Answers

Part 1: System Design

Q1. Max exposure time for < 2 px blur at 100 MPH

   - Ball Velocity v = 100 MPH = 44.704 m/s

   - Standard baseball diameter D = 9 in / pi = 2.86 in = 0.0726 m

   - Assuming conditions from Q2, ball occupies > 200 px:

 Spatial Resolution (R) = 200 px / 0.0726 m = 2754.8 px/m

 Image Velocity (v_px) = v * R = 44.704 * 2754.8 = 123,151 px/s

We want max blur = 2 pixels. Thus:

$$t_{exp} < = 2/v_{px} = 2/123151 = 1.624 x 10^{-5} s$$

$$t_{exp} < = 16.24 \mu s \text{ (or about 1/61,500 shutter speed)}$$

Q2. Sensor resolution & focal length (5m away, 200px diameter)

   - Distance Z = 5 m ; Diameter D = 0.0726 m ; Image d = 200 px

   - Using pinhole camera relation: d / f_px = D / Z

Assignment Answers (Cont.)

Q3. Hough Circle Transform vs YOLO (Deep Learning)

  - Hough Circle is deterministic, runs fast on CPUs, and is geometry-based.

 * Pro: Computationally cheap, real-time edge device friendly.

 * Con: Fails easily on motion blur, shadows, or if ball shape distorts.

  - YOLO/Seg is purely data-driven, learning semantic representations.

 * Pro: Highly robust to blur, varied lighting, and background noise.

 * Con: Requires GPU/NPU for real-time (< 5ms) processing, and

      requires gathering/labeling thousands of baseball frames.

Q4. Visual challenge of 'Bullet Spin' (Axis parallel to Camera)

  - Challenge: The 3D seam pattern doesn't 'rotate around' the visible

 hemisphere of the ball. It only rotates 2D in the image plane.

  - Because depth cues (seams vanishing/appearing over the horizon)

 are absent, estimating the true 3D spatial phase is ill-posed.

  - Logic Change: Instead of mapping seam translation across a 3D sphere,