of θ_0 radians. The only forces acting on the projectile are gravity and the aerodynamic drag, D, which depends on the projectile's speed relative to any wind that might be present. The equations describing the motion of the projectile are

$$\dot{x} = v \cos\theta, \quad \dot{y} = v \sin\theta$$

$$\dot{\theta} = -\frac{g}{v} \cos\theta, \quad \dot{v} = -\frac{D}{m} - g \sin\theta$$

Constants for this problem are the acceleration of gravity, $g = 9.81\text{m/s}^2$, the mass, $m = 15$ kg, and the initial speed, $v_0 = 50$ m/s. The wind is assumed to be horizontal and its speed is a specified function of time, $w(t)$. The aerodynamic drag is proportional to the square of the projectile's velocity relative to the wind.

$$D(t) = \frac{c\rho s}{2} \left((\dot{x} - w(t))^2 + \dot{y}^2\right)$$

where $c = 0.2$ is the drag coefficient, $\rho = 1.29$ kg/m^3 is the density of air, and $s = 0.25\text{m}^2$ is the projectile's cross-sectional area.
Consider four different wind conditions.

- No wind. $w(t) = 0$ for all t.
- Steady head wind. $w(t) = -10$ m/s for all t.
- Intermittent tail wind. $w(t) = 10$ m/s if the integer part of t is even, and zero otherwise.
- Gusty wind. $w(t)$ is a Gaussian random variable with mean zero and standard deviation 10 m/s.

The integer part of a real number t is denoted by $\lfloor t \rfloor$ and is computed in MATLAB by `floor(t)`. A Gaussian random variable with mean 0 and standard σ is generated by `sigma*randn` (see the chapter on random numbers).
For each of these four wind conditions, carry out the following computations. Find the 17 trajectories whose initial angles are multiples of 5 degrees, that is, $\theta_0 = k\pi/36$ radians, $k = 1, 2, \ldots, 17$. Plot all 17 trajectories on one figure. Determine which of these trajectories has the greatest downrange distance. For that trajectory, report the initial angle in degrees, the flight time, the downrange distance, the impact velocity, and the number of steps required by the ODE solver.
Which of the four wind conditions requires the most computation? Why?

7.16. In the 1968 Olympic games in Mexico City, Bob Beamon established a world record with a long jump of 8.90 meters. This was 0.80 meters longer than the previous world record. Since 1968, Beamon's jump has been exceeded only once in competition, by Mike Powell's jump of 8.95 meters in Tokyo in 1991. After Beamon's remarkable jump, some people suggested that the lower air resistance at Mexico City's 7400 ft. altitude was a contributing factor. This problem examines that possibility.

The mathematical model is the same as the cannonball trajectory in the previous exercise. The fixed Cartesian coordinate system has a horizontal x-axis, a vertical y-axis, and an origin at the takeoff board. The jumper's initial velocity has magnitude v_0 and makes an angle with respect to the x-axis of θ_0 radians. The only forces acting after takeoff are gravity and the aerodynamic drag, D, which is proportional to the square of the magnitude of the velocity. There is no wind. The equations describing the jumper's motion are

$$\dot{x} = v\cos\theta, \quad \dot{y} = v\sin\theta$$

$$\dot{\theta} = -\frac{g}{v}\cos\theta, \quad \dot{v} = -\frac{D}{m} - g\sin\theta$$

The drag is

$$D = \frac{c\rho s}{2}\left(\dot{x}^2 + \dot{y}^2\right)$$

Constants for this exercise are the acceleration of gravity, $g = 9.81$ m/s^2, the mass, $m = 80$ kg, the drag coefficient, $c = 0.72$, the jumper's cross-sectional area, $s = 0.50$ m^2, and the take-off angle, $\theta_0 = 22.5^o = \pi/8$ radians.
Compute four different jumps, with different values for initial velocity, v_0, and air density, ρ. The length of each jump is $x(t_f)$ where the air time, t_f, is determined by the condition $y(t_f) = 0$.
(a) "Nominal" jump at high altitude. $v_0 = 10$ m/s, and $\rho = 0.94$ kg/m^3.
(b) "Nominal" jump at sea level. $v_0 = 10$ m/s, and $\rho = 1.29$ kg/m^3.
(c) Sprinter's approach at high altitude. $\rho = 0.94$ kg/m^3. Determine v_0 so that the length of the jump is Beamon's record, 8.90 m.
(d) Sprinter's approach at sea level. $\rho = 1.29$ kg/m^3, and v_0 is the value determined in (c).
Present your results by completing the following table.

v0	theta0	rho	distance
10.0000	22.5000	0.9400	???
10.0000	22.5000	1.2900	???
???	22.5000	0.9400	8.9000
???	22.5000	1.2900	???

Which is the more important, the air density or the jumper's initial velocity?

7.17. A pendulum is a stiff bar of length L supported at one end by a frictionless pin. If gravity is the only force acting on the pendulum, its oscillation is described by the ODE

$$\ddot{\theta} = -(g/L)\sin\theta$$

Here θ is the angular position of the bar, with $\theta = 0$ if the bar is hanging down from the pin and $\theta = \pi$ if the bar is precariously balanced above the pin. Take $L = 12$ inches and $g = 396.09$ inches/s^2. If the pendulum is released