Advanced Modelling, Rendering and Animation, COMP GV14, 2012
Answer THREE of FIVE questions.
Marks for each part of each question are indicated in square brackets
Calculators are NOT permitted

1. **Global Illumination I.**

   a. Photon Mapping.

      i. Describe the photon mapping algorithm in detail. [8 marks]

      ii. In photon mapping, light leaking is a common artifact. When does it occur and how can it be prevented? [5 marks]

      iii. Give the formula for computing reflected radiance (i.e., density estimation) from N nearby photons. Explain in detail what it describes. [5 marks]

      iv. Explain what *russian roulette* means in the context of photon mapping. [2 marks]

   b. Path Tracing.

      i. Describe *Path Tracing* in detail. [6 marks]

      ii. What is stratified sampling and how is it commonly used in path tracing? [3 marks]

      iii. Give two examples of scenes where standard path tracing is very inefficient. Explain why. [4 marks]

[Total 33 marks]

2. **Global Illumination II.**

a. Hierarchical Radiosity.

i. Explain in detail how *refinement* works in Hierarchical Radiosity. You can use pseudocode to illustrate the method. [7 marks]

ii. Describe two versions of the *oracle* in hierarchical radiosity. [3 marks]

b. Precomputed Radiance Transfer.

i. Describe the main idea of the *Precomputed Radiance Transfer* method. [6 marks]

ii. Wavelets are sometimes used for representing precomputed radiance transfer. What are their advantages and disadvantages in this context? [4 marks]

iii. Write down the equation that projects an environment map $L_{\text{env}}(\omega)$ into the spherical harmonics basis. [3 marks]

c. You are asked to write rendering software that supports two different rendering methods: photon mapping and path tracing. What building block (in terms of global illumination) can be used for both of them? [3 marks]

d. Consider a scene with participating media, e.g., fog. Devise a physically accurate rendering algorithm to render such a scene. [7 marks]

[Total 33 marks]

3. **Computer Animation**

a. What is Forward Kinematics (FK), and what is Inverse Kinematics (IK)?

[4 marks]

b. What are the advantages and disadvantages of FK? What are the advantages and disadvantages of IK? In Character Body Animation, give an example of when IK is needed.

[6 marks]

c. Motion Capture is often used in Human Body animation. Please describe at least three methods to collect Motion Capture data. What are the pros and cons of each method?

[9 marks]

d. Why is Motion Editing needed sometimes? Please give at least one example of when motion editing is needed, and explain which motion editing method should be used.

[5 marks]

e. Name four reasons why creating Character Animation is a great challenge?

[4 marks]

f. Please briefly explain Uncanny Valley with a diagram.

[5 marks]

[Total 33 marks]

4. **Colour and Graphics Processing Units (GPUs)**

Colour

a. In colour reproduction, what are the primaries of a device? Please use physical terminology where appropriate.
[2 marks]

b. What is a colour gamut?
[2 marks]

c. Why do some video projectors have six rather than three primaries? Explain using the notion of the colour gamut.
[3 marks]

d. Define the perceptual quantities Hue, Saturation and Value in your own words. How do they relate to the terms Tint and Shade often used by artists?
[5 marks]

e. The HSV colour space builds upon these three quantities. What is the advantage of using HSV over RGB?
[2 marks]

f. What is the Luminance? How do you compute it from a colour spectrum?
[4 marks]

Graphics Processing Units (GPUs)

g. The OpenGL frame buffer consists of a set of target buffers, each of them storing different pixel properties. List four types of such target buffers.
[4 marks]

h. Reading pixel values from the frame buffer may slow down rendering significantly. Why?
[2 marks]

i. Shaders are executed on processor cores with SIMD instruction set. What does SIMD mean? Why is this a suitable design decision for GPUs?
[4 marks]

j. Imagine you had to write code that displays a flag waving in the wind. The flag is of a diffuse material and illuminated by a point light source. How would you distribute all necessary computations over CPU, vertex shader and pixel shader, assuming that you have to compute lighting yourself? (Please maximise computational efficiency and image quality.) How would your distribution of computations differ if the flag was of a shiny material?
[5 marks]

[Total 33 marks]

5. **Reflectance Functions**

a. What does it mean if a material's reflectance is anisotropic? Name two examples of materials with anisotropic reflectance.

[4 marks]

b. List three factors that affect the appearance of translucent objects.

[3 marks]

c. Imagine you were to create a scaled-down replica of a marble statue (again using marble) at a quarter of the original size. Provided you reproduce the geometry exactly and you view the replica from a quarter of the distance (to account for its smaller size), will its appearance look the same? If not, what will be different and what is the origin of this effect?

[3 marks]

d. As discussed in the lecture, the Diffuse Scattering Approximation contains two transmissive Fresnel terms, accounting for light loss when light passes the material-air interface. What effect would omitting each of the two terms have on rendering using this reflectance function?

[4 marks]

e. What dimensionality does a Bidirectional Texture Function (BTF) have?

[2 marks]

f. Define the terms parallax, self-shadowing and masking. For each of these three, explain how it manifests itself in a rectified BTF slice.

[9 marks]

g. A BTF bakes in many real-world lighting effects without having to account for them explicitly. Name an effect that is ***not*** modelled by a BTF?

[2 marks]

h. Describe one possible setup to acquire a BTF. What factors determine spatial and angular resolution?

[6 marks]

[Total 33 marks]

END OF PAPER