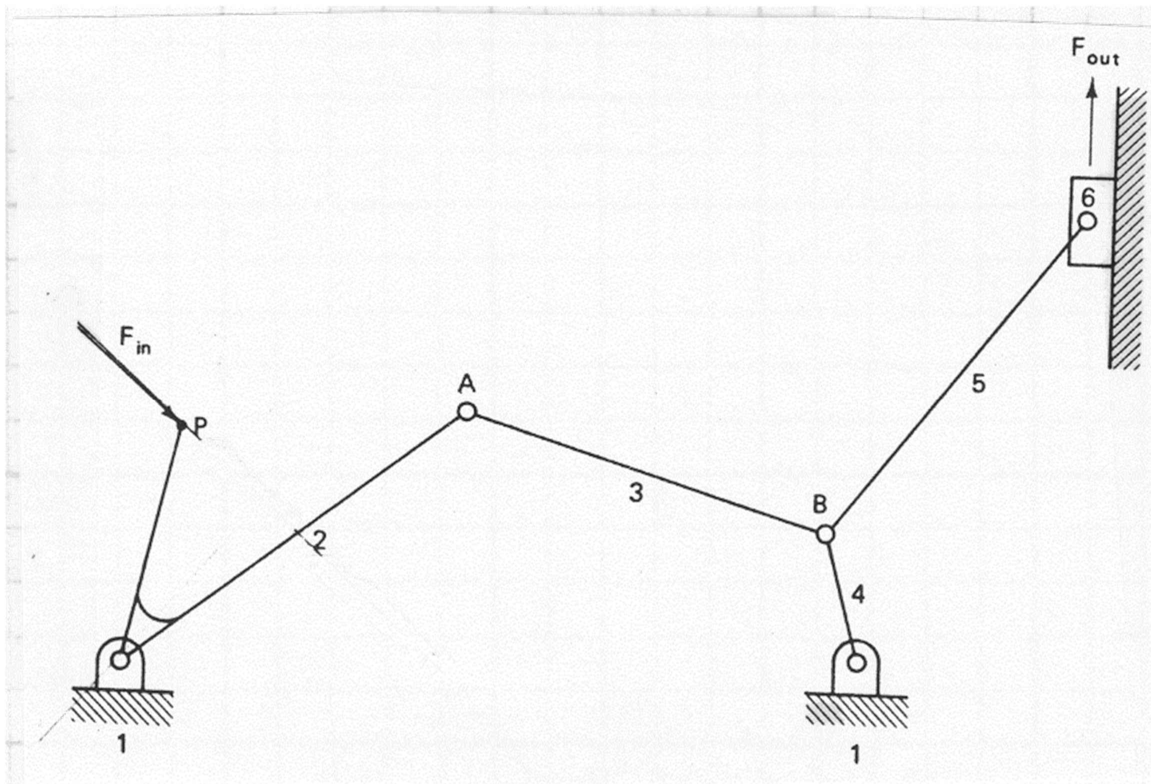
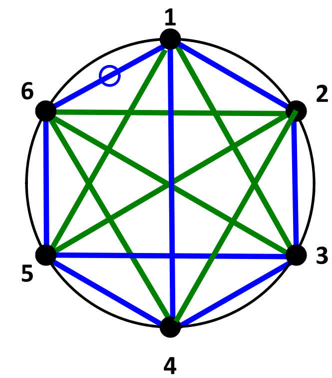
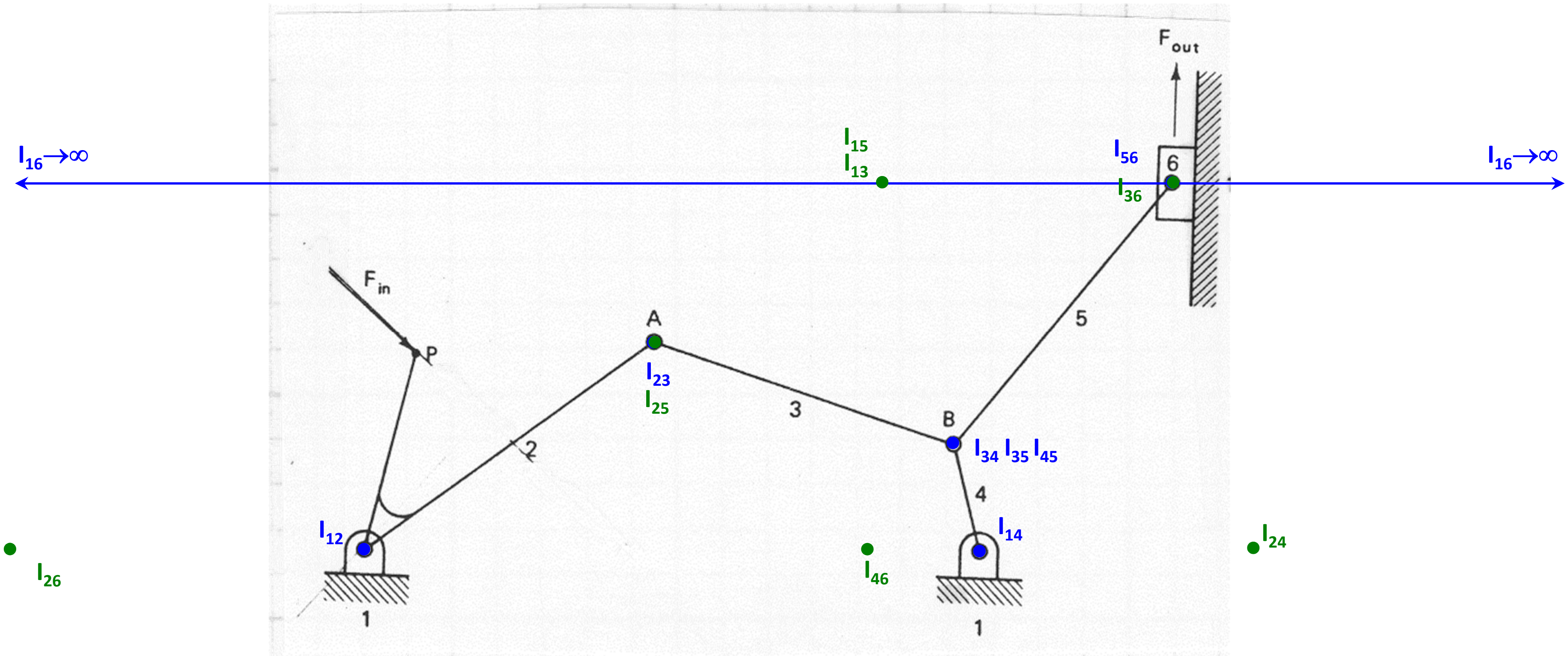
Finding the **LINEAR** and **ANGULAR VELOCITIES** associated with the mechanism shown using **graphical methods**.



ALL INSTANT CENTERS WERE PREVIOUSLY LOCATED FOR THIS MECHANISM

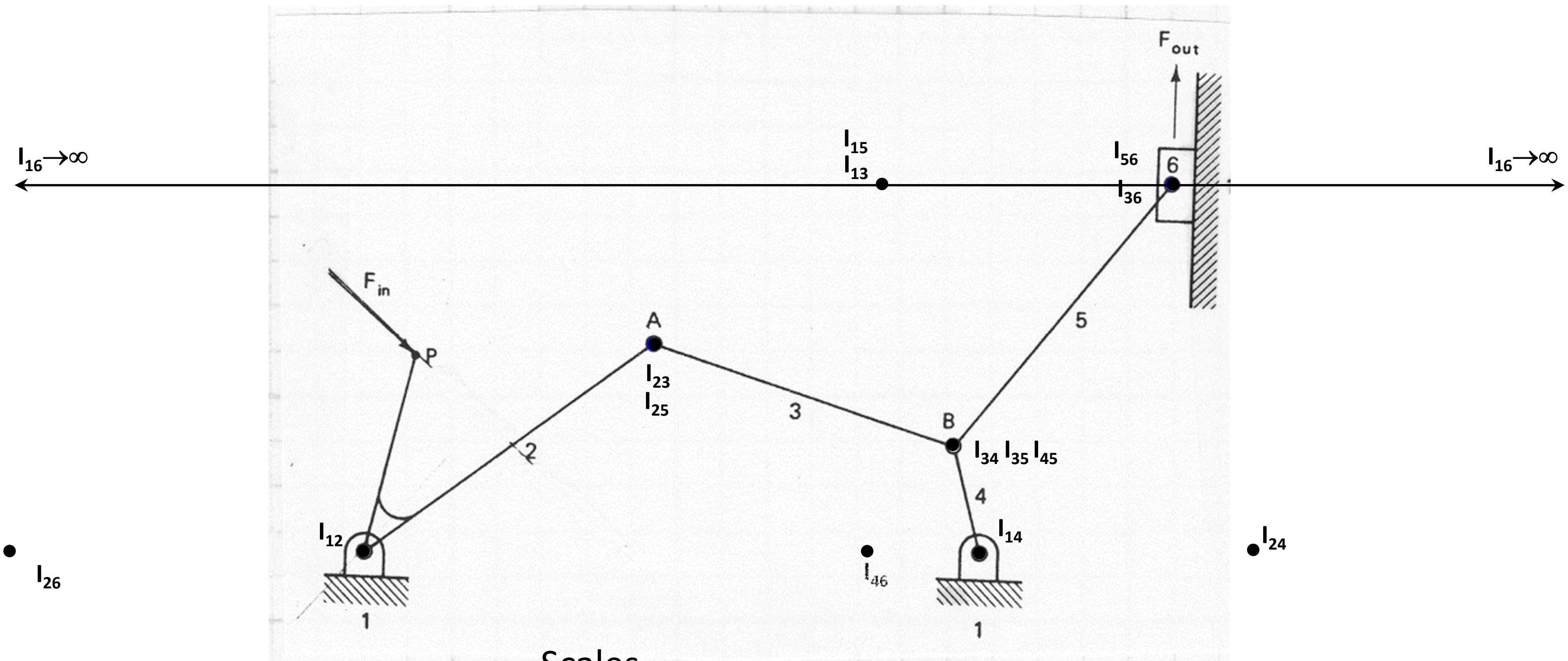




BELOW THE SCALE FOR THE DISTANCE AND VELOCITY ARE SHOWN. THESE WILL ACT AS RULERS FOR THE INSTANT CENTER ANALYSIS (Because of printing distortions, the scales shown may not measure 1 inch).

- **Length Scale: 1in = 1in**

-**Velocity Scale: 1in = 10 in/s**



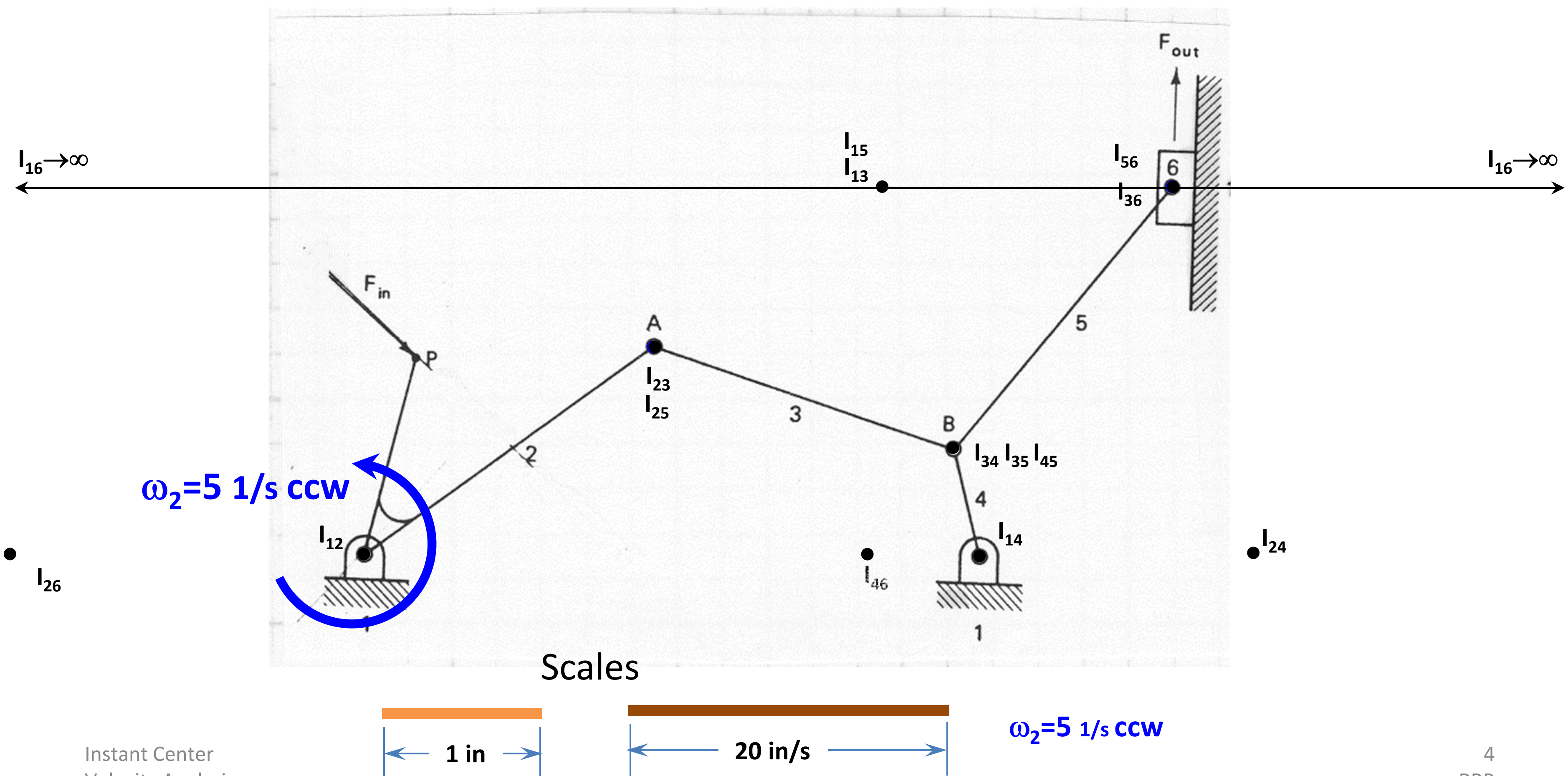
Scales

1 in

20 in/s

The angular velocity of link 2 in this mechanism is given as ω_2=5 1/s ccw.

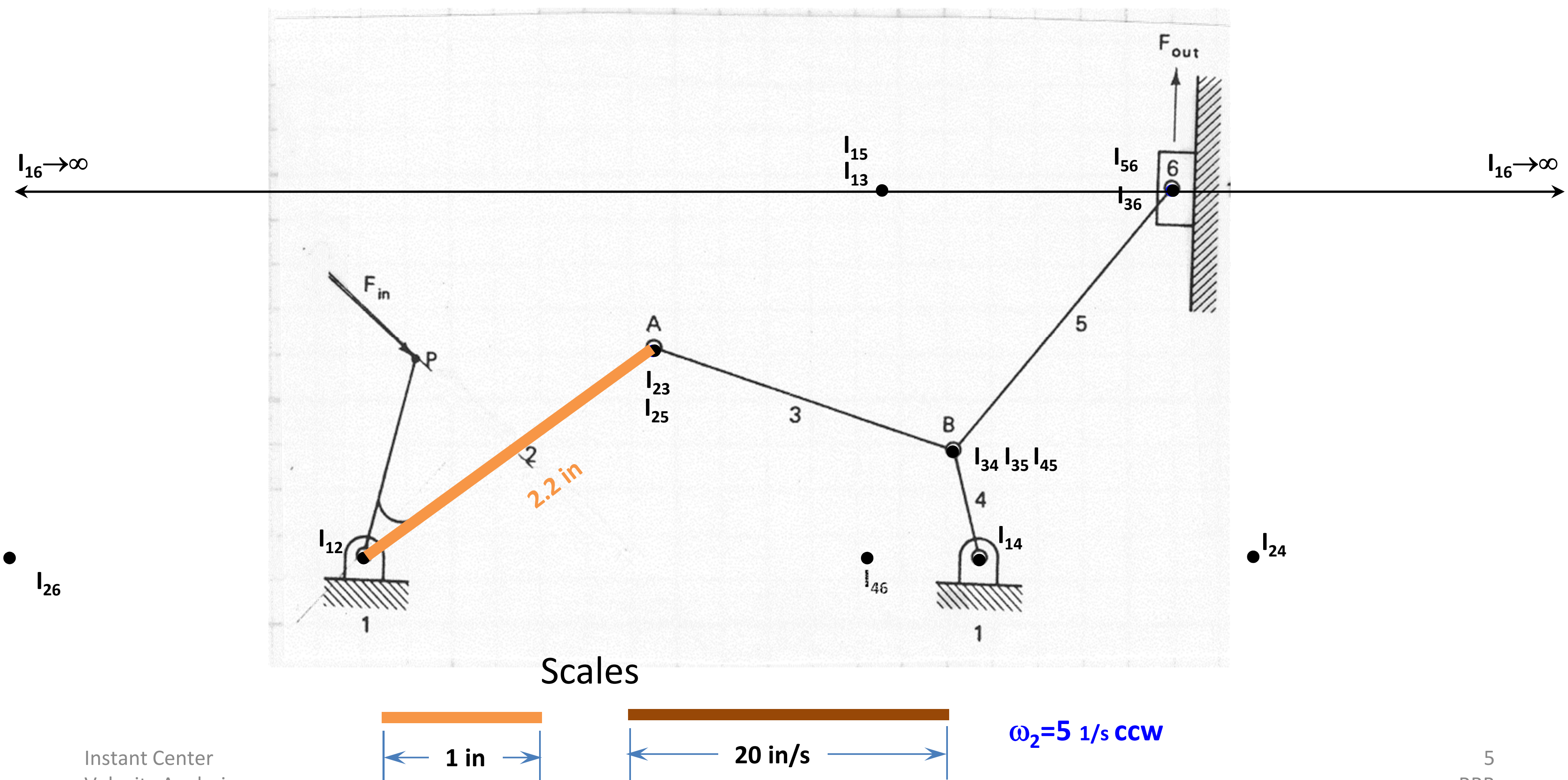
- The linear velocity of point A can now be calculated
  - Assumptions
    - v, ω, & r are orthogonal
    - Planar problem, all rotations out of paper
    - CCW rotations positive, CW rotations negative



ω_2=5 1/s ccw

The angular velocity of link 2 in this mechanism is given as ω_2=5 1/s ccw.

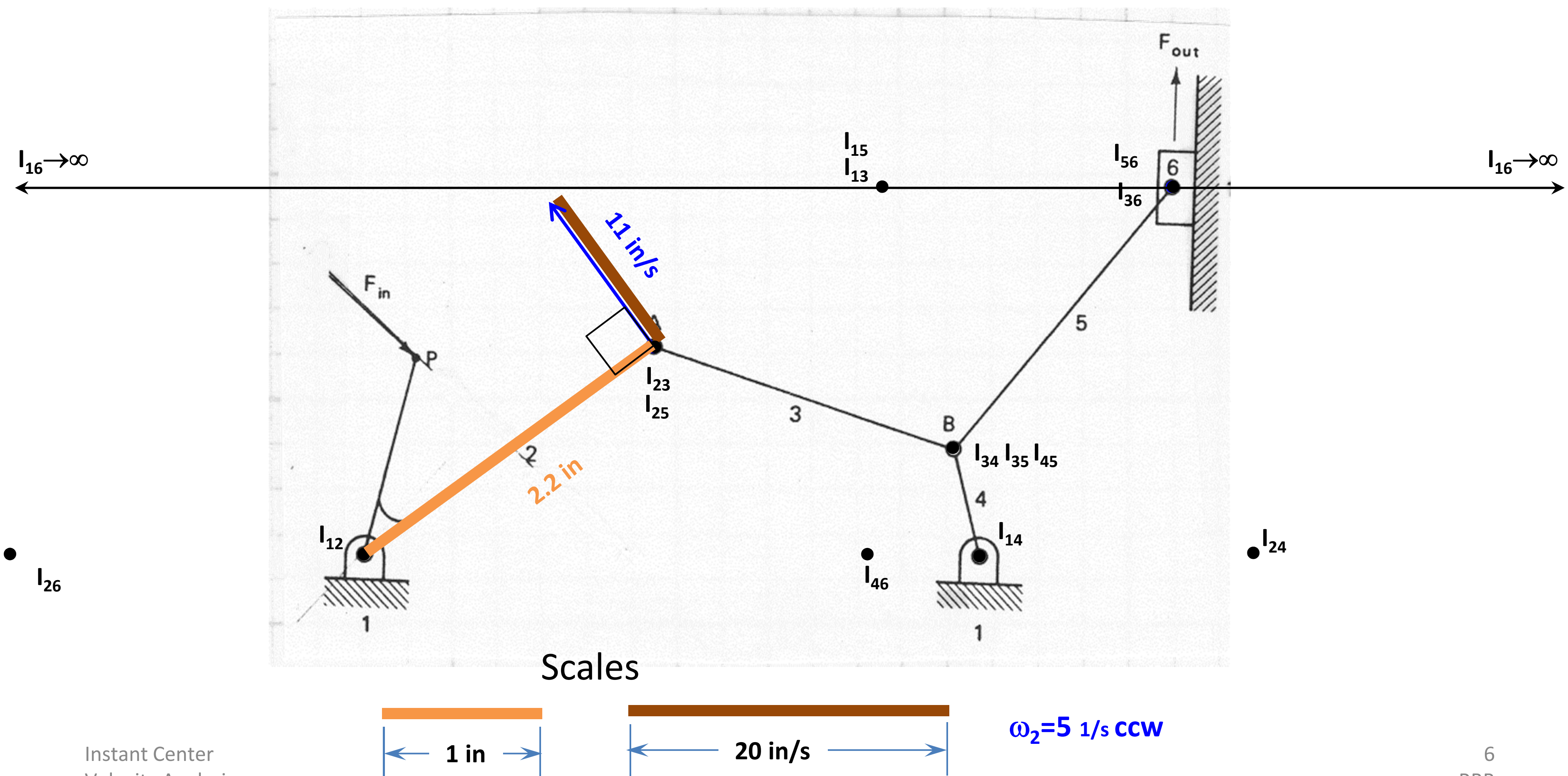
- The linear velocity of point A can now be calculated
  - The distance from I_{12} to A is measured as 2.2 in.



The angular velocity of link 2 in this mechanism is given as ω_2=5 1/s ccw.

- The linear velocity of point A can not we calculated
  - The distance from I_{12} to A is measured as 2.2 in.

