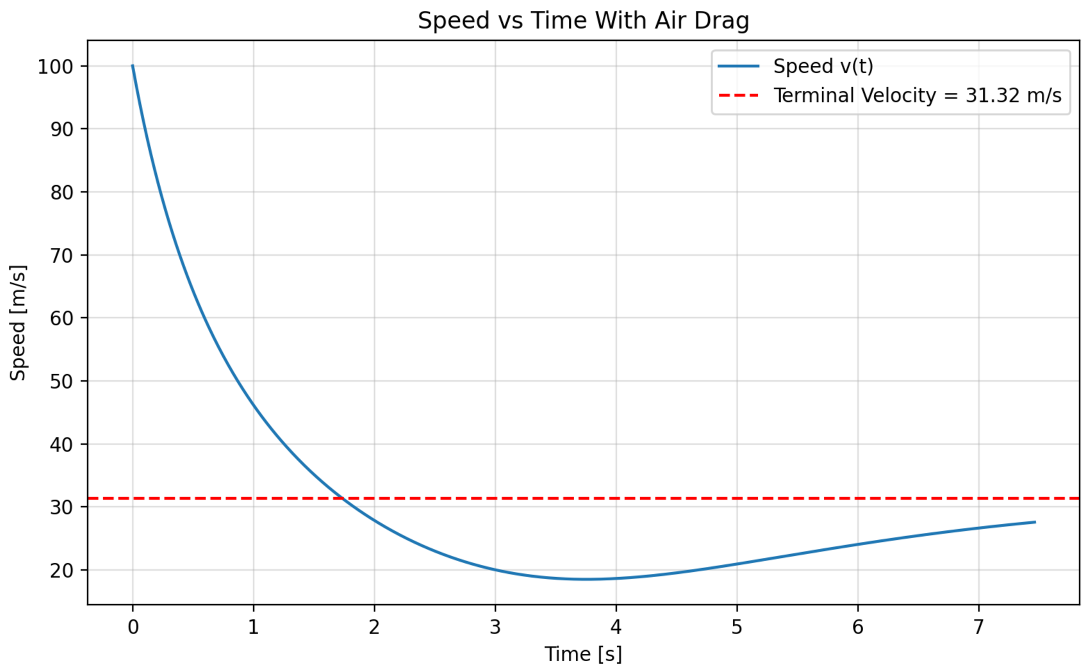
Projectile With Air Drag
Quadratic drag $F_d = -k v^2 \hat{v}$ reduces range and height and dissipates mechanical energy.
Total energy decays monotonically as work is done against drag.





Terminal Velocity

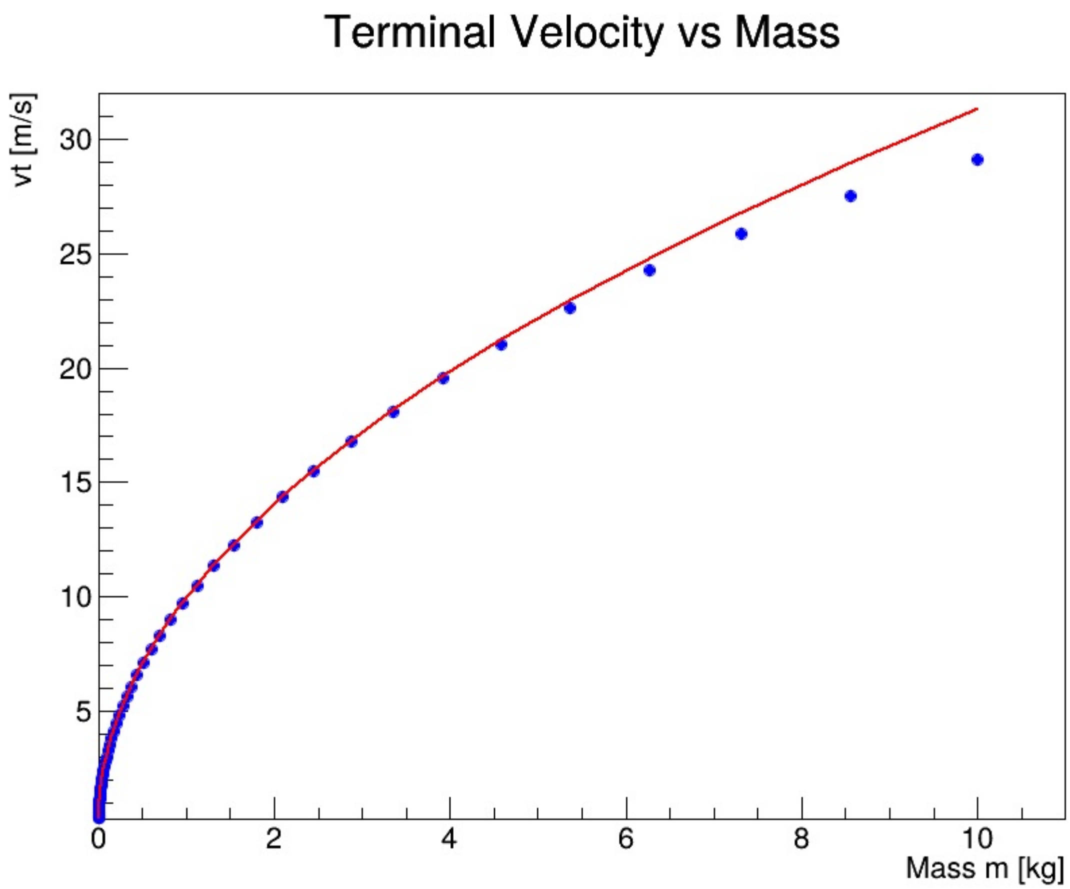
Terminal Velocity
Analytically, vt = sqrt(mg/k). For m = 10 kg and k = 0.1, vt ≈ 31.3 m/s.
The simulation speed curve approaches this value before ground impact.



vt vs Mass

Terminal Velocity vs Mass

A mass scan from 1 g to 10 kg was performed. Simulated vt matches the analytic √m scaling. At high masses, deviations occur because the projectile hits the ground before reaching steady-state vertical descent, preventing true terminal velocity from forming.



Accuracy Checks

- Vacuum limit reproduced exactly.
- Step-size refinement gives stable convergence.
- vt values match analytic predictions.
- Physical behavior consistent with drag physics.

Thus the numerical solution is accurate for the purposes of this assignment.