- This exam is worth 100 points and has 5 problems.
- Show all work and simplify your answers! Answers with no justification will receive no points unless otherwise noted.
- Begin each problem on a new page.
- **DO NOT LEAVE THE EXAM UNTIL YOUR HAVE SATISFACTORILY SCANNED AND UPLOADED YOUR EXAM TO GRADESCOPE.**
- You are taking this exam in a proctored and honor code enforced environment. No calculators, cell phones, or other electronic devices or the internet are permitted during the exam. You are allowed one 8.5"$\times$ 11" crib sheet with writing on one side.
- Remote students are allowed use of a computer during the exam only for a live video of their hands and face and to view the exam in the Zoom meeting. Remote students cannot interact with anyone except the proctor during the exam.

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0. At the top of the first page that you will be scanning and uploading to Gradescope, write the following statement and sign your name to it: "I will abide by the CU Boulder Honor Code on this exam." **FAILURE TO INCLUDE THIS STATEMENT AND YOUR SIGNATURE MAY RESULT IN A PENALTY.**

1. [2350/061424 (10 pts)] Write the word **TRUE** or **FALSE** as appropriate. No work need be shown. No partial credit given.

   (a) Three nonzero vectors are coplanar if and only if their scalar triple product is 0.

   (b) The rectifying plane for any path of the form $\mathbf{r}(t) = \langle c, f(t), g(t)\rangle$ where $f(t)$ and $g(t)$ are differentiable functions that are not everywhere 0, and c is a real constant, will always be parallel to the yz-plane.

   (c) The magnitude of the torque vector is equivalent to the area of the parallelogram formed by the force and radius vectors.

   (d) The surface given by $y^2 - x^2 + 2x + z^2 + 4z = -3$ is a hyperboloid of two sheets.

   (e) If a force acts at an angle of 60° to the displacement, the work done by the force equals one-half the product of the magnitudes of the force and displacement.

2. [2350/061424 (24 pts)] Buzz Lightyear is flying along the path $\mathbf{b}(t) = t^2\,\mathbf{i} + (9+t)\,\mathbf{j} + \sqrt{6}t^{3/2}\,\mathbf{k}$. He is being pursued by Emperor Zurg, whose starship is traveling along the path $\mathbf{h}(t) = \dfrac{t^3}{3}\,\mathbf{i} + 4t\,\mathbf{j} + \sqrt{2}t^2\,\mathbf{k}$. Both paths are valid for $t \geq 0$.

   (a) (8 pts) Is there a time, t, when Zurg's ship will intercept Buzz? If so, find it and the point where this occurs. If not, explain why not.

   (b) (16 pts) Zurg's ship only has enough fuel to travel $\frac{32}{3}$ units of distance.

      i. (12 pts) Where is Zurg's ship when it runs out of fuel? Hint: $t^3 + 12t - 32 = 0$ has only one real root which can be found by guessing and checking.

      ii. (4 pts) Is Buzz safe, that is, can Zurg not catch him?

3. [2350/061424 (12 pts)] Find an equation for the surface consisting of all points that are equidistant from the point $(0, -2, 0)$ and the plane $y = 1$. Identify the surface, being as specifc as possible.

4. [2350/061424 (28 pts)] A bird is flying with a velocity vector of $\mathbf{v}(t) = 2\,\mathbf{i} + 2t\,\mathbf{j} + t^2\,\mathbf{k},\ t \geq 0$. When $t = 0$ its position is $\mathbf{r}(0) = 10\,\mathbf{k}$.

   (a) (10 pts) Where is the bird when $t = 3$?

   (b) (6 pts) Find the curvature of the bird's path.

   (c) (6 pts) What is the magnitude of the tangential component of the bird's acceleration?

   (d) (6 pts) What is the magnitude of the normal component of the bird's acceleration?

5. [2350/061424 (26 pts)] Consider the points $A(1,0,1),\ B(2,2,1),\ C(1,2,2)$ and the line $\dfrac{1-x}{2} = 1 - y = \dfrac{z-2}{3}$.

   (a) (8 pts) Find the equation of the plane containing the points, writing your answer in the form $ax + by + cz = d$.

   (b) (6 pts) Find the area of the triangle whose vertices are the points A, B, C.

   (c) (6 pts) Where does the line intersect the plane?

   (d) (6 pts) Find the angle at which the line hits the plane.