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Write down answers in-between questions. Please answer using short sentences.

The back of each page can be used for practice, but DO NOT write down the answer on the back.

Be sure to write your student number and name on each page.

- 1. (4 pts) A ______ is a function of four real variables that defines how light is reflected at an opaque surface. Fill in the blank. (You can write down either its abbreviation or its full name).
- 2. (6 pts) Write down the degrees of freedom (DOF) of each of the following movements:
 - 1) Translation on a plane
 - 2) Rotation in 3D space
 - 3) Any rigid motion in 3D space
- 3. (6 pts) The following figures shows a texture-mapped 3D mesh model and its texture maps. Write down the type of each texture map (Fill in the blanks (1), (2), (3)).



- 4. (4 pts) Choose **one** false(incorrect) statement about triangle mesh representations.
 - 1) Separate triangle representation stores all vertex positions for each triangle.
 - 2) You can use glDrawArray() to render a triangle mesh written in separate triangle representation.
 - 3) Separate triangle representation is more efficient than indexed triangle set representation in terms of memory space.
 - 4) You can use glDrawElements() to render a triangle mesh written in indexed triangle set representation.

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- 5. (4 pts) Choose **one** false(incorrect) statement about the Phong illumination model.
 - 1) Phong illumination model is composed of three components; ambient, diffuse, specular component.
 - 2) The ambient component provides constant global lighting, which is a severe approximation of indirect lighting.
 - 3) The diffuse component assumes that light is reflected equally in all directions.
 - 4) The specular component simulates highlights on shiny objects in a physically correct way.
- 6. (4 pts) Choose one false(incorrect) statement about computer animation.
 - 1) In key frame animation, animators just specify important events at key frames and computer fill in the remaining frames.
 - 2) Optical passive motion capture is the most popular method for motion capture.
 - 3) Skeletal animation is very popular for facial animation.
 - 4) Physically-based simulation can be used to generate high-quality computer animation because physical reality plays a key role in animation quality.
- 7. (6 pts) Choose ALL materials that do not cause diffuse reflection.



- 8. (6 pts) Choose ALL false(incorrect) statements about the visibility problem.
 - 1) Invisible primitives should be removed for efficient and correct rendering.
 - 2) Clipping is the process of removing primitives occluded by other objects closer to the camera.
 - 3) Back-face culling uses the dot product between surface normal and camera view vector.
 - 4) Painter's algorithm is the most popular hidden surface removal algorithm.

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- 9. (6 pts) Choose ALL false(incorrect) statements about the interpolation of 3D orientations (or rotations). (Note that slerp($\mathbf{R}_1, \mathbf{R}_2, t$) = $\mathbf{R}_1 \exp(t \cdot \log(\mathbf{R}_1^T \mathbf{R}_2))$)
 - 1) Slerp is a correct method for linear interpolation of two 3D orientations.
 - 2) Linear interpolation between two rotation vectors results in correctly interpolated rotation.
 - 3) In terms of rotation vectors and rotation matrices, logarithm mapping (log()) means converting rotation matrix representation to rotation vector representation.
 - 4) The Rodrigues' rotation formula can be an implementation of logarithm mapping (log()).
- 10. (8 pts) Below is the pseudo code for z-buffer (depth buffer) algorithm. Fill in the blanks (1) and (2). You have to use functions already used in the code and variables already defined in the code.

```
allocate depth_buffer;
for each pixel (x,y)
write_frame_buffer(x,y,backgrnd_color);
write_depth_buffer(x,y,farPlane_depth);
for each polygon
for each pixel (x,y) in polygon
color = polygon's color at (x,y);
p<sub>z</sub> = polygon's z-value at (x,y);
if (p<sub>z</sub> < read_depth_buffer(x,y))
______(1)_____;
_____(2)_____;
```

- 11. (6 pts) Express a rotation matrix **R** for a rotation about an arbitrary axis **a** by angle θ using following two rotation matrices:
 - 1) \mathbf{R}_{az} : A rotation matrix that rotates the axis **a** so that it is aligned with the Z-axis.
 - 2) \mathbf{R}_{z} : A rotation matrix for rotation about the Z-axis by angle θ
- 12. (7 pts) If \mathbf{R}_1 and \mathbf{R}_2 are rotation matrices, then $\mathbf{R}_1\mathbf{R}_2$ is a rotation matrix as well. Prove it mathematically. (Hint: use the two major properties of a rotation matrix)

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- 13. (8 pts) Below are four curves and their "control points/polygon." Some of the control polygons are the Bezier control polygon for the curve drawn with it; the others are not. You may assume that none of the control points overlap or are repeated.
 - 1) Indicate which of the control polygons are Bezier control polygons for the corresponding curve and which are not.
 - 2) For non-Bezier control polygons you choose, explain why they are not Bezier control polygons.



14. (7 pts) Let's say we have some "unfamiliar" quartic (fourth degree) polynomial curve, which has five basis functions b₀(t), b₁(t) b₂(t), b₃(t), b₄(t) and corresponding control points p₀, p₁, p₂, p₃, p₄. The following figure shows the basis functions (black solid and dashed curves are the basis functions):



1) Write down the curve equations **p**(t) in parametric form, formulating with given basis functions and control points.

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2) Which of the five control points **p**₀, **p**₁, **p**₂, **p**₃, **p**₄ will the curve pass through, and for what values of t?

15. (6 pts) Write down at least two drawbacks of Euler angle representation for 3D orientation.

16. (6 pts) What is the difference between normal mapping and bump mapping? Briefly describe the difference.

17. (6 pts) What is the difference between Gouraud shading and Phong shading? Briefly describe the difference.