ME3455

CFD Lab

Assignment 4

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ME21BTECH11001

Question: Solve for the deformation of interfaces in a test-tube containing centrifuged blood. Three layers and their properties are described in the pdf uploaded to classroom. You can use the mesh file provided already on google classroom. You can use the UDF provided and modify it for your purposes. The tube is accelerated with a value ax = 2g for 20 ms, maintained at a constant velocity for 10 ms and finally decelerated at the rate of ax = −4g for 10 ms. Simulate until 20 ms after the test-tube stops moving. Use g = −9.81 m/s 2 in the y direction. Prepare a short report with the following.

(a) Plot acceleration as a function of time for the duration of the simulation, from 0 ms to 60 ms.

- 0 ms to 20 ms: ax = 2g, ay = 0
- 20 ms to 30 ms: ax = 0 , ay = 0
- 30 ms to 40 ms: ax = -4g, ay = 0
- 40 ms to 60 ms ax = 0, ay=0

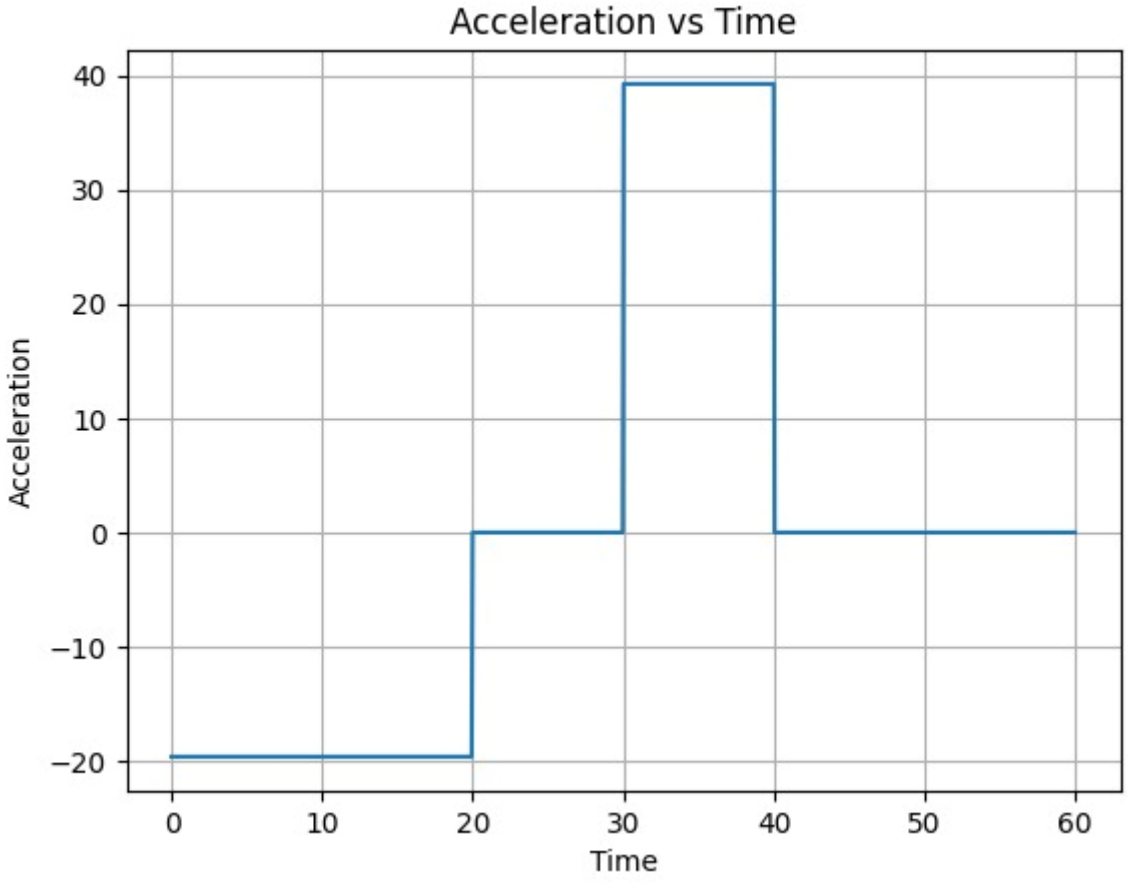

Fig: Acceleration vs time graph

Ay remains 0 throughout and considering ***g=-9.81 m/s^2 .***

➔ Centrifugation of blood leads to separation in three layers

- Erythrocytes: contains densely packed platelets
- Buffy coat: water-like substance with white blood cells
- Plasma: clear, water-like fluid

➔ A centrifuged test tube placed on a conveyor belt to transport it across a lab is subjected to several body forces.

- Common problems:
- Remixing of buffy coat and plasma
- Sloshing and spillage of plasma

(b) Plot contours of density or any other variable that shows the three layers and the deformation of the air-plasma interface every 5 ms including the initial condition.

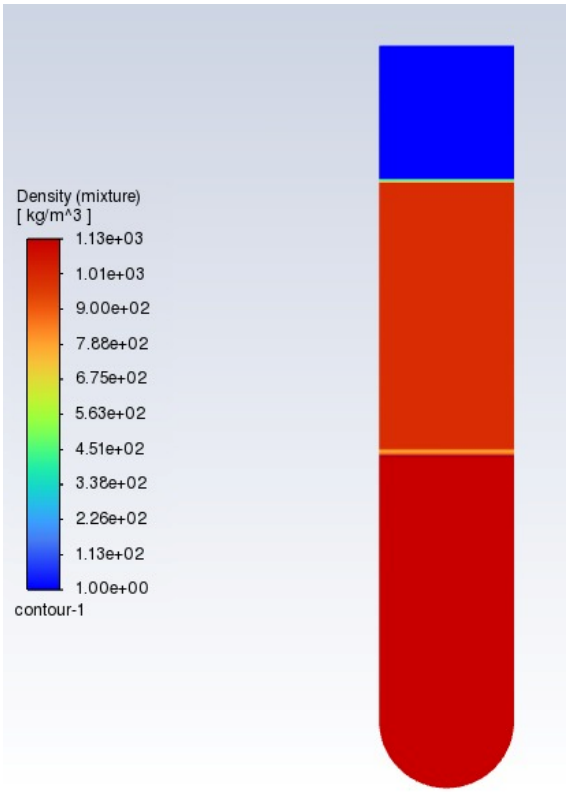

Fig: Initial Contour of Density Mixture

Three layers in the domain

- Platelets (erythrocytes)
- Plasma
- Air
- Note: Buffy Coat is subsumed in Plasma

