PHYS 121 — HW2 (Redesigned by ChatGPT 5.0)

Learning-by-doing version with scaffolds, required sketches, and reflective checks.

Student Name: ____________________________. NetID: _________________.

Q1. The Spider-Man Swing — Tension & Strength (8 pts)

Spiderman swings on a silk line attached to the top of a 25th-floor building. At the *bottom* of the arc he appears to move about *twice the traffic speed* at street level.

1) Sketch a free body diagram (FBD) for when his motion is at the bottom of the swing.
2) Choose your own variables and then derive a symbolic expression for the tension in the silk line.
3) Now substitute reasonable values into your expression and find the tension in the silk line.
4) The silk will break if the tension per cross sectional area exceeds the tensile strength (measured in N/m^2 or in Pascals). Knowing this, and looking up some numbers as necessary, what would be the minimum possible diameter for Spiderman's Silk Web?

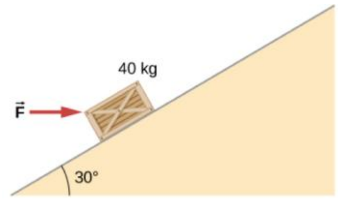
Q2. Terminal Speed of a Motorboat (12 pts)

A boat (mass 190 kg) starts from rest. Thrust is constant 40.0 N; water drag is *numerically equivalent* to 2v (N), where v is the speed of the boat.

1) Sketch v(t) qualitatively (label v_∞). Write the differential equation from Newton's 2nd law. 2) Solve the linear differential equation; report v(t) and v_∞. 3) Mark v=0.63 v_∞ at t=τ (the time constant) on your sketch. 4) Check: As $t\to\infty$ your $v(t) \to v_\infty$; as $t\to 0$, slope dv/dt equals what? Compare to F_{net}/m.

Q3. Work on a Box up an Incline (10 pts)

A 45-kg box is pushed up a 30° incline a distance 8.0 m at constant speed by a *horizontal* force F. $\mu_k = 0.35$.



1) Draw two views: (i) FBD with axes along or normal [which one is a better choice?] to the incline; (ii) geometry showing F's components, if applicable.
2) Force balance along the incline → solve for F.
3) Compute work by: (a) applied force; (b) friction; (c) gravity; (d) net. Explain the sign of each.
4) Check: network vs. ΔK; does constant speed demand $W_{net} = 0$?

Q4. Vertical Spring Gun (6 pts)

A massless spring ($k = 14$ N/cm) launches a 15-g ball straight up. The ball rises 5.0 m above the spring's uncompressed end. How much was the spring initially compressed?

1) Draw a sketch to illustrate the situation and label the quantities you need to use in your calculation.
2) Energy equation from compressed to top (including the extra rise by x while leaving the spring).
3) Solve the quadratic for x; choose the physical root; report x with units.

Q5. Kinetic Energy of a Massive Spring (10 pts)

A spring of mass M and equilibrium length L is fixed at the left end. The right end (x=L) moves at speed v along +x (horizontally); local speed varies *linearly* with position.

1) Draw a **rod model**: a slice of length dx at position x has dm = (M/L) dx [M/L is the linear mass density] and speed v(x). 2) Write dK and integrate from 0→L. 3) Report total K in terms of M and v; compare to (1/2) M v^2 and explain the difference.

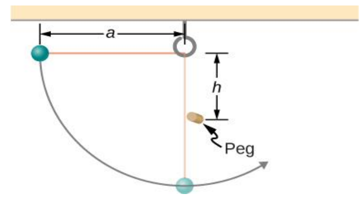
Q6. Power, Drag, and Fuel (10 pts)

At 15 m/s, the engine delivers 20 hp (horse power) to the wheels. Consider (i) speed-independent drag (constant force) and (ii) drag $\propto$ speed.

1) Case (i): Find the drag force at 15 m/s and the required power at 30 m/s. Energy for 10 km at 15 m/s? at 30 m/s? Assume 25% efficiency. 2) Case (ii): With $F_d = k\,v$ matched at 15 m/s, find power at 30 m/s and the energy for 10 km at both speeds. 3) Reflection: Compare trends to your driving experience, if any; what do they imply about real air resistance?

Q7. Peg and Complete Loop (10 pts)

A pendulum (string length a) is released from horizontal. A peg sits a distance h below the support. Show the ball will loop the peg only if $h > 3a/5$.



1) Use energy to find v at the bottom (just before the string catches).
2) Use energy conservation, if applicable, from bottom → top of the small circle and the non-slack condition at the top.
3) Conclude the inequality for h in terms of a and explain each step.

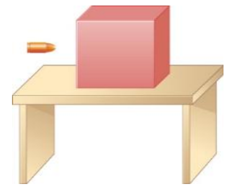
Q8. Bungee Jump Estimate (8 pts)

Peter (72 kg) falls 15 m before the bungee begins to stretch; the cord behaves like a spring with $k=50$ N/m. Neglect air; ignore cord mass. How far below the bridge is the lowest point?

1) Sketch forces during free fall vs. stretch. 2) Write an energy equation from the platform to the bottom (include the 15 m drop plus stretch x). 3) Solve for $x>0$ and report the total drop.

Q9. Bullet + Block (10 pts)

A 220-g bullet at 400 m/s (east) shots and embeds in a 1.30-kg block on a frictionless table.



1) Sketch momentum vectors of the bullet and the block before/after the impact.
2) Find the common speed immediately after the impact.
3) Compute the impulses on the bullet and on the block (magnitude & direction).
4) If the interaction lasts 3 ms, compute the average force magnitude.

Q10. Explore Vesta (10 pts)

Assume Vesta is a sphere of diameter 520 km and mass 2.67×10^{20} kg.

1) Compute escape speed from the surface. 2) Find the orbital period for a circular orbit 15 km above the surface. 3) Reflection: Why is a spherical model only marginally useful? What features of Vesta [check the image of Vesta] make real orbits tricky?

Bonus (0–2 pts): Terminal-speed experiment

Design a terminal-speed experiment: Propose a safe tabletop or outdoor method to estimate a terminal speed (boat, drone, falling object, etc.). Include sketches, data you'd collect, equations you'd fit, and sources of uncertainty. [3-5 bullet points, 1-2 sentences each]

Assistance notes: