Note: This is (one of) last year's final exams – the topics last year might've been slightly different than this year's…

Name: _____ Score: ___ / 100

There are 110 points ~~possible on this test. Good luck! Please turn in your cheat sheet~~ with this test.

1. Compute the following numerically using the quantities given:

$$\vec{v} = [1 \quad -2 \quad 3] \qquad \vec{w} = [0 \quad 4 \quad 5] \qquad A = \begin{bmatrix} 0.5 & 2 & 1 \\ 1 & 3 & -1 \end{bmatrix}$$

$$B = \begin{bmatrix} 4 & 1 & 6 & 0 \\ 0 & 5 & 7 & 2 \\ 3 & -3 & 2 & 0 \end{bmatrix}$$

a. (**3 points**) $\vec{v} \bullet \vec{w}$

b. (**3 points**) $\vec{v}\, x\, \vec{w}$

c. (**3 points**) $\vec{v} - \vec{w}$

d. (**3 points**) $\vec{v} * \vec{w}$

e. (**4 points**) $\vec{w} * A^T$

f. (**4 points**) $A * B$

2. (**12 points**) Write a python class called **Asteroid** which:
    a. Has these attributes:
        i. **mVel**: a 2d VectorN.
        ii. **mPos**: A 2d VectorN.
        iii. **mRadius**: the radius. The user should pass this as well when creating an Asteroid.
        iv. [Anything else you deem necessary]
    b. Has these methods / behaviors:
        i. To create an asteroid (these numbers are just examples – make sure your code will work with any values):

```
x = 400
y = 300
degrees = 23
radius = 20
speed = 150        # px / s
a = Asteroid(x, y, degrees, speed, radius, "brown_rock.png")
```

        ii. Make this happen (the values are position, radius, and velocity:

```
print(a)    # {<Vector2: 400, 300> 30 <Vector2: 0.0, 0.0>
```

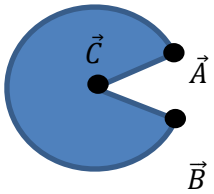
        iii. Make this happen (i.e. determine [using circle-circle hit check] if two Asteroids overlap:

```
if a == b:
    print("Hit!")
```

        iv. Make this happen (i.e. return the degree (0 degrees = right, 90 = up, etc.) heading of the Asteroid

```
print(a.getDirection())                # 37.2
```

3. (**10 points**) Suppose you are given



   a. $\vec{A}, \vec{B}, and\ \vec{C}$: 3 points that define pacman's mouth (they're 3d but all lie on a common plane -- don't assume *what* plane it's on)
   b. $\vec{P}$: the position of a power pellet (this also lies on the plane)
   c. **n**: the radius of the power pellet.
   d. **s**: pacman's radius

   Write an algorithm to determine if any part of pacman is touching the power pellet.

4. (**8 points**) Suppose you are given:
   a. $\widehat{camX}$
   b. $\overrightarrow{camPos}$
   c. $\overrightarrow{camCOI}$

   Symbolically calculate the other two camera axes in a left-handed system.

5. (**8 points**) Suppose you are ray and a plane. Suppose you have done a ray-plane intersection and have determined that the ray hits the plane at a distance of t. Symbolically show how to find a point which is 10 units away from the intersection point (but still along the ray – you can assume the ray is at least 10 units from the intersection).

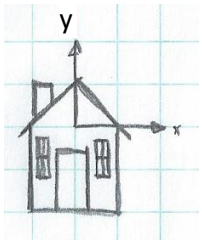
6. (**10 points**) Show the specular part of the standard lighting equation. In your answer, describe the variable names you're using (less than one sentence each)

7. (**8 points**) Show how to create a single matrix which scales by (5x, 3y, 0.5z) *then* translates by (+6x, -4y, 0z) *then* rotates by 15 degrees around the z-axis. I do want numbers in this answer, but I only care about how you set up the construction of this matrix, not the actual final numbers.

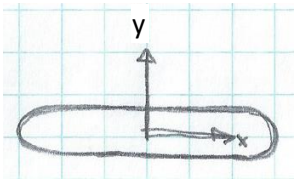
8. (**5 points**) When multiplying a 4x4 matrix and a 4x4 matrix, how many scalar multiplications are performed?