Plotting contours every 5 ms are the following: -

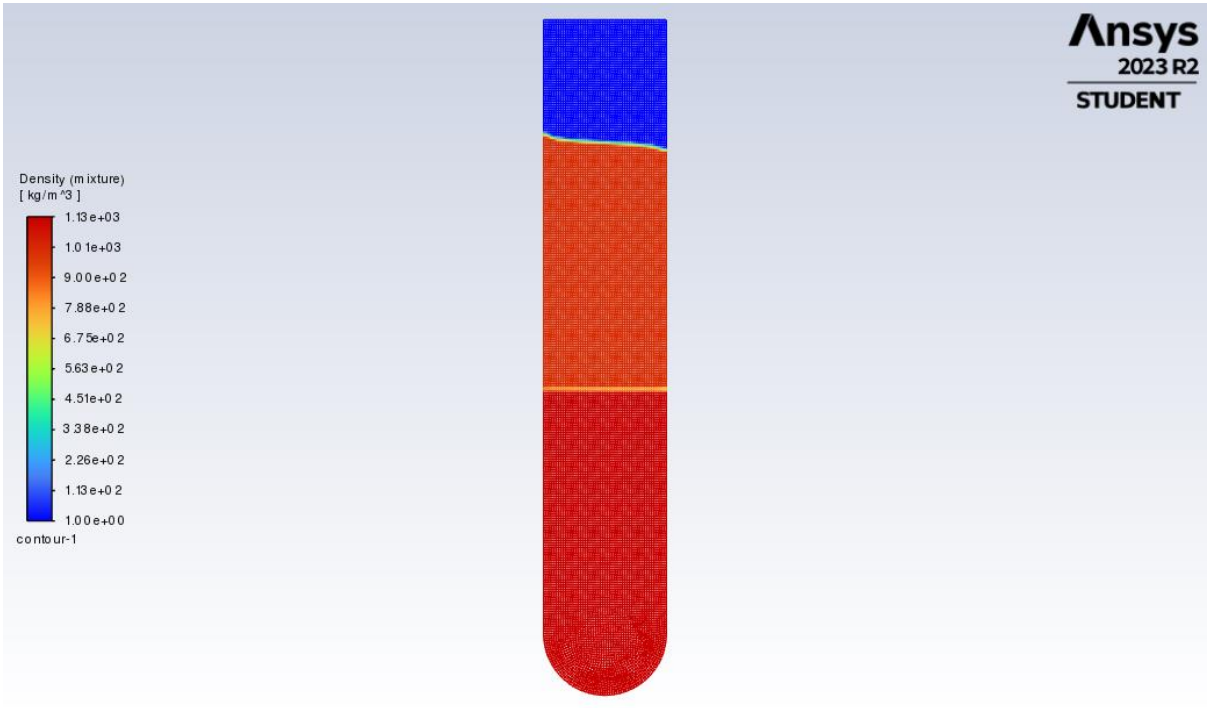

Fig: Frame 1

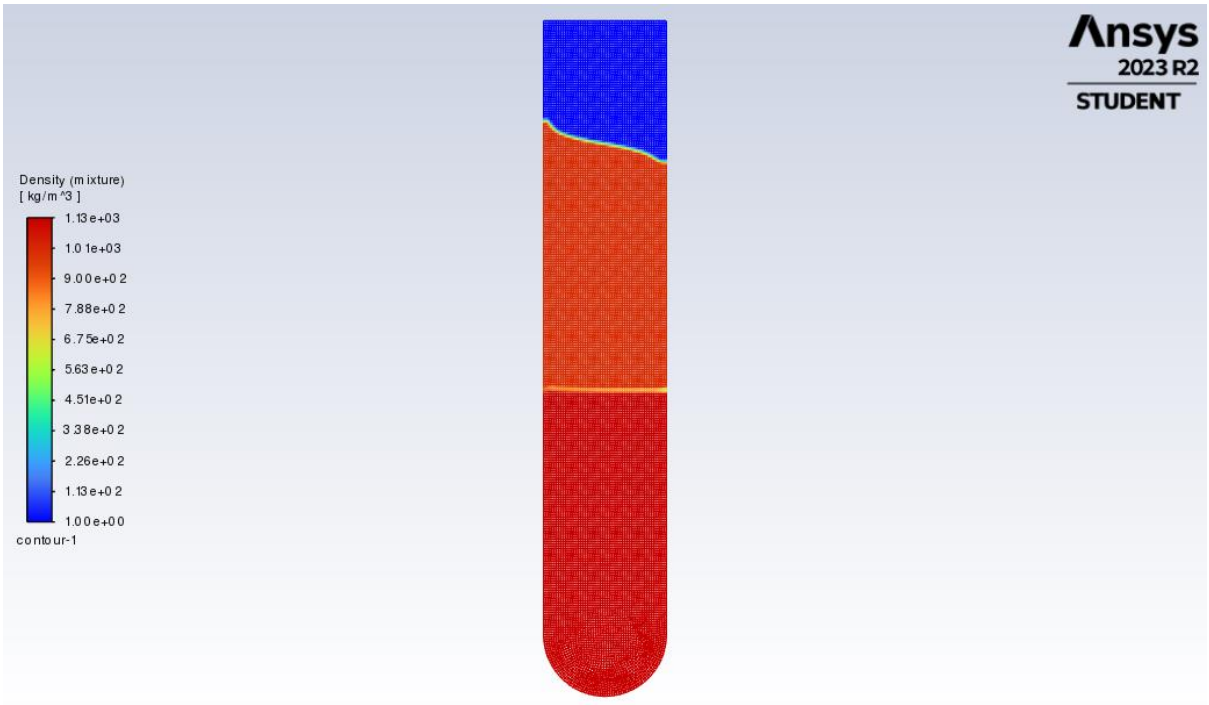

Fig: Frame 2

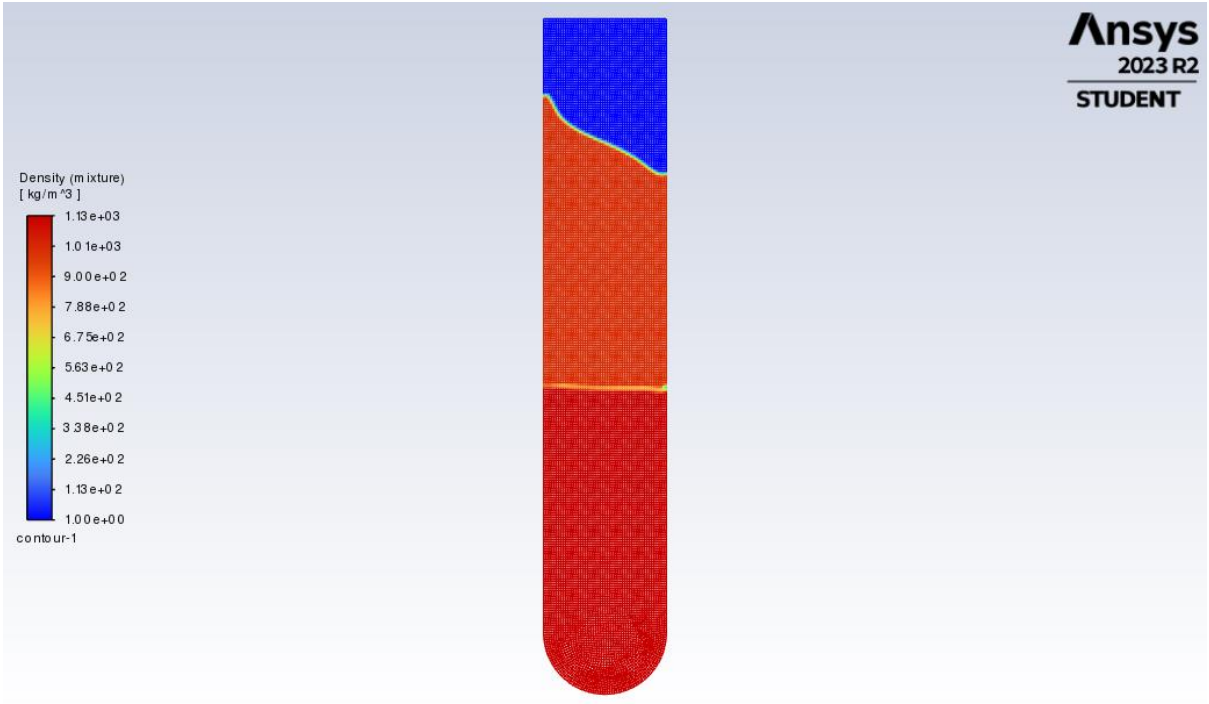

Fig: Frame 3

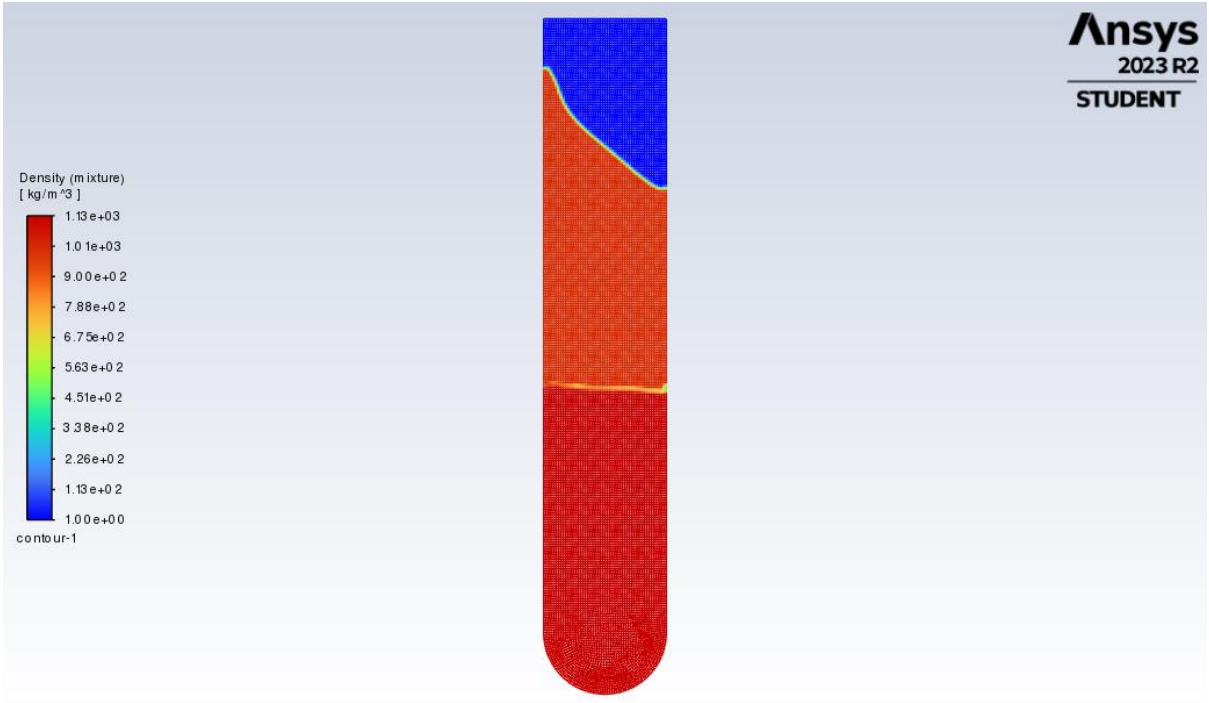

Fig: Frame 4

