1. Name THREE types of **orientation representation** that are used in Computer Animation and state the type of tasks for which each of them is suitable.

(5 marks)

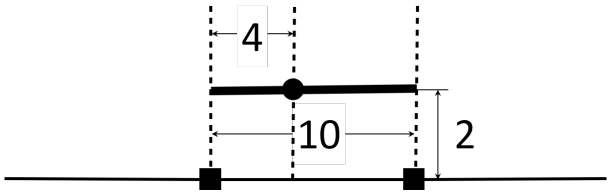
2. Briefly sketch how you would model a sunrise using **keyframing**. (5 marks)

3. What is a **gimbal lock** and when does it occur? (4 marks)

4. This question is about **non-rigid deformation**.

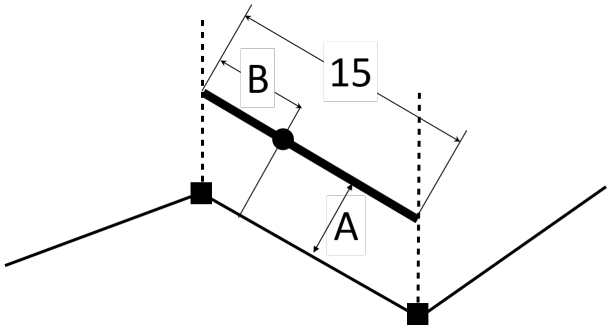
   a) Give a brief description of **direct vertex manipulation**. (6 marks)

   b) The following diagram shows a 2d skeleton at rest, with three bone segments as well as an object vertex (round dot) that has been assigned to the middle segment.



(Figure 1)

The diagram below shows the same skeleton and the object vertex undergoing a deformation.



(Figure 2)

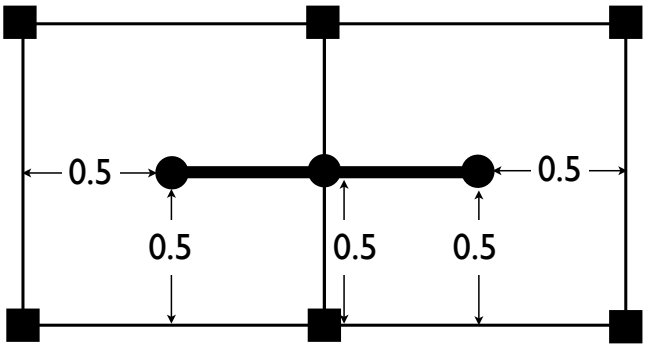
Using the distances indicated on the two diagrams, derive the distances denoted by A and B.

(4 marks)

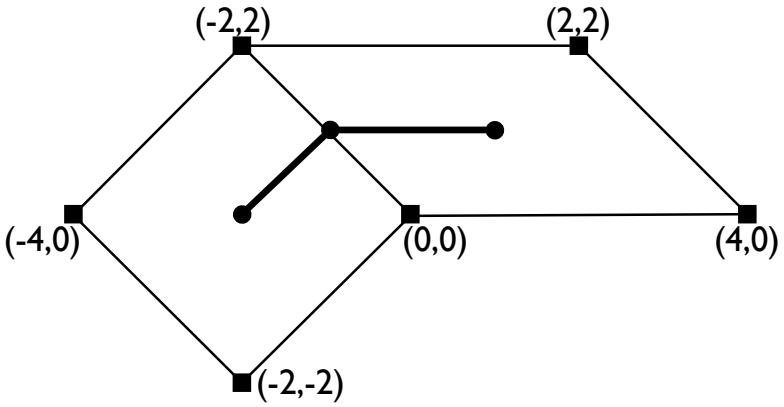
(question continues on next page. . .)

(Question 4 continued. . .)

c) This part is about 2d grid deformation using **bilinear interpolation**.



(Figure 3)



(Figure 4)

Figure 1 shows a simple 2d object consisting of three vertices (round dots) that is embedded into a 2×3 lattice. In Figure 2 the grid points have been dragged to the new positions shown. Use **bilinear interpolation** to obtain the deformed positions of the three object vertices in this new configuration. (15 marks)

5. How many parameters are needed to describe the configuration of a rigid object in 3d space? (3 marks)

6. Which animation technique would you use to model each of the following:

   a) A flying airplane
   b) A forest
   c) A humanoid robot walking
   d) Smoke coming out of an explosion

(Question 6 continued...)

e) A bowling alley
f) An egg splatting against the wall
g) A fly-through a scene

(7 marks)

7. Name the FIVE different spaces that form part of the **display pipeline**.

(5 marks)

8. Give definitions of **forward and inverse kinematics**. Which one is harder to achieve? Give an example of an animation task for which each technique is more suitable.

(7 marks)

9. Sketch a simple robotic arm and count the **degrees of freedom** necessary to fully describe its configuration. Explain your answer.

(3 marks)

10. A rotation matrix in two dimensions is given by

$$\begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$

By considering two rotations at $+90$ and -90 degrees as well as their desired midpoint, explain why interpolating between rotation matrices is not a good idea. Illustrate your argument by giving the corresponding matrices.

You are reminded of the following facts from basic trigonometry: $\sin(90) = 1$, $\sin(-90) = -1$, $\cos(90) = \cos(-90) = 0$, $\sin(0) = 0$, $\cos(0) = 1$

(5 marks)

11. An animated 3d object moves along the x-y plane using keyframing. The following keyframes on the object's position have been defined:

frame	0	10	20	30	40
t_x	1	3	9	15	20
t_y	0	5	7	4	-2

(Question 11 continued...)

Using **linear interpolation**, write down the translation matrices describing the object's position at $t = 20$ and $t = 30$ and thus compute the interpolated translation matrix at time $t = 22$.

(5 marks)

12. The following table represents a track of a marker in two dimensions across seven frames. Compute the mean-filtered and median filtered tracks using a window of size 3 for frames 1,2,3,4 and 5. What type of error can be observed around $t = 3$? By plotting the unfiltered track together with the two filtered versions, explain which of the two types of filter performs better here and why.

t	0	1	2	3	4	5	6
x	1	2	4	5	6	7	8
y	1	3	4	12	4	3	1

(5 marks)

13. Describe the **simulation loop** employed in physics-based animation of rigid bodies.

(5 marks)

14. Two widely used methods for generating and animating natural objects and phenomena are **L-systems** and **particle systems**. Give the output of the initial state and the first TWO iterations of the following L-system:

```
Axiom F
F→F[+F]F angle = 60°
```

both in string representation and in graphical form. (8 marks)

15. Briefly describe what particle systems are and how they are used to create animated effects. Name two examples of phenomena that can be modelled by particle systems.

(8 marks)

END OF ASSESSMENT