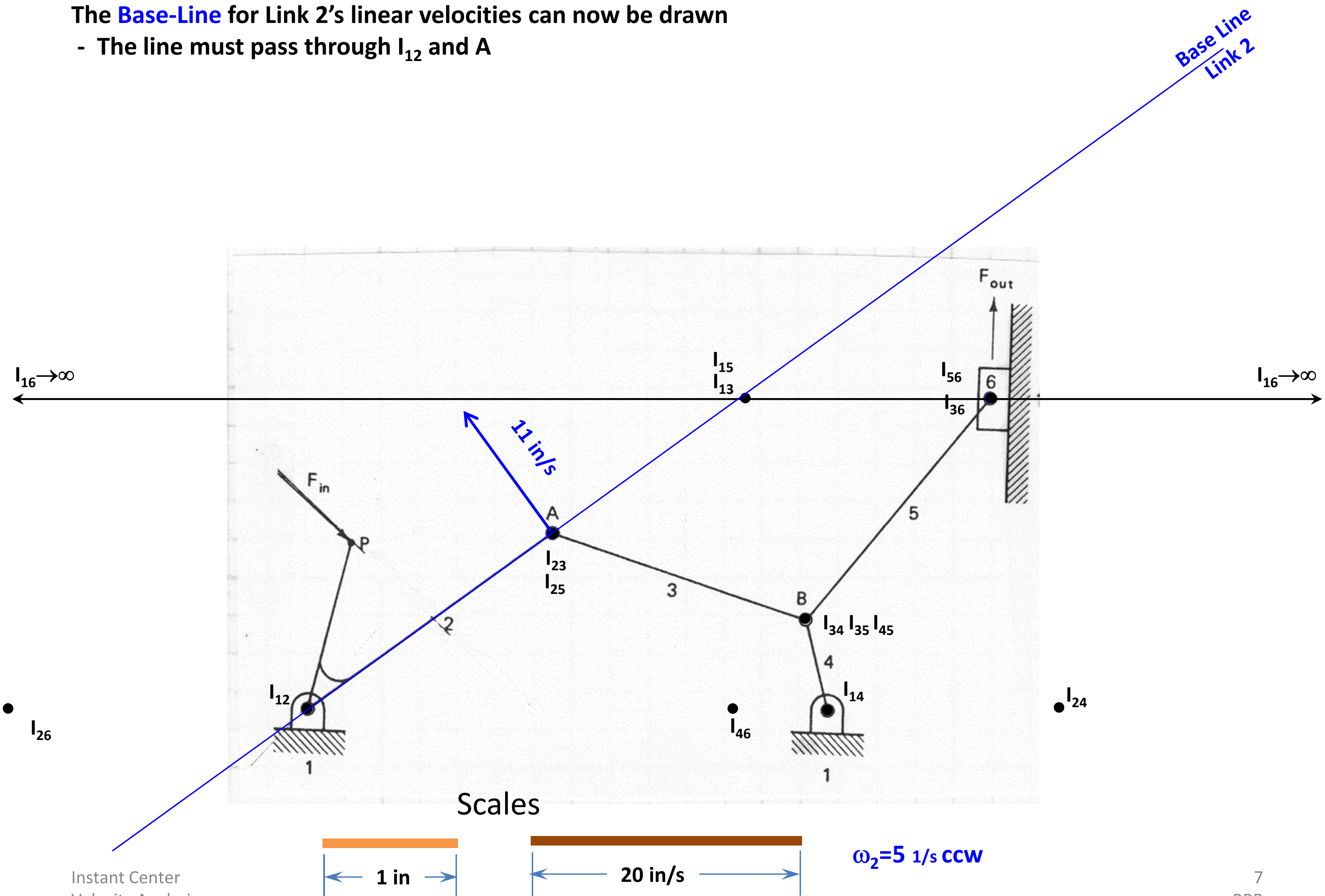
$$v_A = \omega_2 \cdot r_{AI_{12}} = 5\tfrac{1}{s} \cdot 2.2in = 11\tfrac{in}{s}$$



The angular velocity of link 2 in this mechanism is given as ω_2=5 1/s ccw.

The Base-Line for Link 2's linear velocities can now be drawn

- The line must pass through I_{12} and A

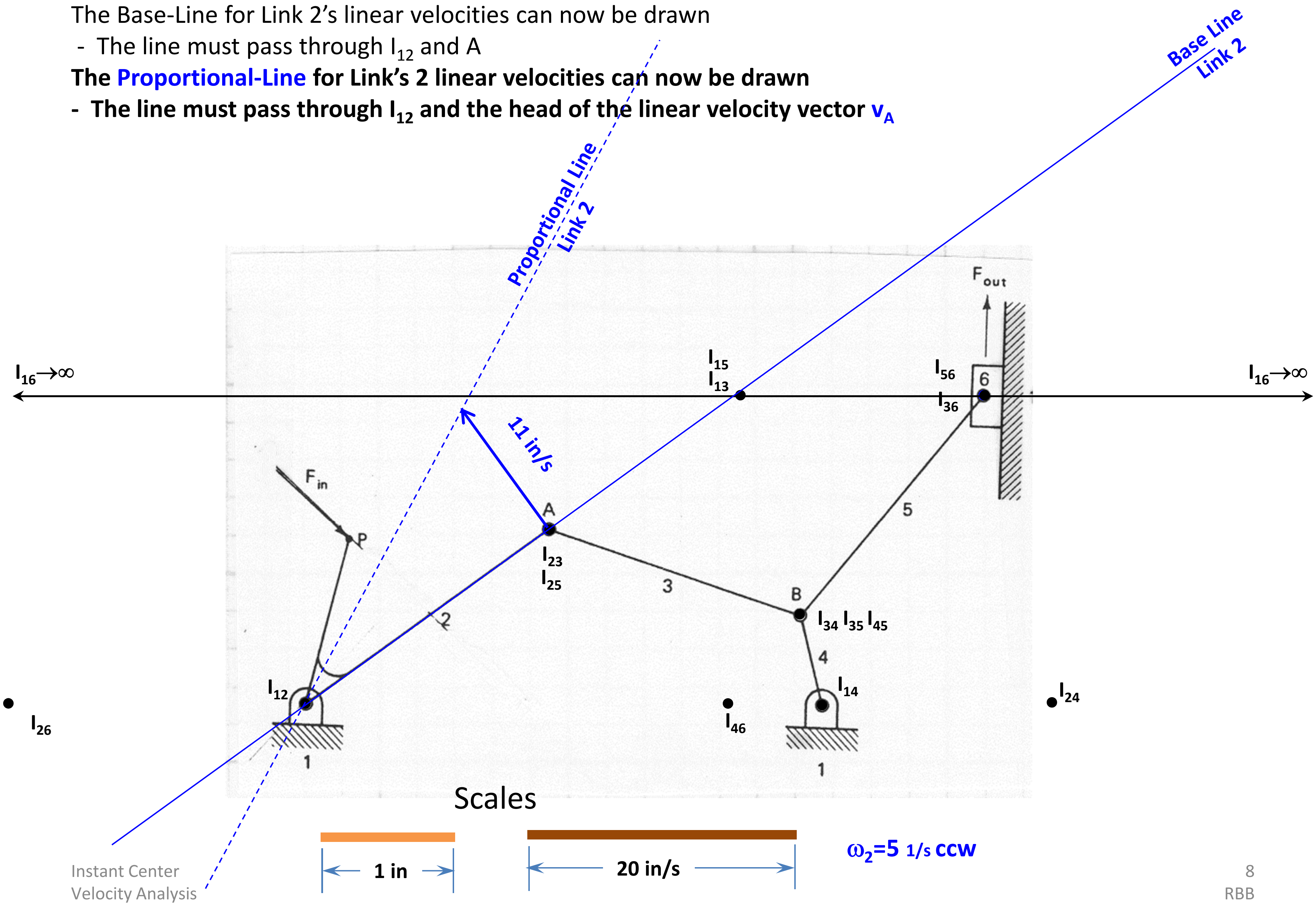


The angular velocity of link 2 in this mechanism is given as ω_2=5 1/s ccw.
The Base-Line for Link 2's linear velocities can now be drawn

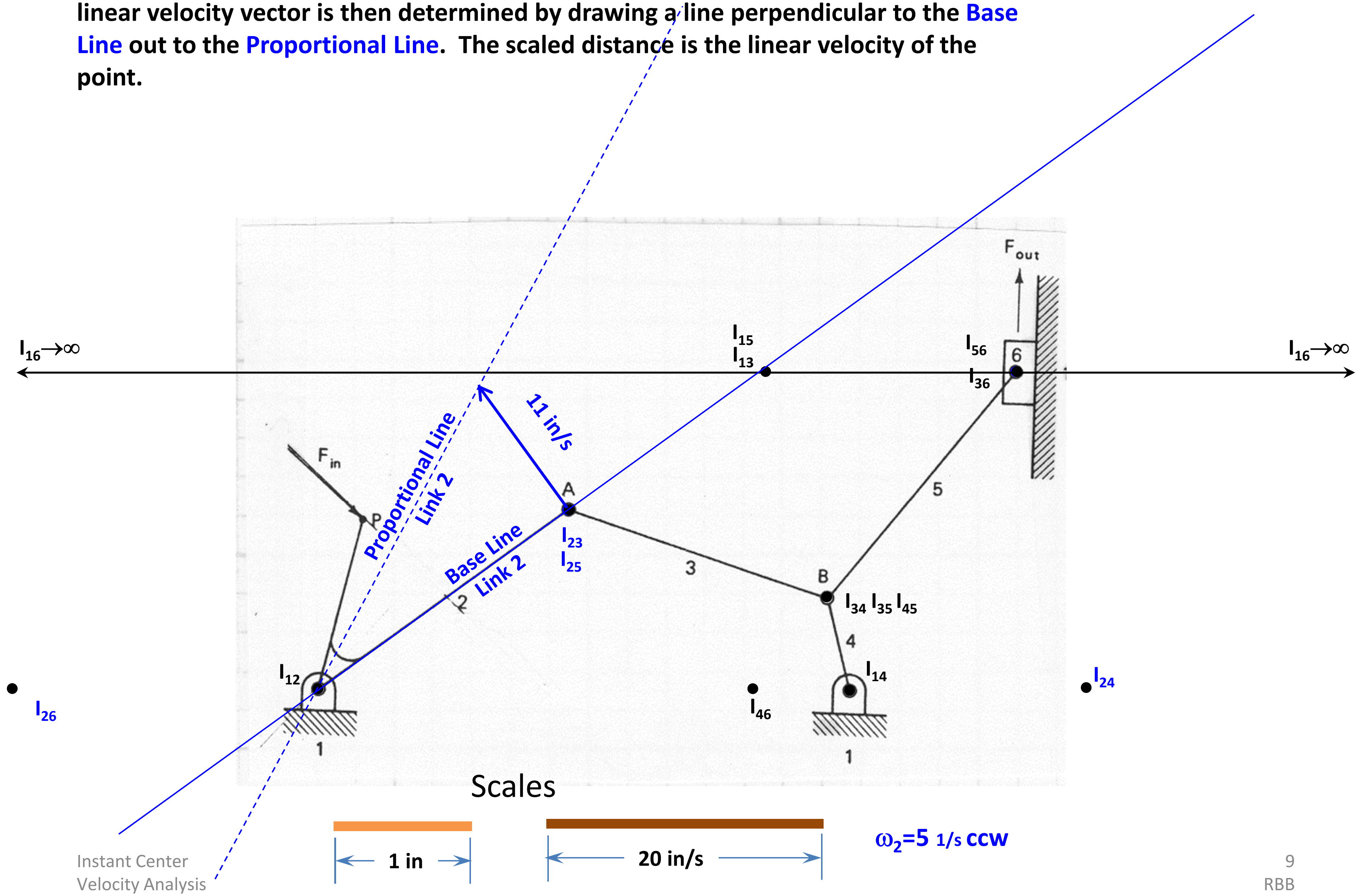
- The line must pass through I_{12} and A

The Proportional-Line for Link's 2 linear velocities can now be drawn

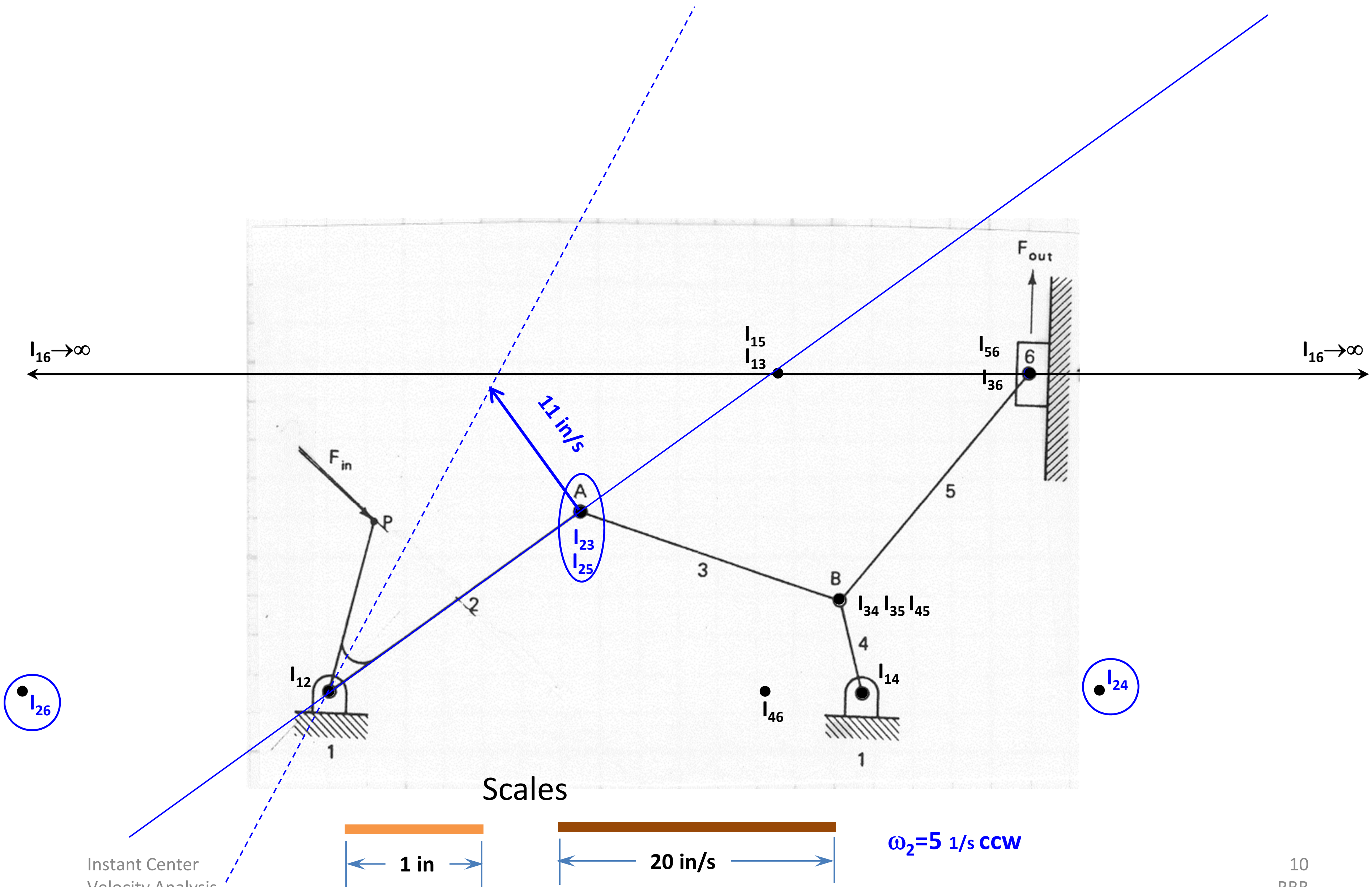
- **The line must pass through I_{12} and the head of the linear velocity vector v_A**



The velocity of any point on Link 2 can now be determined by scribing an arc centered at I_{12}, from the point of interest on Link 2 to the Link 2 Base Line. The linear velocity vector is then determined by drawing a line perpendicular to the Base Line out to the Proportional Line. The scaled distance is the linear velocity of the point.



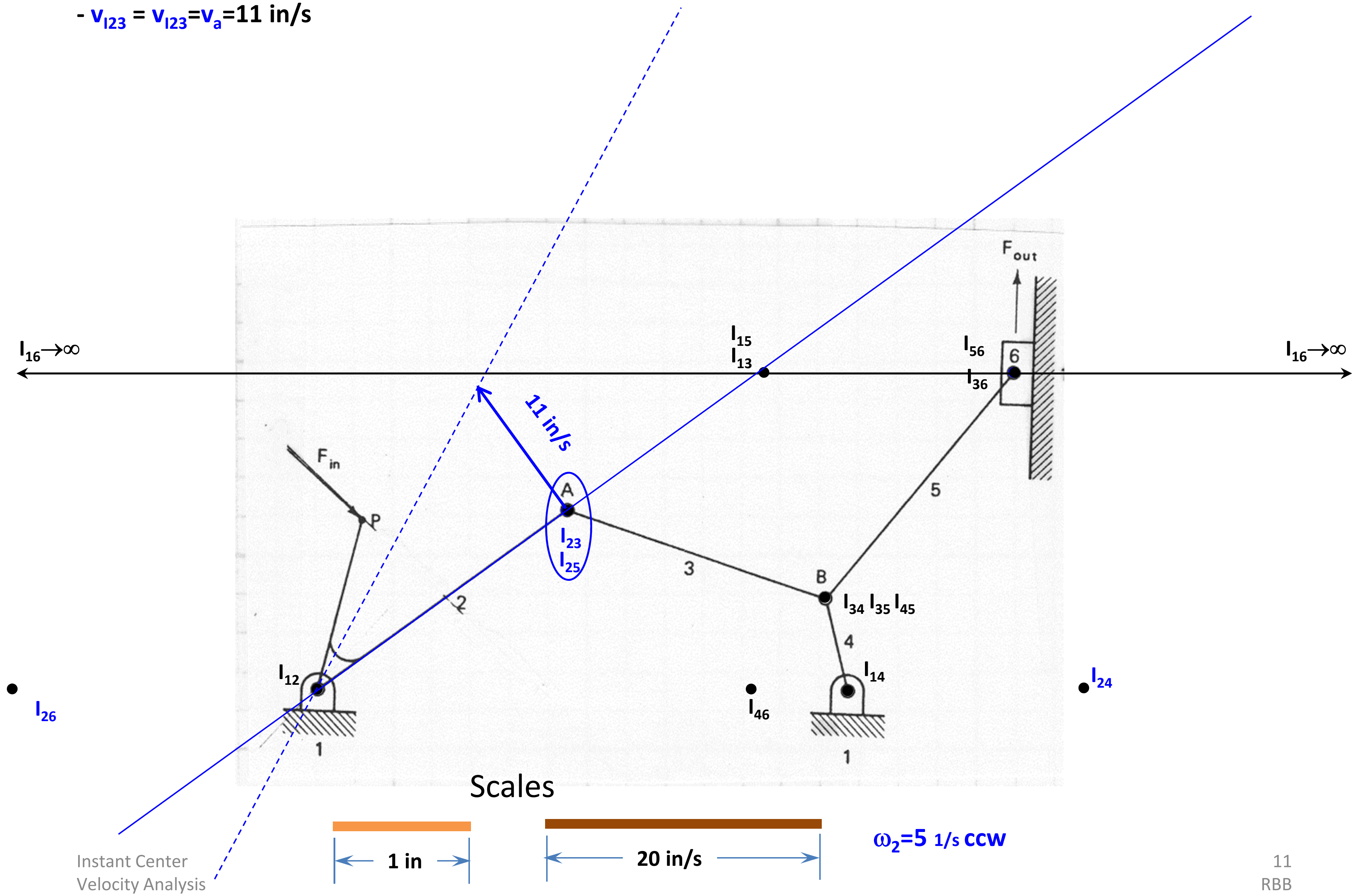
The linear velocities of Instant Centers I_{23}, I_{24}, I_{25}, and I_{26} can now be found



The linear velocities of Instant Centers I_{23}, I_{24}, I_{25}, and I_{26} can now be found

- The linear velocities of I_{23}, and I_{25} are seen to be v_A because they are at A.