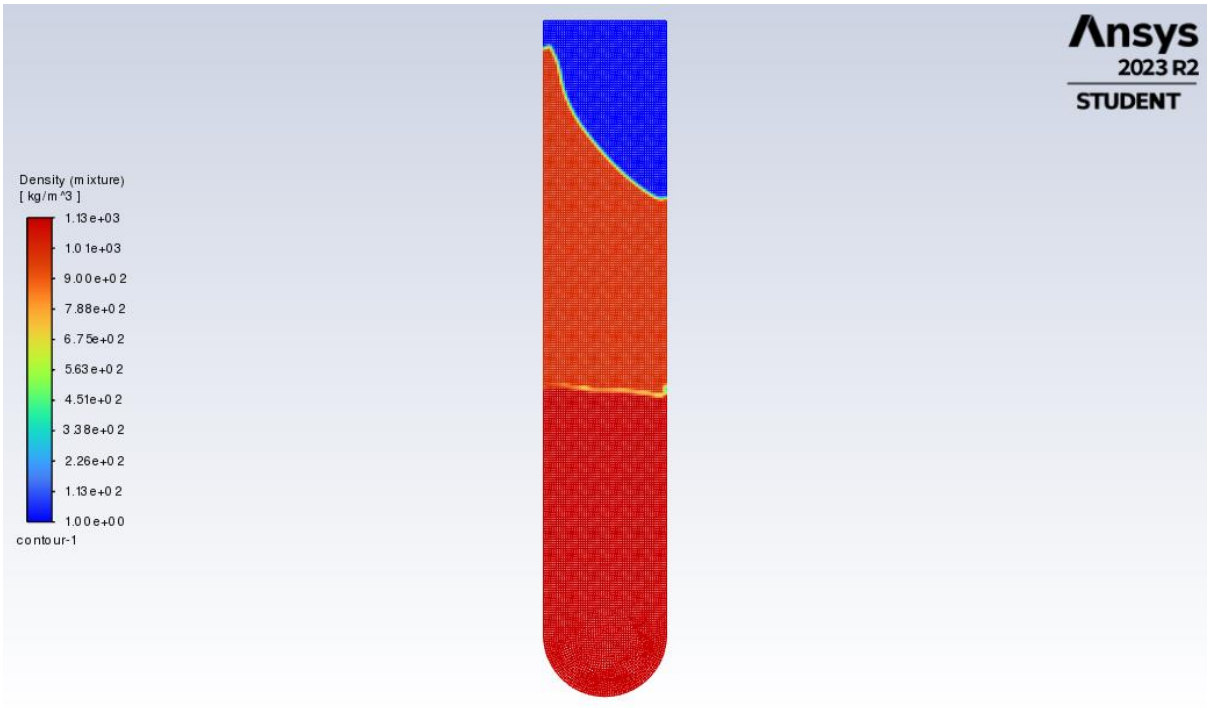

Fig: Frame 5

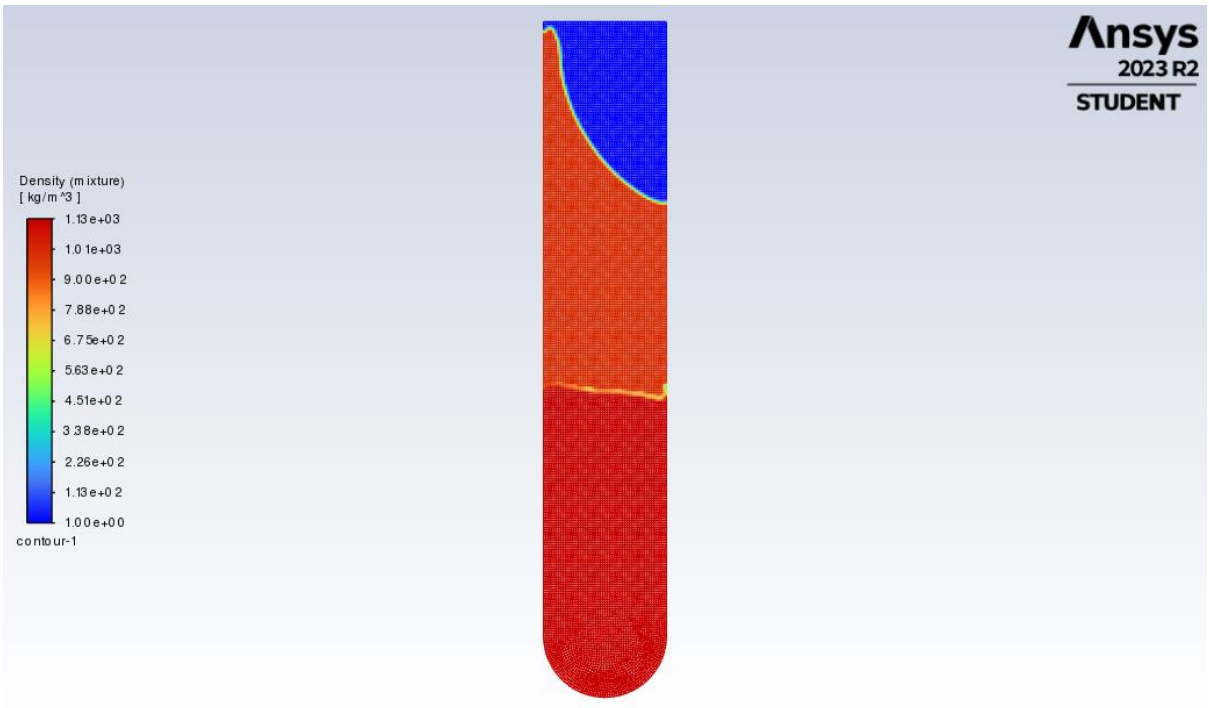

Fig: Frame 6

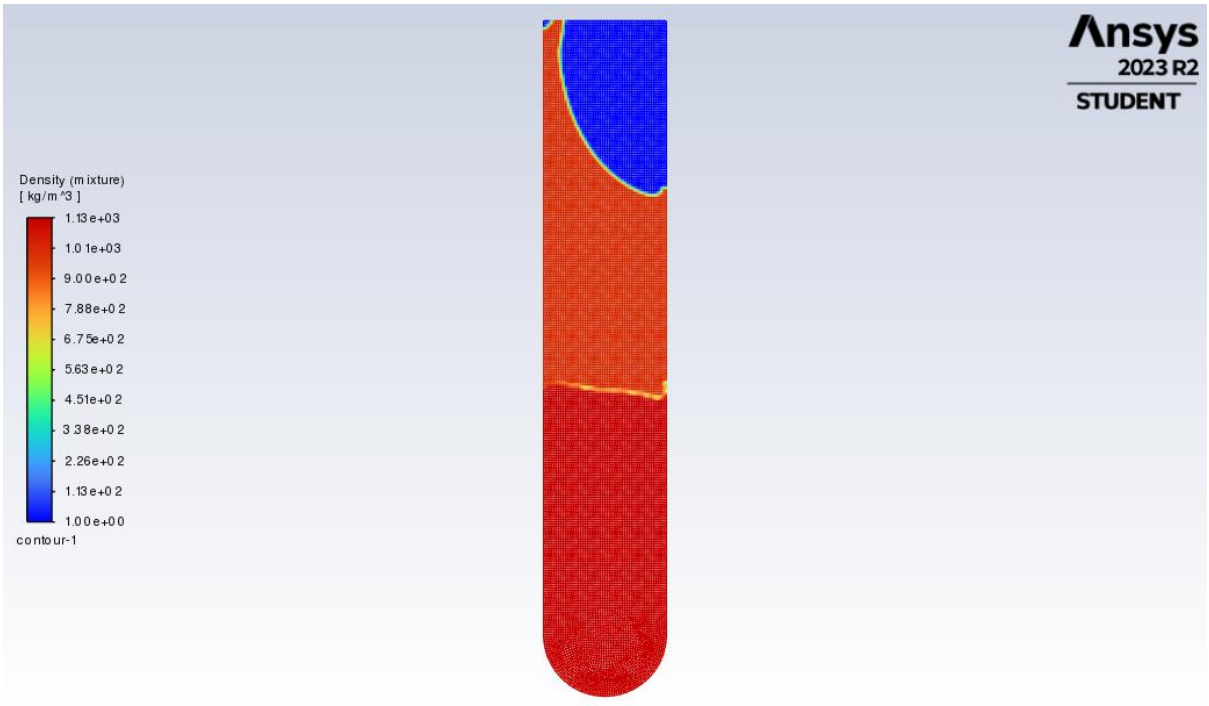

Fig: Frame 7

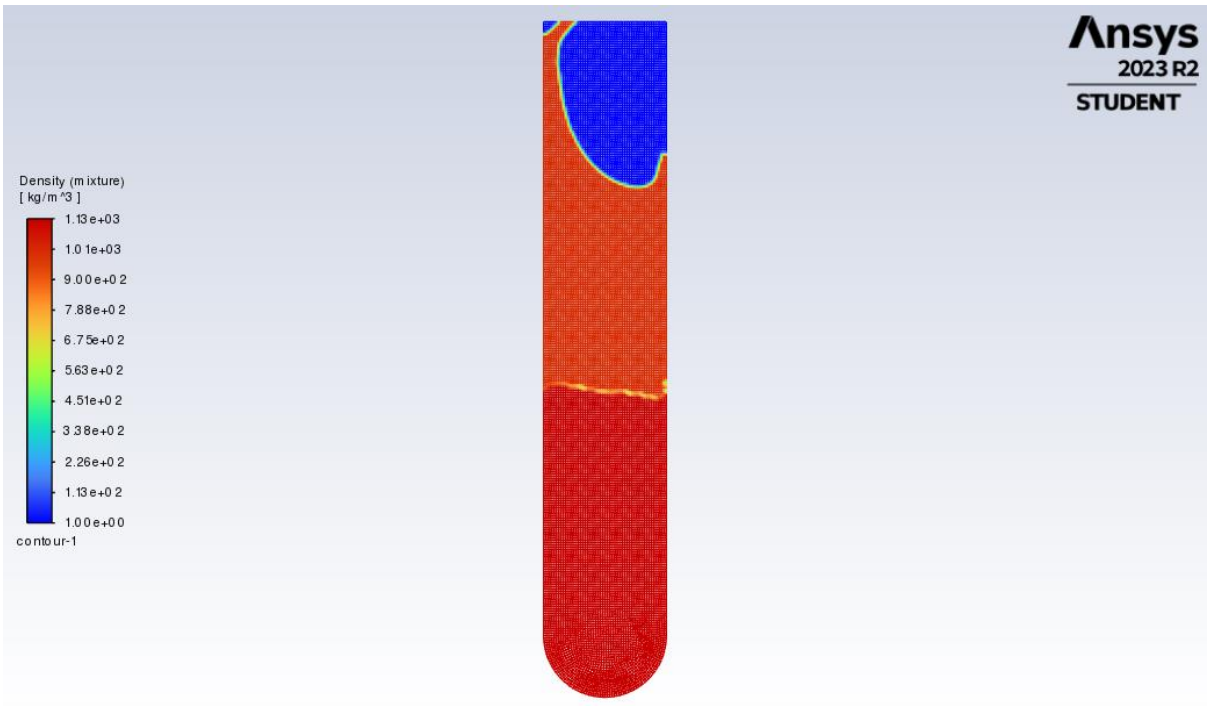

Fig: Frame 8

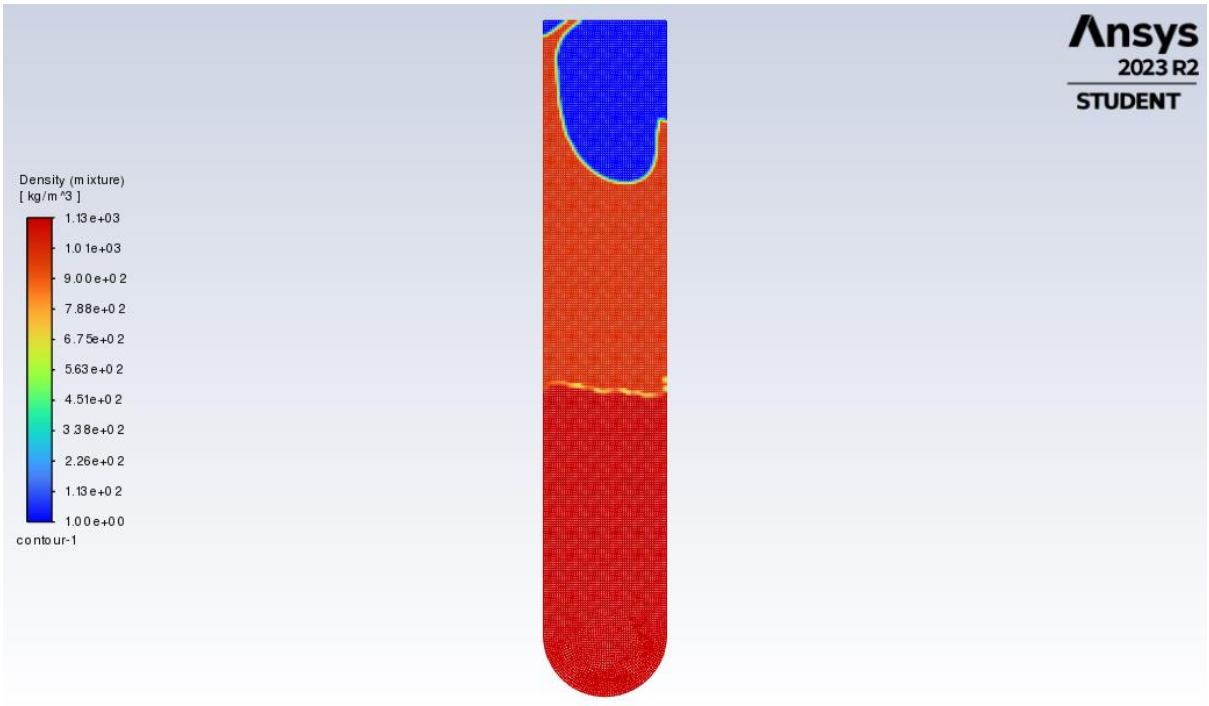

Fig: Frame 9

