Lab 3: Plate Kinematics (35 points)

Group Exercises
The purpose of the group exercises is to allow you to gain confidence with velocity space diagrams while working on a team. Because you must reach an agreement about how to construct the velocity space vectors from the given plate geometry, you are less likely to make common errors. Dissect and solve each problem together. Each student should then develop the velocity space diagram on their own lab sheet. This group portion of the lab should be completed by the end of today’s lab. You may hand in the individual portion before the next lab session. Include all your work.

Relative motions in plane space
1. (4 pts) Two examples of transform faults are shown below. For each diagram, make a prediction about what will happen to the length of the transform fault in the immediate future. Will the transform fault increase in length, decrease in length, or remain constant in length? If you predict a change in transform fault length, what will be the rate of change of fault length? You may be able to just reason out your answer. However, you should also develop a velocity space diagram for each of these problems, drawing and labeling all plate boundaries. It’s good practice for the problems to come.

a.

Plate Geometry

Velocity Space Diagram

A

B

5 cm/yr

1 cm/yr
2. (8 pts) Here’s a more challenging plate motion problem involving four plates named after towns in Chile (pictured on the next page). This problem may look imposing, but is straightforward if you just attack it systematically. North is up in the diagram; the convergence direction of the Andacollo Plate with respect to the Constitution Plate is N10°W and the convergence direction of the Valparaiso Plate under the Litipampa Plate is S45°W. There is a RTF triple junction, J, between the Constitution, Andacollo, and Valparaiso Plates. There is another triple junction, Q, between the Andacollo, Valparaiso, and Litipampa Plates. Develop a velocity space diagram for both of these triple junctions. Locate and label the positions of all the plates and all the plate boundaries in velocity space. Also locate the triple junctions, J and Q, in velocity space. Then answer the following questions:

a. What is the velocity and direction of triple junction J, relative to the Andacollo Plate?

b. What kind of triple junction is Q? (Stable or Unstable? TTT, RRR, FFF, etc?)

c. What is the velocity and direction of triple junction Q, relative to the Litipampa Plate?

d. What is the velocity and direction of triple junction J, relative to the Litipampa Plate?

e. What is the fate of this plate configuration? Think about it relative to the Constitution and Litipampa Plates.
Relative motions on the sphere

Example The sphere below shows the relative rotation of Plate B with respect to Plate A. The relative rotation vector, $\mathbf{A}\omega\mathbf{B}$, is shown and the ridges, trenches, and transform faults separating Plates A and B are illustrated. The rate of angular rotation ($\mathbf{A}\omega\mathbf{B}$) of Plate B with respect to Plate A is $7.8\times10^{-7}/\text{yr} = 0.78^\circ/\text{m.y.} = 1.36\times10^{-8}\text{ rad/yr}$ (note that the radian unit is dimensionless). For convenience, a latitude/longitude grid (in $10^\circ$ increments) is provided with the grid axis located at the pole of relative rotation.
Formula for velocity on a sphere, \( \mathbf{v} = [A\omega B] [R] [\sin(q)] \)

where:
\( \mathbf{v} \) is velocity
\( A\omega B \) is angular rotation rate
\( R \) is Earth radius = 6370 km = 6.37\( \times \)10\(^9\) mm
\( q \) is angular distance from the pole of relative rotation

a. **Determine the full spreading rates of the ridge at points 1, 2, and 3:**

Point 1:
- \( q = 25^\circ \)
- \( \mathbf{v} = [A\omega B] [R] [\sin(q)] = [1.36\times10^{-8}/\text{yr}] [6.37\times10^9 \text{ mm}] [\sin(25^\circ)] = 36.6 \text{ mm/yr} = 36.6 \text{ km/m.y.} \)

Point 2:
- \( q = 60^\circ \)
- \( \mathbf{v} = [A\omega B] [R] [\sin(q)] = [1.36\times10^{-8}/\text{yr}] [6.37\times10^9 \text{ mm}] [\sin(60^\circ)] = 75.0 \text{ mm/yr} = 75.0 \text{ km/m.y.} \)

