Problem 1

Question 1:
X-rays are a type of electromagnetic radiation which can penetrate solid objects, such as human tissues. This invention is applied in medical imaging which works on the principle of the different degrees of absorbing X-rays in the different body tissues. The dense difference inside the object creates a contrast, allowing them to be visualized. Specifically, when the X-ray beams pass through the body, some of them are allowed to penetrate the less dense human tissue and reach the detector on the other side. Thus, the detector can convert the passed-through beams into electrical signals, which later become an image. As a result, the brighter parts in the image are the area where larger amounts of X-rays beam locate.

Reference: https://www.nibib.nih.gov/science-education/science-topics/x-rays#:~:text=X%2Drays%20are%20a%20form,and%20structures%20inside%20the%20body.

Question 2:
Filtered Back Projection is an image reconstruction technique used for computed tomography (CT) scans. The FBP algorithm consists of two parts, filtration and projection. During the projection phase, the FBP algorithm firstly collects a set of X-rays projections from different angles of the object as inputs, then back-projecting them onto a reconstruction grid and produces a two-dimensional image of the object. The back-projection process involves taking each projection and mapping it onto the corresponding line in the reconstruction grid. However, the back-projection process can introduce blurring effects into the reconstructed image. Recalling the Fourier Slice Theorem, the Fourier domain of the object is sampled more densely in the low frequency than in the high frequency. The low frequencies in image processing represent the smoothing effect in the time domain, thus the reconstructed image looks blurry after the back-projection. To emphasize this issue, a filtration step is applied to the projections prior to back-projection. During the filtering phase, each projection convolves with a filter function designed to bypass the low-frequency responses and emphasize higher-frequency domains. Together with the filtration and back-projecting phase, the Filtered Back Projection algorithm provides a method to reconstruct a computed tomography image clearly.

Reference: https://howradiologyworks.com/filtered-backprojection-fbp-illustrated-guide-for-radiologic-technologists/

Question 3:
The Computed Tomography (CT) scan is a medical image technique that provides a more detailed three-dimensional image of a specific body structure. This is useful when the area of interest is on the softer part of the human tissue. Conventional X-ray imaging works well on high-density human tissue, such as identifying bone fractures. However, the entire body thickness is projected onto the photographic film which results in overlapping between many different types of tissues. This makes the work become difficult when we try to classify various kinds of organs. Thus, the CT scan was invented to tackle the issue. The working principle of CT images is still based on the emission of X-

rays. However, the CT scan emits the electron at 360 degrees and forms a slice of the image at that specific angle. Finally, by using the FBP algorithm mentioned above, it generates a three-dimensional image from thousands of two-dimensional image slices. Since the CT scan concatenates all the two-dimensional slices along the axis to form a volumetric image, it is also called Computed Axial Tomography.

Reference: https://howradiologyworks.com/ctgenerations/

Question 4:
One existing method for CT (Computed Tomography) reconstruction from multi-view X-rays is by applying the Filtered Back Projection (FBP) algorithm. The object to be scan will be sent into a circular machine. Outside the circular machine, there is a source machine which will emit an amount of electrons to the tungsten ring. The electrons then collide with also are reflected by the tungsten ring. Finally the electrons trajectory are adjusted to the direction of the objects we plan to scan. While emitting the electrons, the tungsten ring will move along with its circular trajectory and reflect the particles from multiple angles simultaneously . The purpose of this is to form a multi-view X rays images on the other side of the tungsten ring. After that, we can use the FBP algorithm to initially back project a set of blurred images onto the reconstruction grid. Secondly, the FBP algorithm will filter the noisy images and compute final clear CT images. While, the tungsten ring and the source emitter are operating, the object is put on a gantry that will move translationally to pass through ring. As a result, we are able to get multiple two-dimensional image slices of the object. Finally, we can concatenate all the slices to form a three-dimensional volumetric model that improve our understanding of human body.

Reference: https://www.youtube.com/watch?v=pIQD8jdmaVM

Problem 2

Question 1:
ITK-SNAP (Insight Segmentation and Registration Toolkit-Simple Normalized Applications and Programming) is an open-source software used for medical image segmentation and visualization. ITK-SNAP supports, Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT) for medical imaging in DICOM, NIFTI and Analyze file types.

Reference: https://en.wikipedia.org/wiki/ITK-SNAP#:~:text=ITK%2DSNAP%20can%20read%20and,%2C%20NIfTI%2C%20and%20Mayo%20Analyze.

Question 2:

First I download the dataset also the ITK-SNAP software on my PC. Then, I click “Open Main Images” inside “File” and open images as main images. Additionally, I click the “Open Segmentation” and find the ground truth labels for their corresponding images then apply it. Lastly, I open dataset.json file to inspect their label contents and click “Segmentation Label Editor” to change their label names accordingly. You can see the label names in the bottom left window.