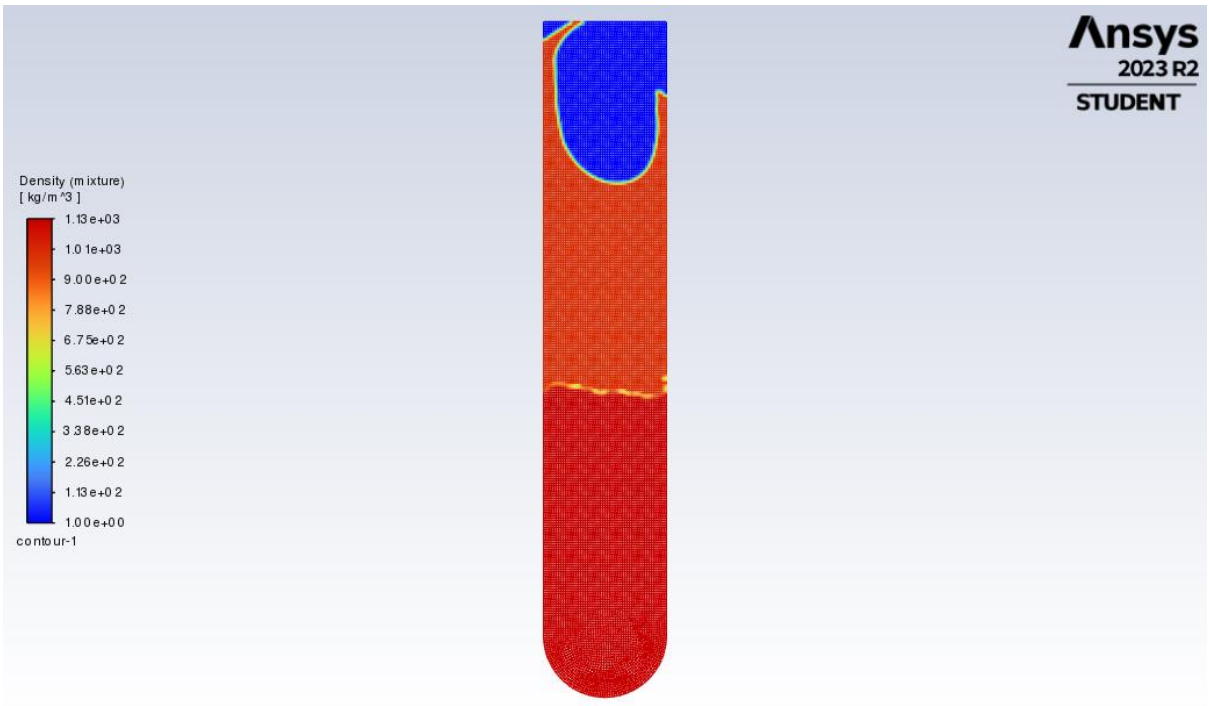

Fig: Frame 10

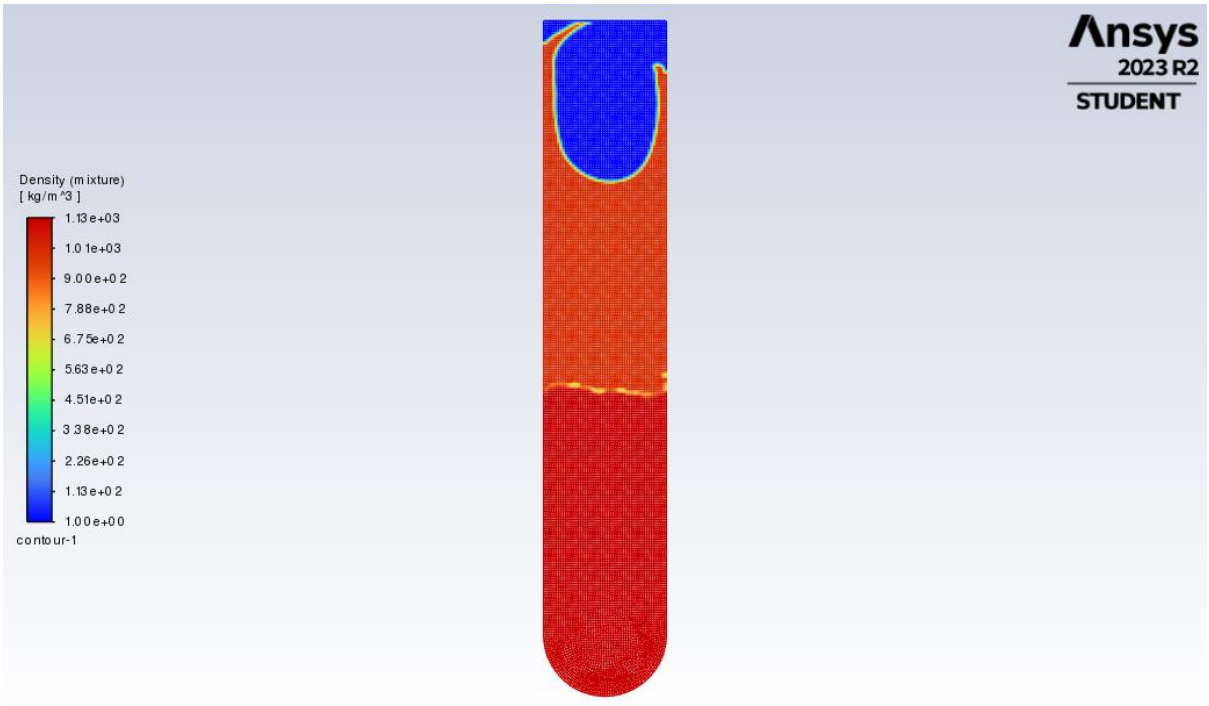

Fig: Frame 11

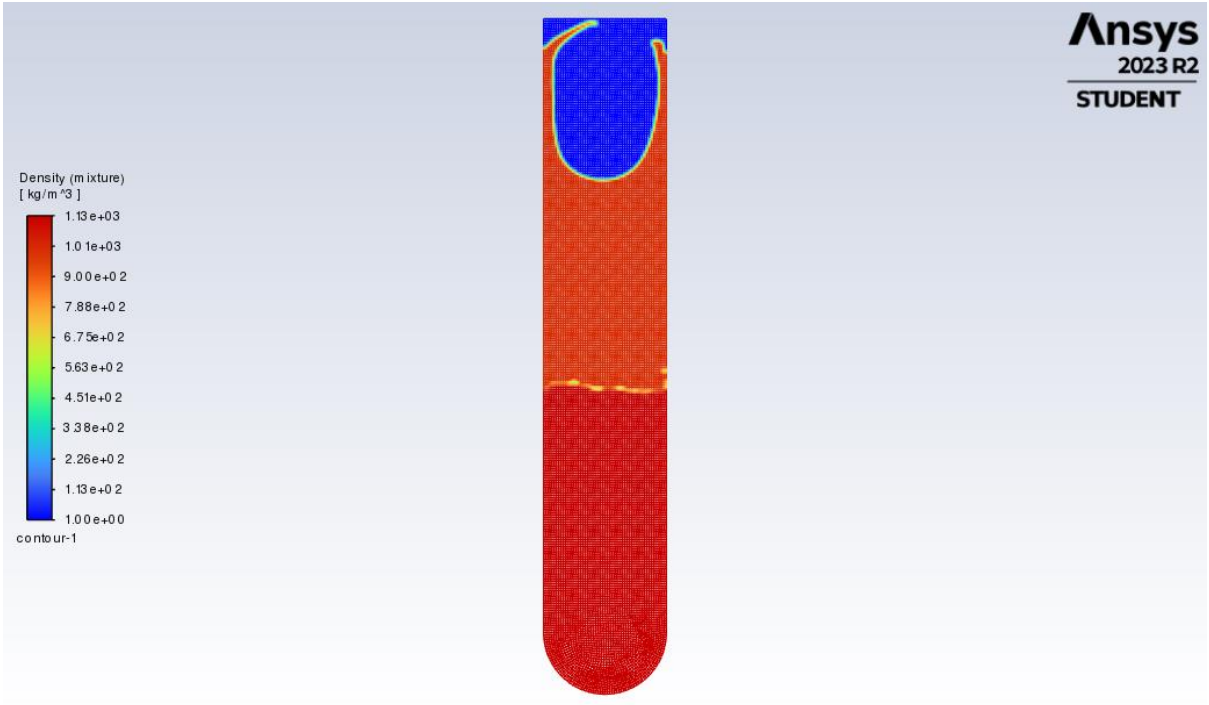

Fig: Frame 12

Description and Reasoning

- ***Layered Composition:***

Different layers in the blood sample, including platelets, plasma, and air, have distinct densities, influencing their response to centrifugal forces.

- ***Centrifuge Dynamics:***

Movement along a conveyor belt represents the centrifugation process, applying body forces on the test tube and inducing separation of blood components.

- ***Plasma Spillage Mechanism:***

Imbalances in centrifugal forces or external factors can lead to plasma spillage as the layers experience differential movement.

- ***Air Layer Influence:***

The presence of an air layer introduces a dynamic element, affecting the overall fluid behaviour during centrifugation.

- ***Buffy Coat Integration:***

The buffy coat, part of the plasma layer, contributes to spillage dynamics, influencing fluid behaviour during separation.

(c) Estimate roughly at what time instant the blood plasma spills out of the tube.