9. (**8 points**) Merida fires an arrow from position $\vec{P}$ in direction $\hat{D}$ at a target with position $\vec{T}$ (this point represents the center of the bullseye) and normal $\hat{N}$ (this is the perpendicular to the plane the front of the bullseye lies upon). Note: she doesn't necessarily hit T – the position of the hit . Ignore gravity, wind resistance, etc. and assume that all positions are measure in inches from some reference position (which isn't important). The target has 4 concentric rings that are each 2 inches across and are worth 100, 75, 50, 25 points each (100 is the bulls-eye). Write a symbolic algorithm to determine how many (if any) points she earns.

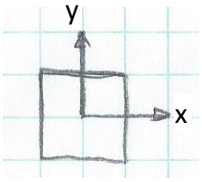
10. (**11 points**) Suppose you are given the following models (one grid mark = ½ world unit) and the scene graph shown to the right. Sketch the world *and* indicate the local coordinate systems of each node (assume left-handed world).



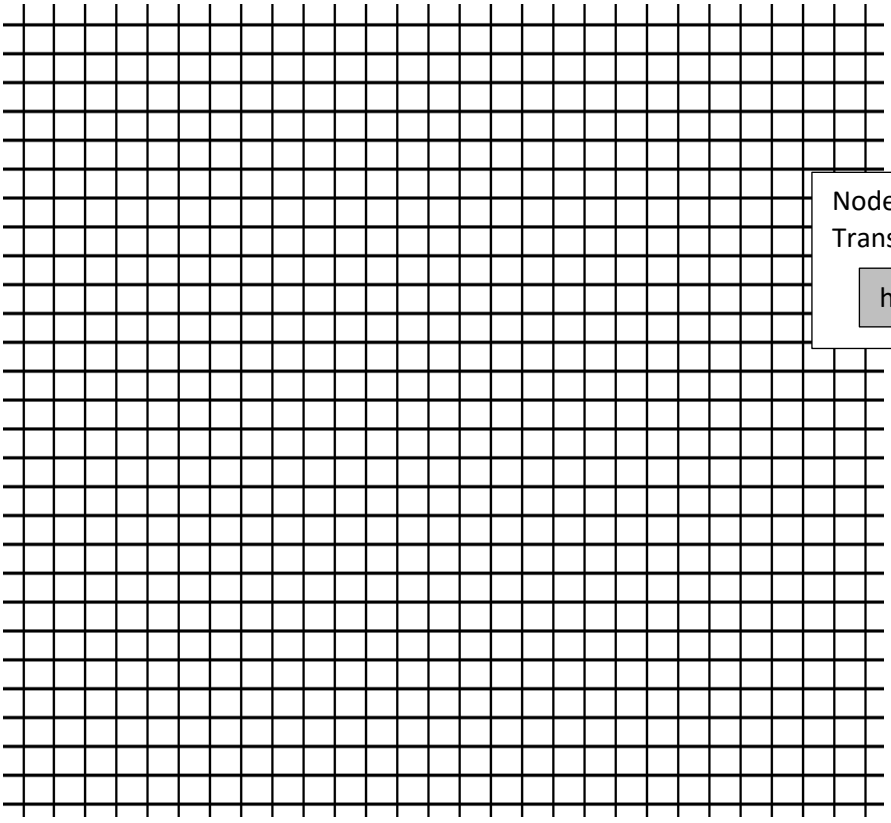
house

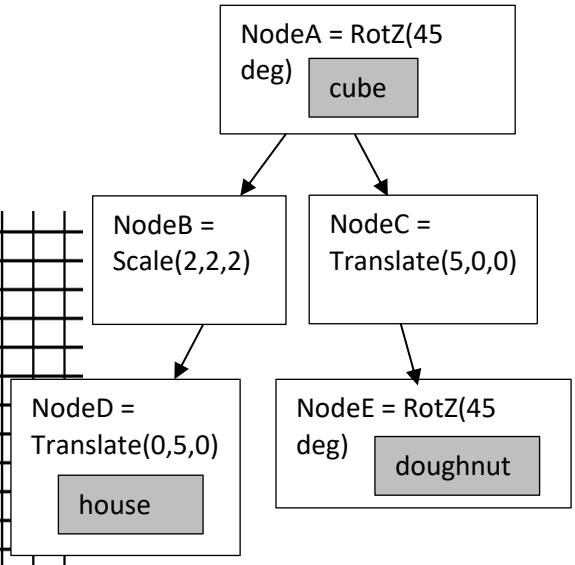


doughnut



cube





11. (**3 points**) I think I'll get a _____ in this class [no wrong answer – just seeing if it matches reality]

Have a great summer!!