- v_{I23} = v_{I23}=v_a=11 in/s



Scales

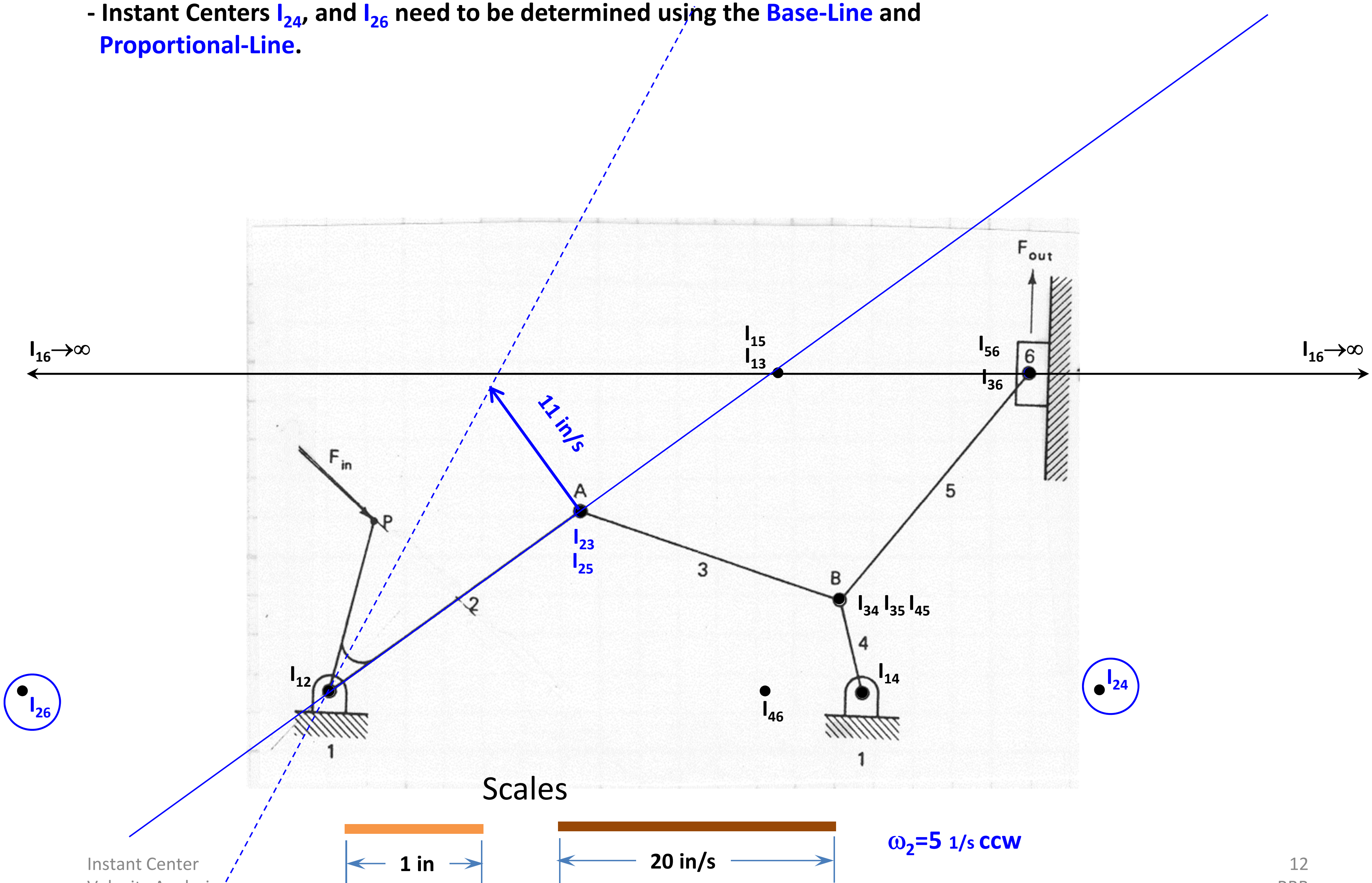
1 in

20 in/s

ω_2=5 1/s ccw

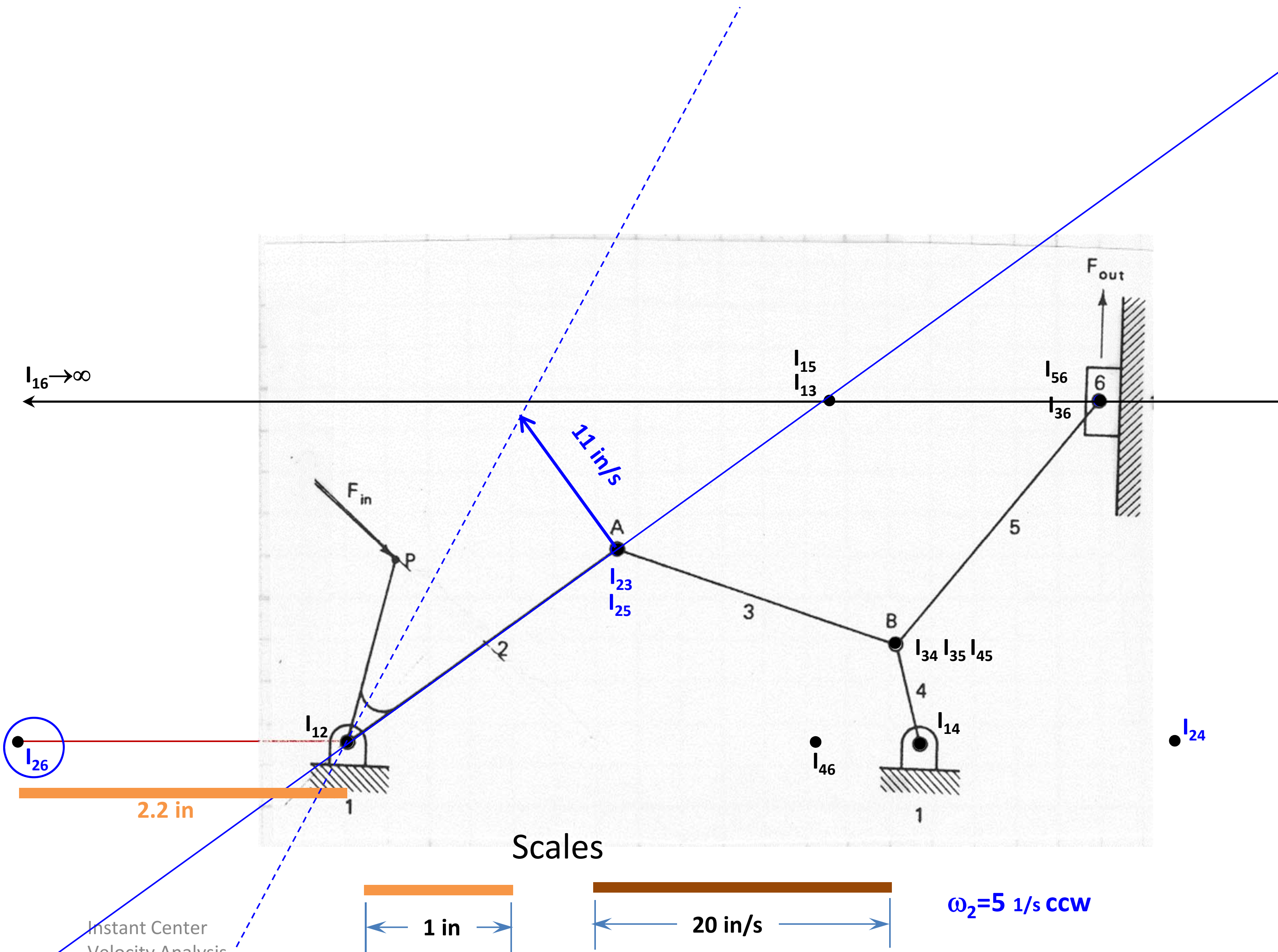
The linear velocities of Instant Centers I_{23}, I_{24}, I_{25}, and I_{26} can now be found

- The linear velocities of I_{23}, and I_{25} are seen to be v_A because they are at A.
- **Instant Centers I_{24}, and I_{26} need to be determined using the Base-Line and Proportional-Line.**



Determining the Linear Velocity of Instant Center I_{26}

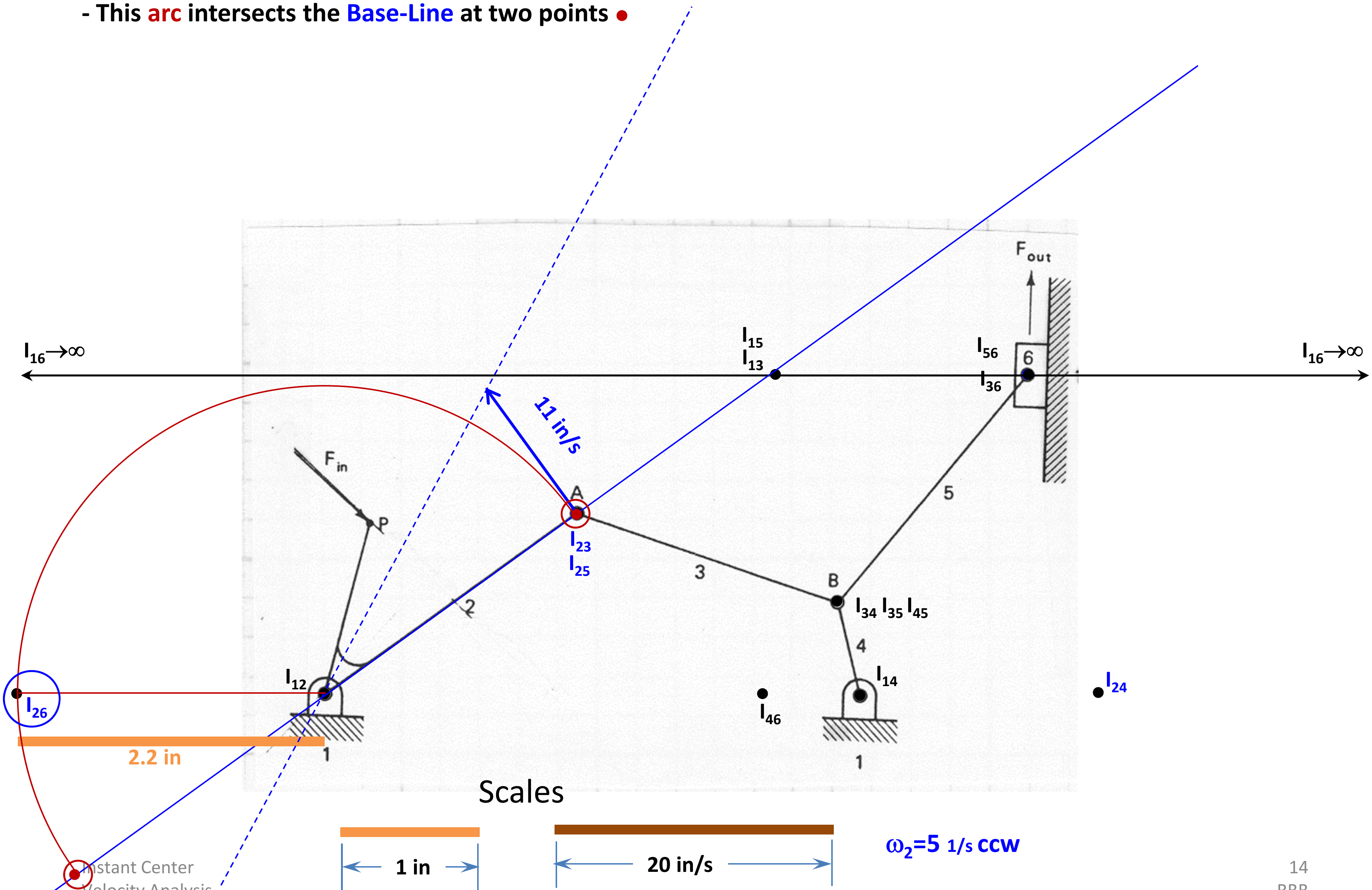
- I_{26} is the location on Link 2 where the linear velocity is the same as on Link 6



Determining the Linear Velocity of Instant Center I_{26}

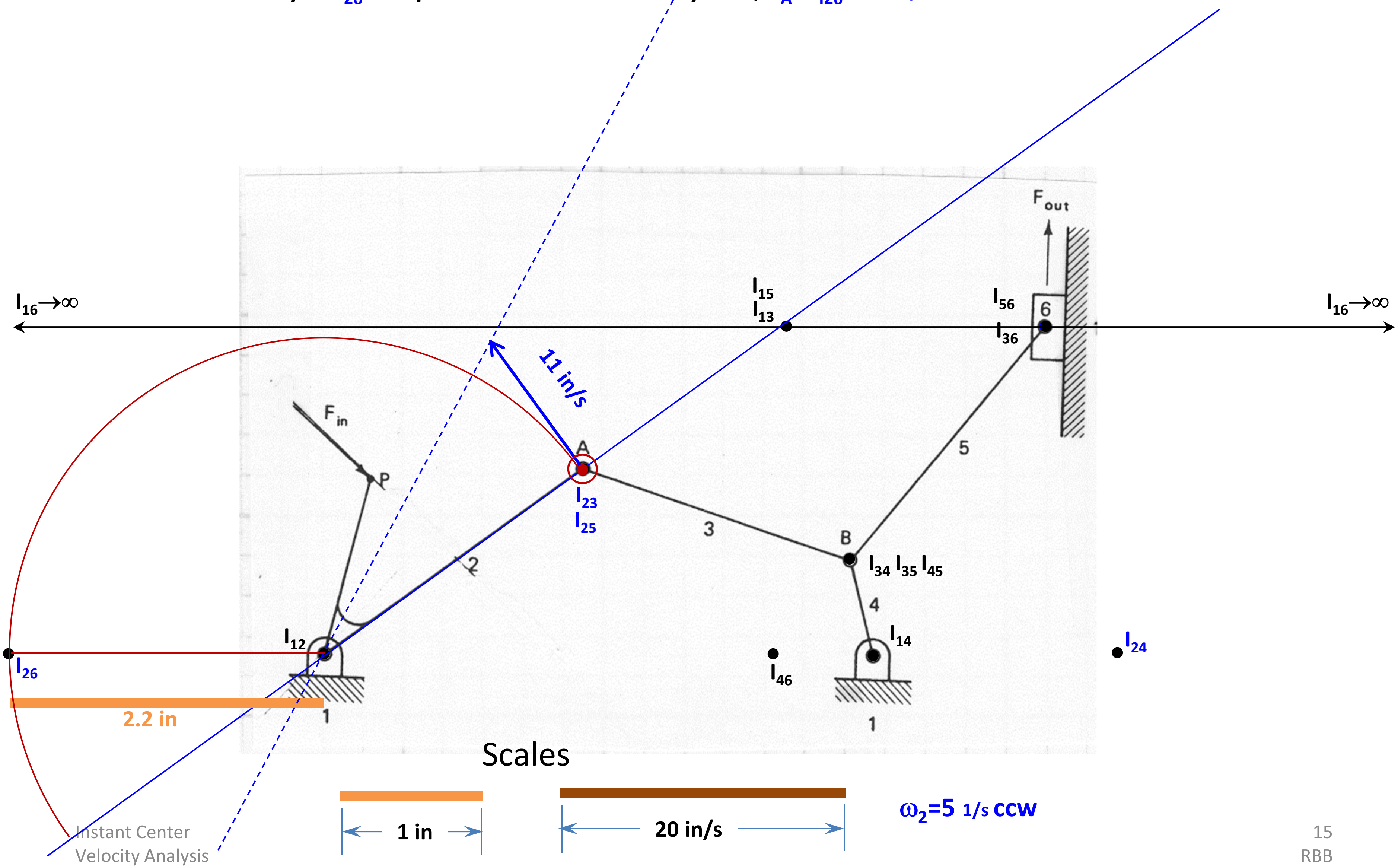
- A circular arc is scribed from I_{26} back to the Link 2 Base-Line

- This arc intersects the Base-Line at two points ●



Determining the Linear Velocity of Instant Center I_{26}

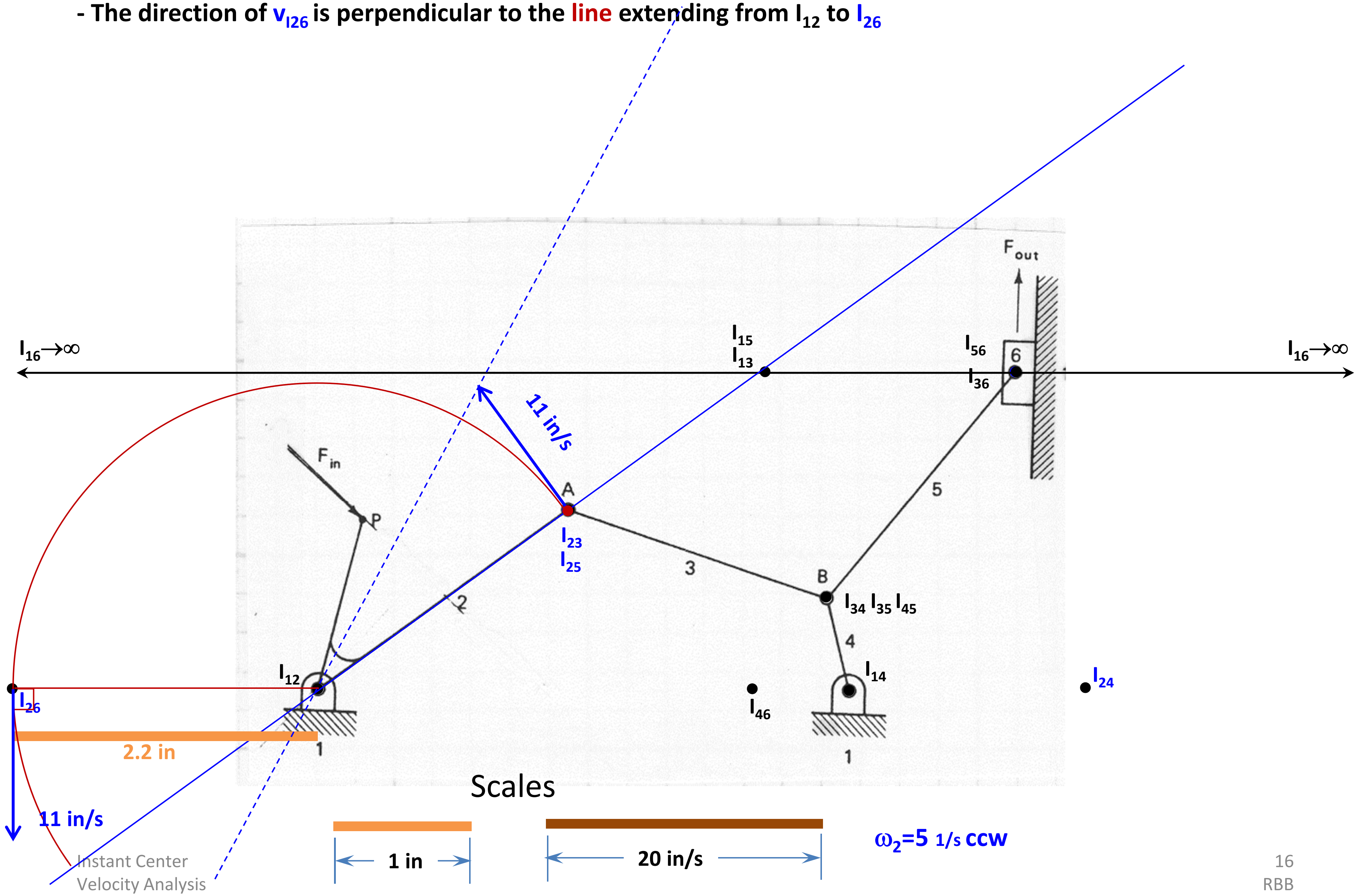
- **Either point can be used to determine the velocity**
- **Since the arc intersects the Link 2 Base-Line at A, that intersection will be used**
- **The linear velocity at I_{26} is equal to the linear velocity at A, $v_A = v_{I26} = 11$ in/s**



Determining the Linear Velocity of Instant Center I_{26}

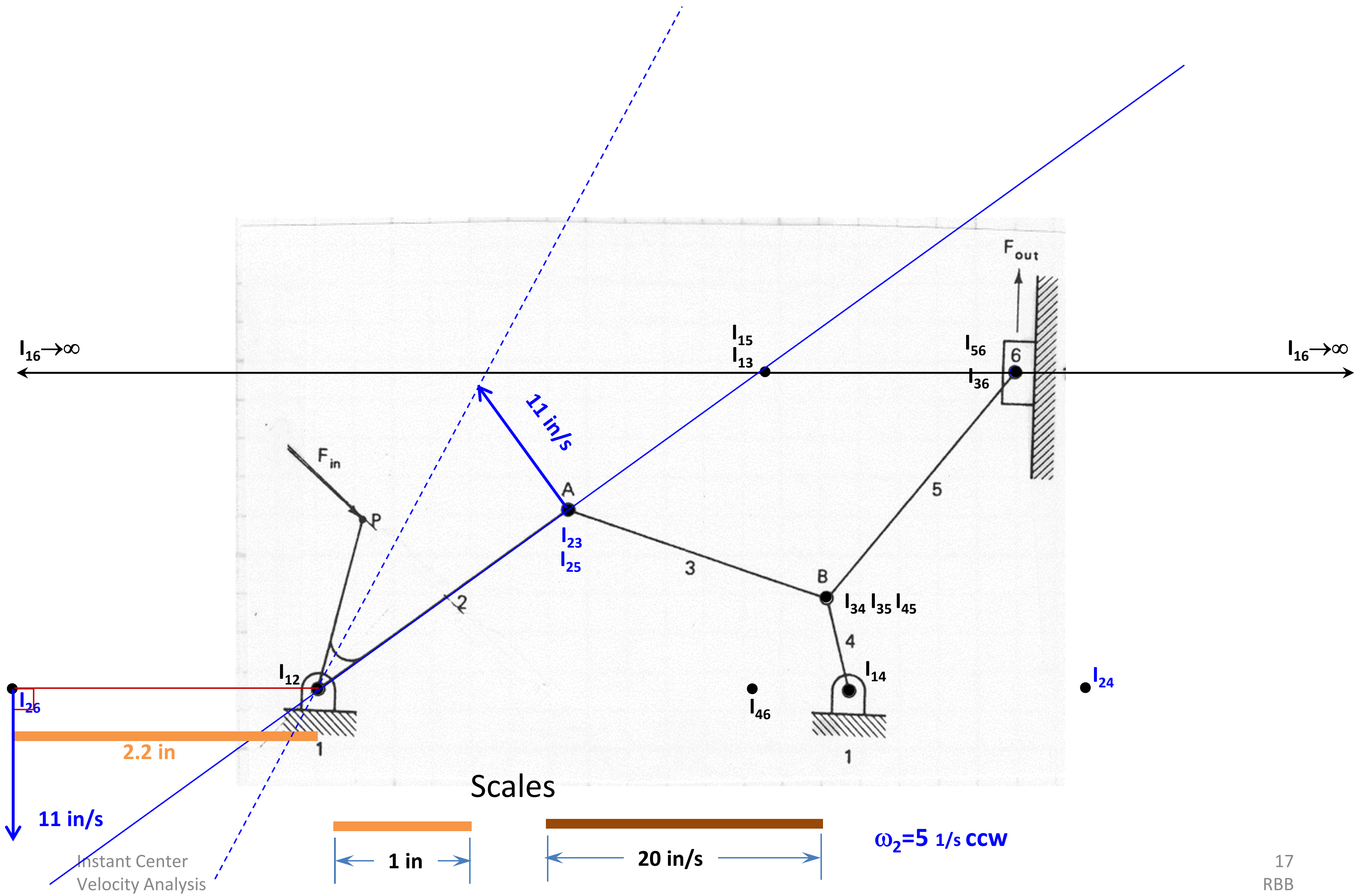
- The magnitude of the linear velocity at I_{26} is $v_A = v_{I26}$

- The direction of v_{I26} is perpendicular to the line extending from I_{12} to I_{26}



An **ALTERNATE** approach to determining the Linear Velocity of Instant Center I_{26}

- The distance from I_{12} to I_{26} is measured as 2.2 in.



An ALTERNATE approach to determining the Linear Velocity of Instant Center I_{26}

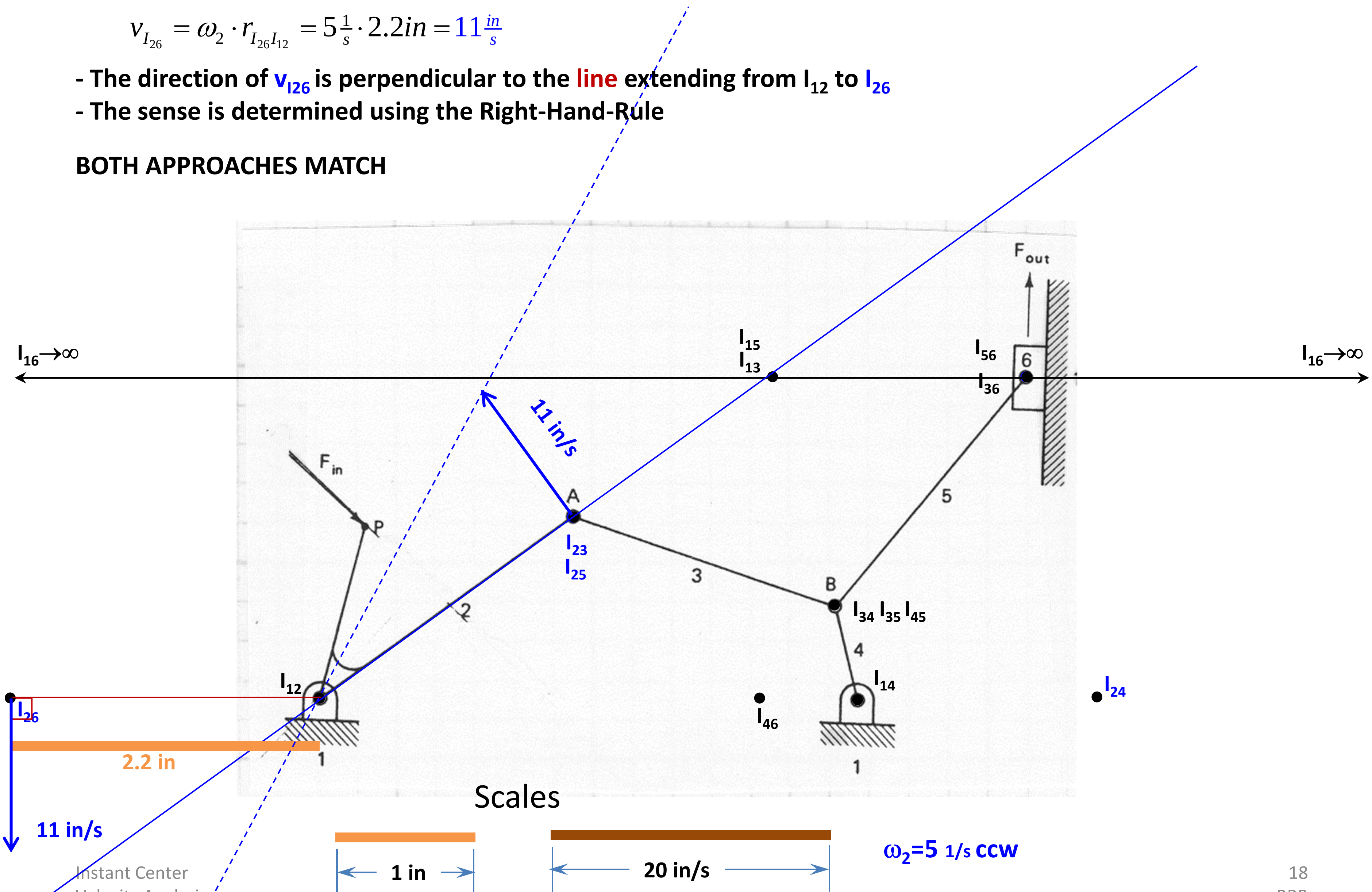
- The distance from I_{12} to I_{26} is measured as 2.2 in.

$$v_{I_{26}} = \omega_2 \cdot r_{I_{26}I_{12}} = 5\tfrac{1}{s} \cdot 2.2in = 11\tfrac{in}{s}$$

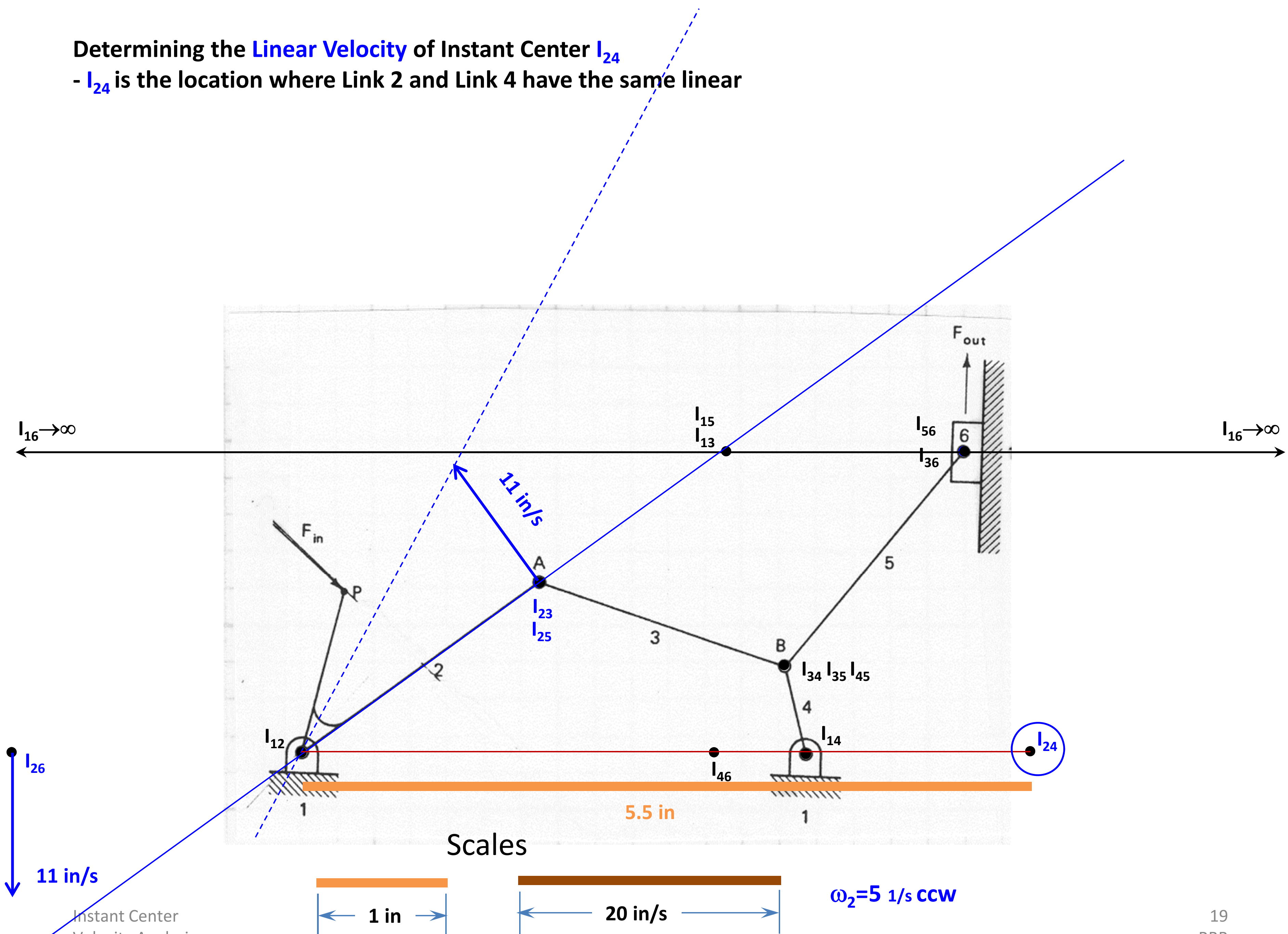
- The direction of v_{I26} is perpendicular to the line extending from I_{12} to I_{26}

- The sense is determined using the Right-Hand-Rule

BOTH APPROACHES MATCH



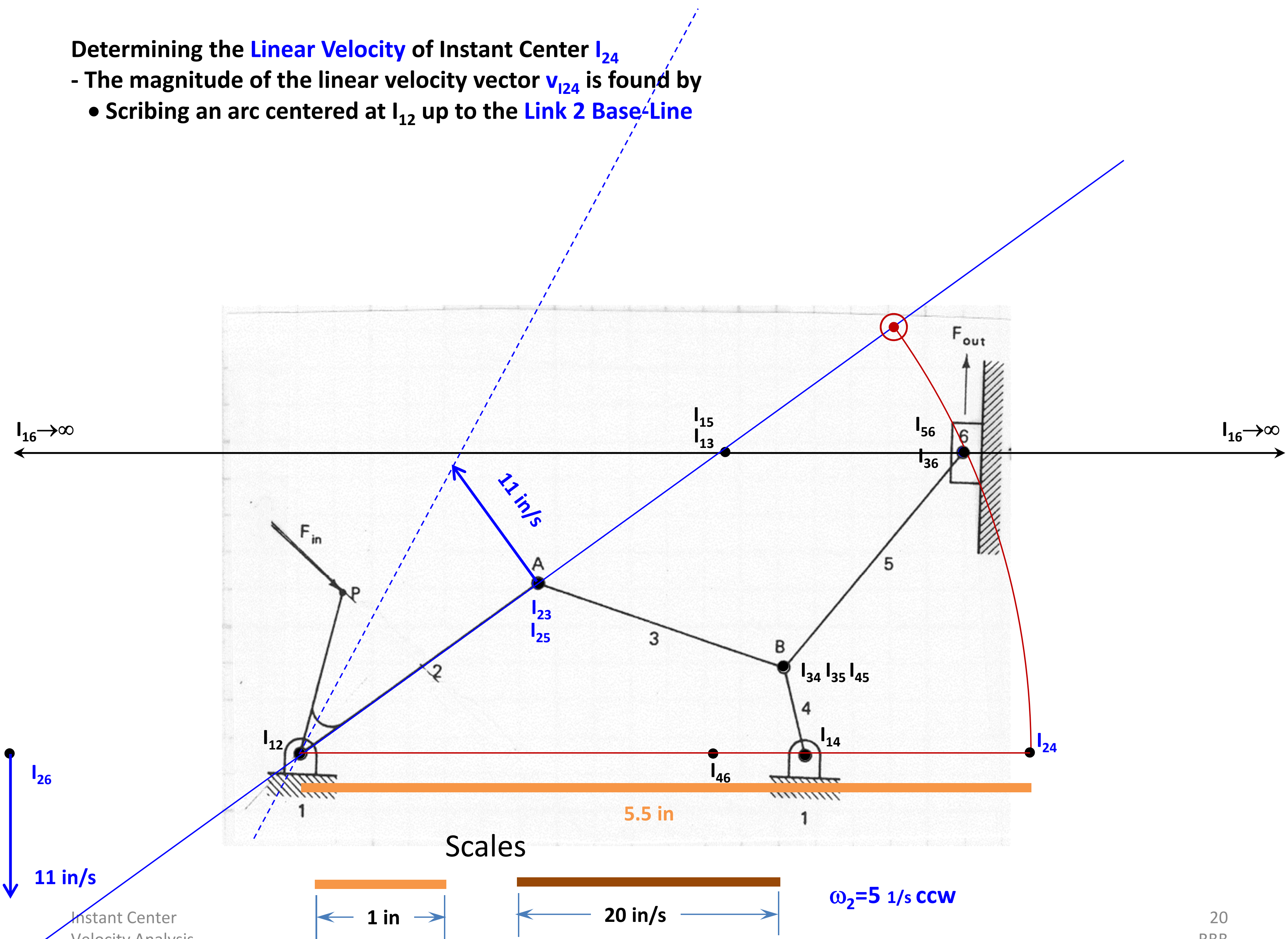
Determining the Linear Velocity of Instant Center I_{24}
- I_{24} is the location where Link 2 and Link 4 have the same linear



Determining the Linear Velocity of Instant Center I_{24}

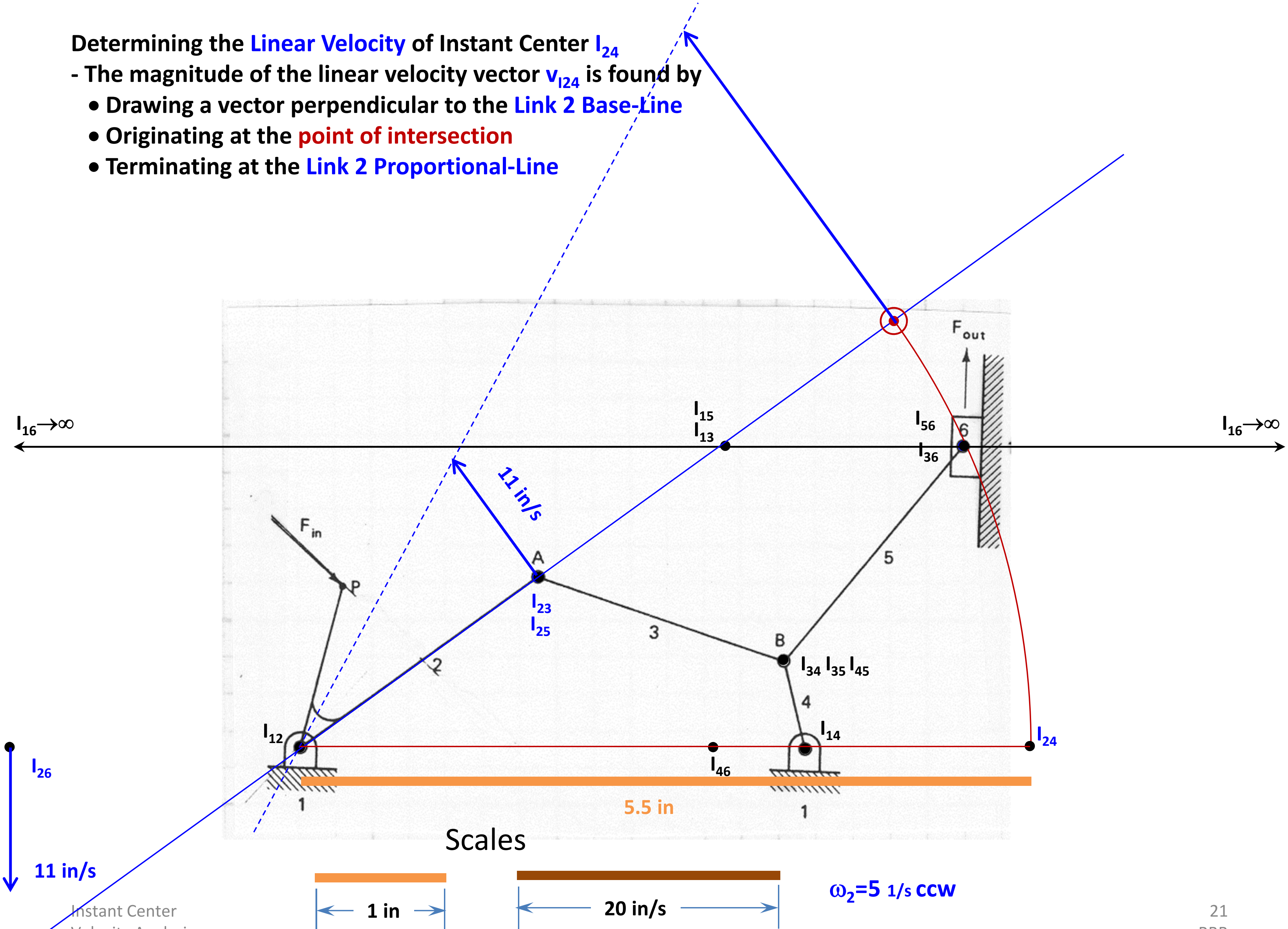
- The magnitude of the linear velocity vector v_{I24} is found by