Point 3:
- \( q = 90^\circ \)
- \( \mathbf{v} = [A\omega B] [R] [\sin(q)] = [1.36\times10^{-8}/\text{yr}] [6.37\times10^9 \text{ mm}] [\sin(90^\circ)] = 86.6 \text{ mm/yr} = 86.6 \text{ km/m.y.} \)

b. **Determine the convergence rates along the trench at points 4 and 5:**

Point 4:
- \( q = 30^\circ \)
- \( \mathbf{v} = [A\omega B] [R] [\sin(q)] = [1.36\times10^{-8}/\text{yr}] [6.37\times10^9 \text{ mm}] [\sin(30^\circ)] = 43.3 \text{ mm/yr} = 43.3 \text{ km/m.y.} \)

Point 5:
- \( q = 60^\circ \)
- \( \mathbf{v} = [A\omega B] [R] [\sin(q)] = [1.36\times10^{-8}/\text{yr}] [6.37\times10^9 \text{ mm}] [\sin(60^\circ)] = 75.0 \text{ mm/yr} = 75.0 \text{ km/m.y.} \)
3. (8 pts) The sphere below shows the relative rotation of Plate A with respect to Plate B. Consider Plate B to be stationary, as the diagram shows us locking down Plate B. The relative rotation vector, $B\omega_A$, is shown and the ridges, trenches, and transform faults separating Plates A and B are illustrated. The rate of angular rotation of Plate A with respect to Plate B is $5 \times 10^{-7}\,\text{o/yr} = 0.5^\circ/\text{m.y.} = 8.73 \times 10^{-9}\,\text{rad/yr}$. A latitude/longitude grid is provided (in 10° increments) with the grid axis located at the pole of rotation.

![Diagram of plate rotation](image)

a. Determine the full spreading rates of the ridge at points 2 and 3.

b. Determine the convergence rates along the trench at points 1 and 4.

c. Again assuming that Plate B is fixed and Plate A is in motion, draw the positions of all the plate boundaries at a time 40 m.y. into the future. Be careful! It is easy to jump to incorrect conclusions about what moves and what doesn't move. It is also easy to judge too quickly the rates of motion of the plate boundaries. Remember, the angular rotation rate of 0.5°/m.y. is the rotation of Plate A with respect to Plate B.
**Individual Exercises**

Now that you've got some experience wrangling with velocity space diagrams, try problems 4 and 5 on your own. You may either hand in your answers to the individual portion at the end of your lab session or at the start of your next lab. However, we strongly recommend that you start these problems during the lab session. That way, you can get assistance if you get stuck.

**Relative motions in plane space**

4. (7 pts) Consider the geometry shown below for Plates A, B, and C. The rate of ridge spreading between plates A and B is shown as is the rate of convergence between plates B and C. Determine the relative motion vector (both direction and magnitude) of Plate C with respect to Plate A. North is up in the diagram. It is easiest to solve this problem graphically by developing a velocity space diagram.
5. **(8 pts)** Now tackle a three-plate problem involving a triple junction. Consider the geometry shown below for Plates A, B, and C. There is a FFT triple junction for which we need to develop a velocity space diagram. The relative motion of Plate C with respect to Plate B is 2.2 cm/yr in the direction S 26° W. The transform fault between Plates A and B and the Trench between Plates B and C are co-linear. Again, north is up in the diagram. Develop a velocity space diagram for this triple junction. Locate and label the positions of all the plates and all the plate boundaries in velocity space. Also locate the triple junction, J, in velocity space. To which plate, if any, is the triple junction attached?

![Plate Geometry and Velocity Space Diagram](image)

**BONUS (4 pts.)** Triple junctions have played an important role in the evolution of Western North America over the last 30 million years. Explain how.