PHYS 121 — HW1 (Redesigned by ChatGPT 5.0)

Learning-by-doing version with sketches, checks, and clear scaffolding.

Student Name: ___________________________. NetID: ________________.

Submission & Format (read me first)

• Show your reasoning. Every part must include a labeled sketch/diagram when asked.
• Box final answers with units and significant figures.
• If you use any AI tools, append a 1–3 sentence "Assistance note" describing exactly what it did for you at the end of your submission.
• Upload to Gradescope as a single PDF; scan your hand sketches clearly.

Tip: For force/friction problems, build a clean free-body diagram before any algebra.

Q1. Units & Measurement (8 pts)

A paint's coverage is 435 ft^2/gal. ($feet^2$/gallon, 1 gal = 3.785 L)

1) Sketch a tiny "unit-tile" of paint: annotate area and film thickness.
2) Convert $ft^2 \rightarrow m^2$ and gal → L with a factor-label chain.
3) Report in m^2/L, then convert to pure SI (m^{-1}).
4) Invert the quantity; interpret physically as required volume per area (L/m^2) and relate it to film thickness.
5) Sanity check: if you need ~0.1 L per m^2, what room size does 1 gallon cover?

Q2. Vectors (8 pts)

Here are three vectors in *meters*:

$$\vec{d}_1 = -3.0\hat{\imath} - 3.0\hat{\jmath} + 2.0\hat{k}$$
$$\vec{d}_2 = -2.0\hat{\imath} - 4.0\hat{\jmath} + 2.0\hat{k}$$
$$\vec{d}_3 = 2.0\hat{\imath} + 3.0\hat{\jmath} + 1.0\hat{k}$$

What results from (a) $\vec{d}_1 \cdot \left(\vec{d}_2 + \vec{d}_3\right)$, (b) $\vec{d}_1 \cdot \left(\vec{d}_2 \times \vec{d}_3\right)$, and (c) $\vec{d}_1 \times \left(\vec{d}_2 + \vec{d}_3\right)$? Reflection [not graded]: try to draw it out and check when do drawings catch algebra mistakes?

Q3. 1D Kinematics (10 pts)

$x(t) = 5.0\, t^2 - 4.0\, t^3$ (meters).

1) Differentiate to get v(t), a(t).
2) Sketches (required): qualitative x(t), v(t), a(t); mark key times.
3) Evaluate v(2.5 s), a(2.5 s).
4) Extremum: set v=0 → candidates; confirm max via a.
5) Compute x_{max} and the time when velocity is zero; annotate on your sketches.
6) Check: units and limiting behavior.

Q4. Projectile + Relative Motion in 3D (10 pts)

Baseball launched at 28 m/s, 55°. An outfielder is 85 m from the batter and 22° off the vertical plane of flight.

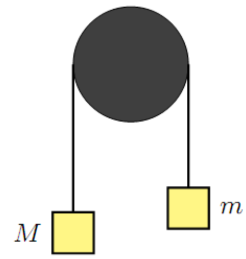
1) Two drawings (required): side view (projectile plane) and top view (show the 22° offset).
2) Choose axes; write $r_{ball}(t)$.
3) Time of flight to same height from y(t).
4) Fielder path: constant-speed straight line from initial position to ball at catch time; write $r_f(t)$.
5) Solve required speed and heading; report angle relative to his/fielder sightline to home plate.
6) Check: as 22°→0, do formulas reduce sensibly?

Q5. Relative Motion—Boat vs Current (9 pts)

Round trip total distance D; boat speed v in still water; current u. Compare (a) up & downstream vs (b) straight across & back. Assume $u < v$.

1) Diagrams (required): (a) river axis with upstream/downstream legs; (b) cross-current headings with velocity triangles.
2) Derive times needed for (a) and (b).
3) State clearly why $u<v$ is needed.
4) Check: as $u \to 0$, times must match.

Q6. Capstan-Style Friction over a Cylinder (8 pts)



String over top of a fixed cylinder ($R = 10$ cm). Masses $m = 10$ kg and M at the two ends; $\mu_s = 0.45$. Find max/min M so the string does not slip.

1) Two drawings (required): (i) FBDs of masses; (ii) infinitesimal string element on cylinder.
2) Use wrap angle $\theta = \pi$ rad (half-wrap) and justify.
3) Derive the capstan relation: $\int dT/T = \mu_s \int d\theta$.
4) Two impending-motion cases → bounds on M.
5) Check: as $\mu_s \to 0$, window collapses to $M \approx m$.

Q7. Newton's Laws on Ice (8 pts)

Drone, with m = 2.00 kg, goes from 3.00 ***i*** m/s to (9.00 ***i*** + 4.00 ***j***) m/s in 10.0 s due to a constant horizontal force.

1) Drawing (required): velocity triangle (initial, final, change).
2) Δv components → $F = m(\Delta v/\Delta t)$ → F_x, F_y.
3) Magnitude & direction; include small orientation sketch (angle from +x).

Bonus (0–2 pts): Timekeeping today

What’s the current definition of the second and any imminent redefinition plans? Cite an authoritative source, 2–5 sentences.

Assistance notes: