

# Membrane flutter in three-dimensional inviscid flow

## Movie Caption List

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### **Caption for movie 1:**

We show 3 types of membrane motion from Group 1 in the order mentioned below.

i. Membrane motion with (FRFF, fixed-free-fixed-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-1}$ , pretension  $T_0 = 10^{-0.75}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the purple region (■) in figure 12.

ii. Membrane motion with (FRFR, fixed-free-fixed-free) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^1$ , pretension  $T_0 = 10^{-0.75}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the green region (■) in figure 12.

iii. Membrane motion with (FFFF, fixed-fixed-fixed-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^0$ , pretension  $T_0 = 10^{-0.25}$ , and stretching rigidity  $R_3 = 10^0$ . This motion corresponds to the yellow region (■) in figure 12 and it is periodic.

### **Caption for movie 2:**

We show 3 types of membrane motion from Group 2 in the order mentioned below.

i. Membrane motion with (FRRF, fixed-free-free-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-1}$ , pretension  $T_0 = 10^{-1.25}$ , and stretching rigidity  $R_3 = 10^0$ . This motion corresponds to the small-mass region of figure 13 and it is periodic.

ii. Membrane motion with (FRRF, fixed-free-free-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{0.5}$ , pretension  $T_0 = 10^{-0.5}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the moderate-mass region of figure 13 and it is periodic.

iii. Membrane motion with (FRRR, fixed-free-free-free) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{1.5}$ , pretension  $T_0 = 10^{-0.5}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the large-mass region of figure 13.

**Caption for movie 3:**

Group 3: Membrane motion with (RRFF, free-free-fixed-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-1}$ , pretension  $T_0 = 10^1$ , and stretching rigidity  $R_3 = 10^4$ . This motion corresponds to the light purple region (■) in figure 14 and it is periodic.

**Caption for movie 4:**

Group 3: Membrane motion with (RFFF, free-fixed-fixed-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-1.5}$ , pretension  $T_0 = 10^{0.5}$ , and stretching rigidity  $R_3 = 10^0$ . This motion corresponds to the yellow region (■) in figure 14 and it is periodic.

**Caption for movie 5:**

Group 3: Membrane motion with (RRFR, free-free-fixed-free) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-1.5}$ , pretension  $T_0 = 10^{1.75}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the dark purple region (■) in figure 14 and it is periodic.

**Caption for movie 6:**

We show 3 types of membrane motion from Group 4 in the order mentioned below.

i. Membrane motion with (RRRR, free-free-free-free) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{0.5}$ , pretension  $T_0 = 10^{-0.5}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the gray region (■) in figure 15.

ii. Membrane motion with (RRRF, free-free-free-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-0.5}$ , pretension  $T_0 = 10^{-0.75}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the purple region (■) in figure 15.

iii. Membrane motion with (RFRF, free-fixed-free-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-2}$ , pretension  $T_0 = 10^{-0.75}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the blue region (■) in figure 15.


**Caption for movie 7:**

Group 4: Membrane motion with (RFRF, free-fixed-free-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-0.5}$ , pretension  $T_0 = 10^{-1}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the green region (■) in figure 15 and it is periodic.


**Caption for movie 8:**

Group 4: Membrane motion with (RFRF, free-fixed-free-fixed) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^2$ , pretension  $T_0 = 10^{-0.5}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the yellow region (■) in figure 15.

**Caption for movie 9:**

Group 4: Membrane motion with (RRRR, free-free-free-free) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^0$ , pretension  $T_0 = 10^{-0.75}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the orange region () in figure 15 and it is periodic.

**Caption for movie 10:**

Group 4: Membrane motion with (RRRR, free-free-free-free) boundary conditions and with dimensionless quantities: membrane mass  $R_1 = 10^{-2}$ , pretension  $T_0 = 10^{-1}$ , and stretching rigidity  $R_3 = 10^1$ . This motion corresponds to the red region () in figure 15.

The  $x$ -axis shows the  $x(\alpha_1, \alpha_2, t)$ -coordinate of the membrane, the  $y$ -axis shows the  $y(\alpha_1, \alpha_2, t)$ -coordinate, and the  $z$ -axis shows the  $z(\alpha_1, \alpha_2, t)$ -coordinate. In all the videos the frame rate has been adjusted to show the motion over a time period that captures the overall motion of the membrane.