In between 6^{th} & 7^{th} frame the blood plasma spills out of the tube as shown below :-

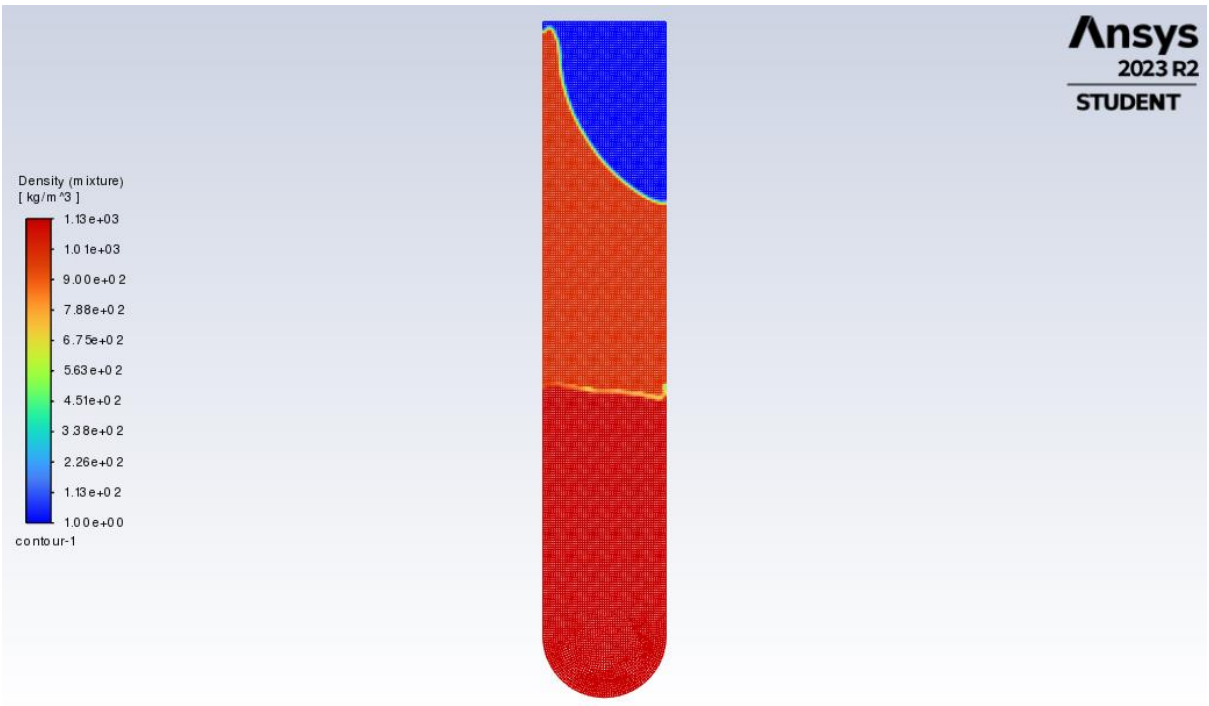

Fig: Frame 6

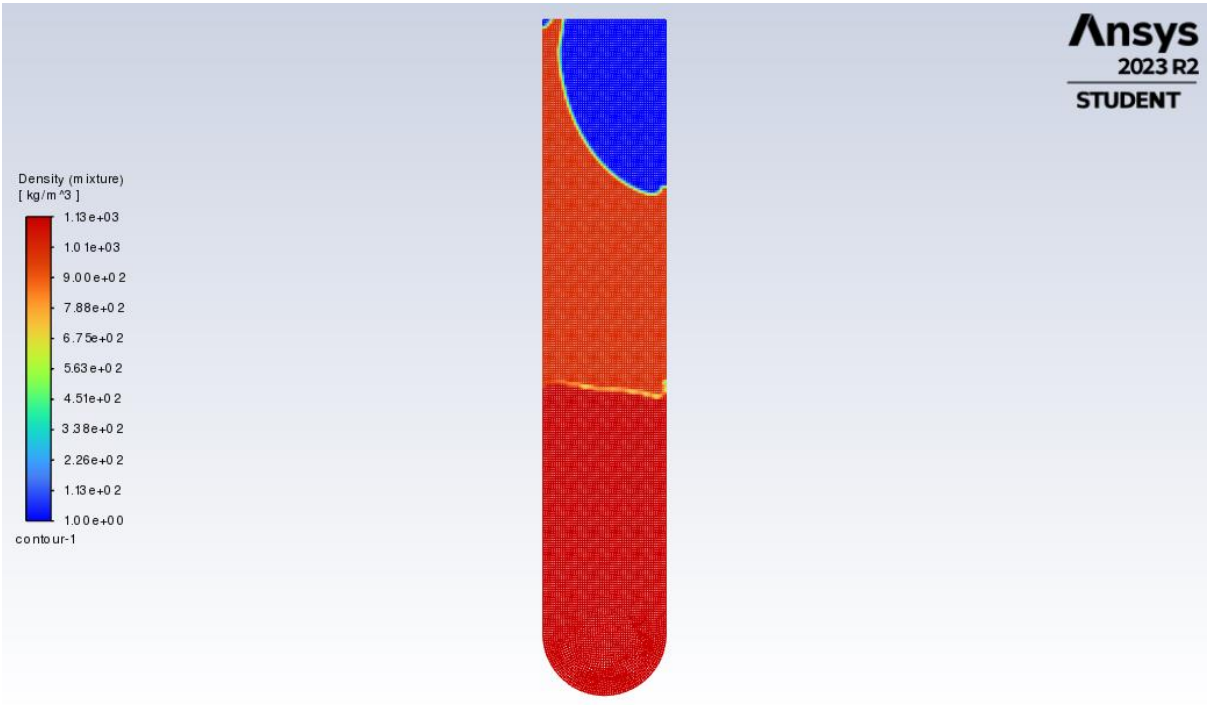

Fig: Frame 7

Description & Reasoning

Frame interval is 0.005 s

So therefore, at the 7^{th} frame the time is = 7*(time interval) = 7*(0.005) = 0.035 s = 35 ms

At the 6^{th} interval time is = 6*(0.005) = 30 ms.

- We can see from the above plots that while moving from Frame 6 to Frame 7 the plasma spills out.
- So, the plasma spills out between 30 -35 ms of time interval.

Reason: Centrifugal forces acting on the blood sample during this simulated
movement contribute to the observed plasma spillage.