- **Scribing an arc centered at I_{12} up to the Link 2 Base-Line**



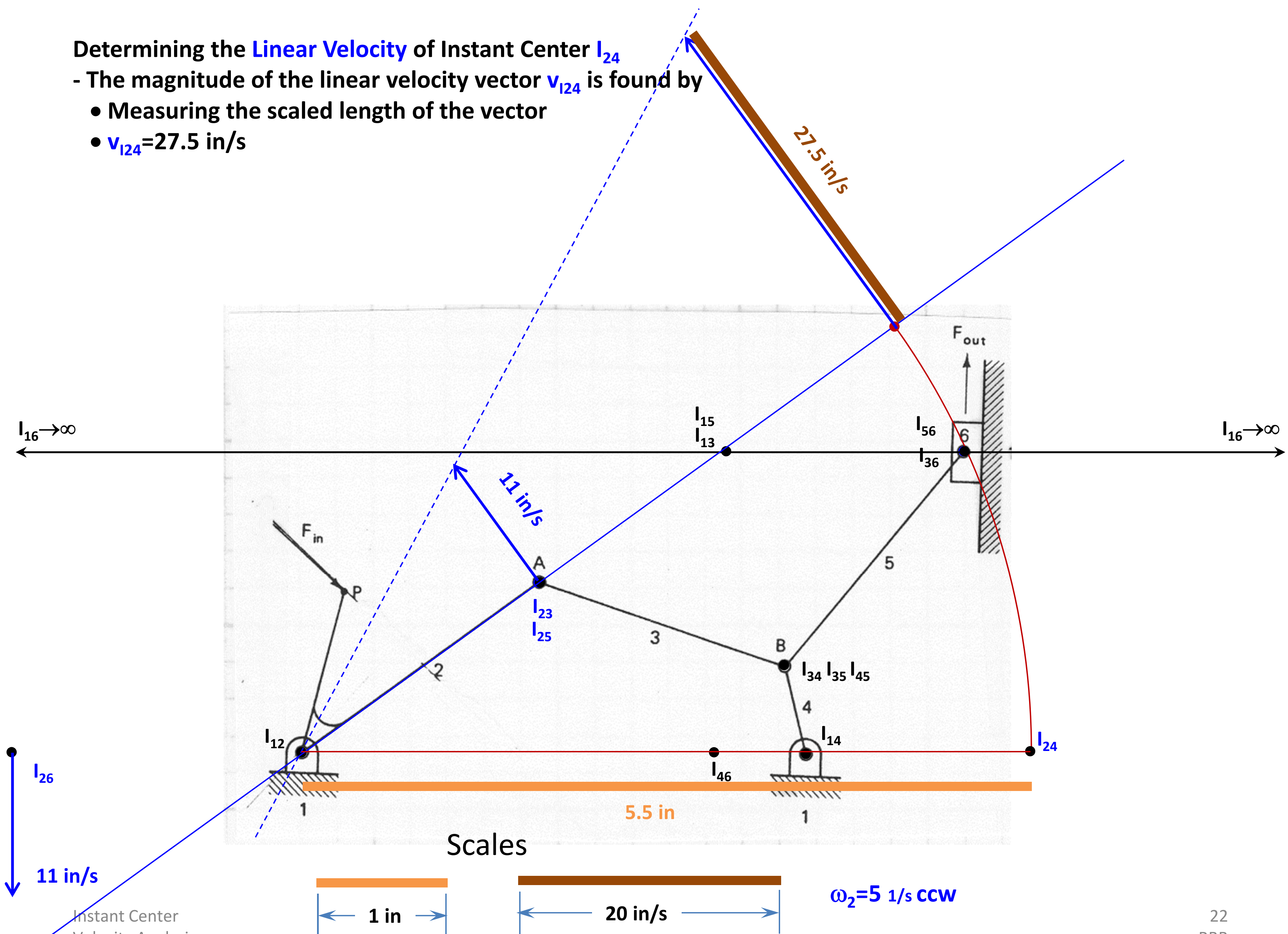
Determining the Linear Velocity of Instant Center I_{24}

- The magnitude of the linear velocity vector v_{I24} is found by
  - Drawing a vector perpendicular to the Link 2 Base-Line
  - Originating at the point of intersection
  - Terminating at the Link 2 Proportional-Line



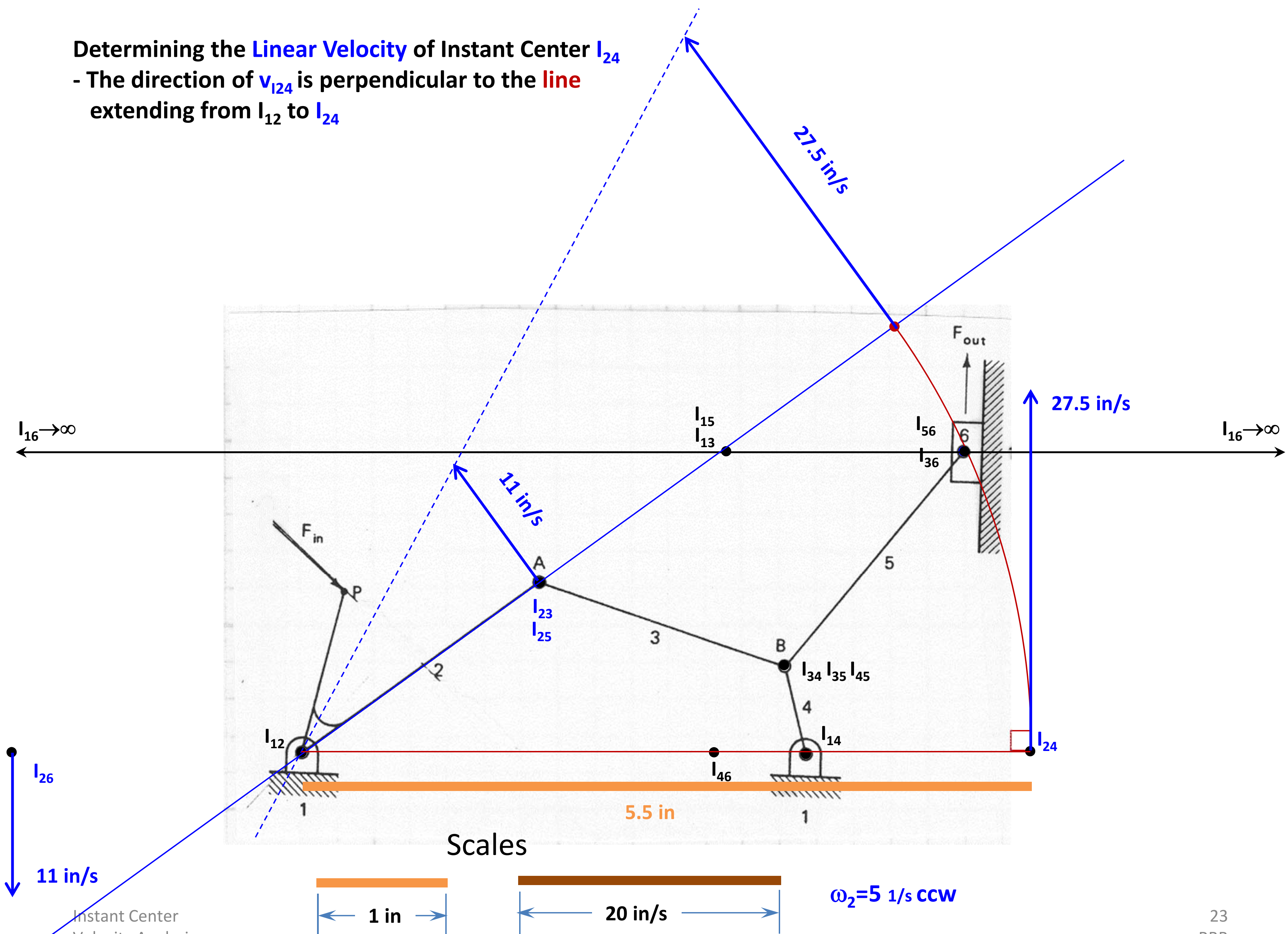
Determining the Linear Velocity of Instant Center I_{24}

- **The magnitude of the linear velocity vector v_{I24} is found by**
  - **Measuring the scaled length of the vector**
  - **v_{I24}=27.5 in/s**



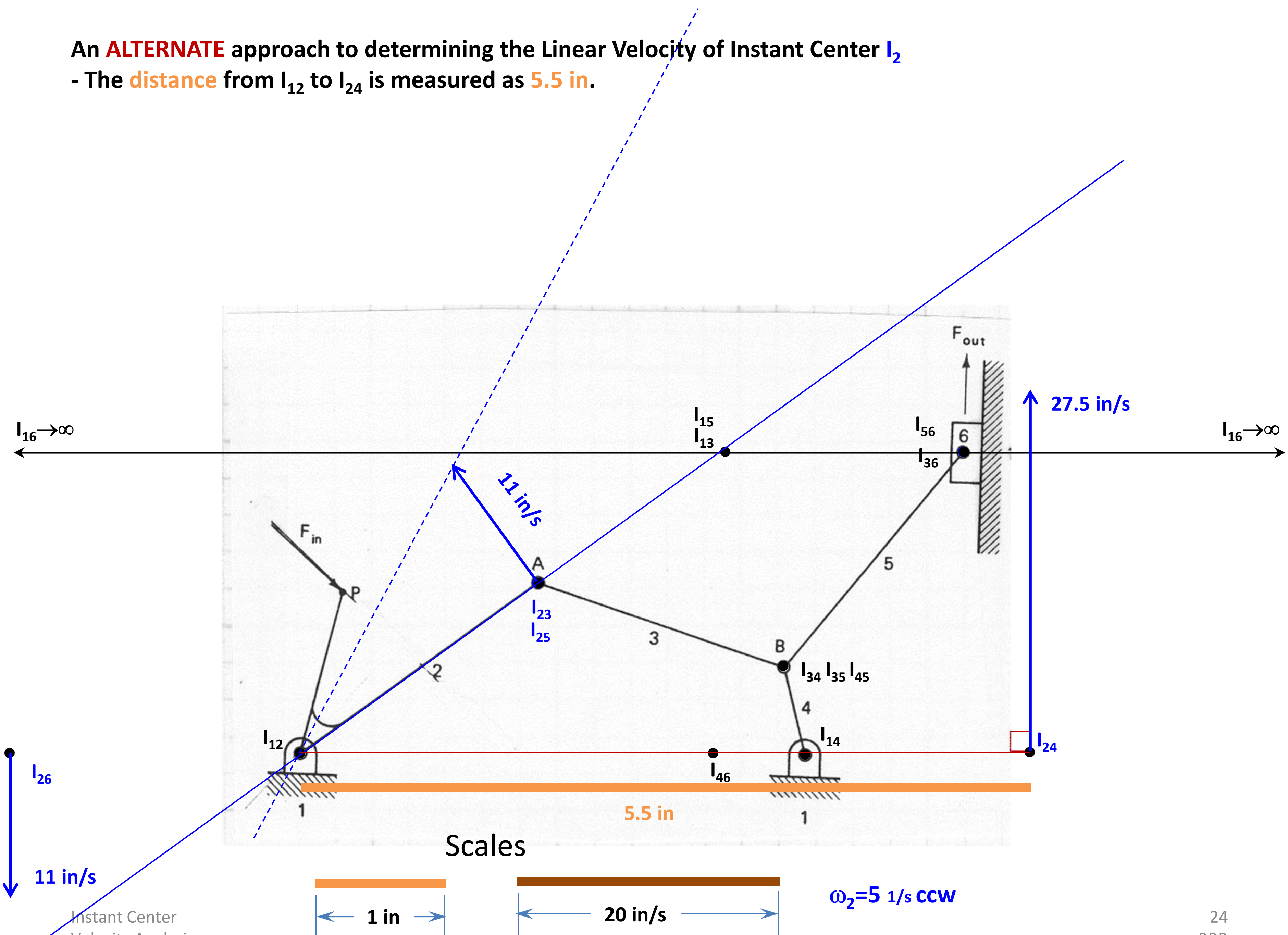
Determining the Linear Velocity of Instant Center I_{24}

- The direction of v_{I24} is perpendicular to the line extending from I_{12} to I_{24}



An ALTERNATE approach to determining the Linear Velocity of Instant Center I_2

- The distance from I_{12} to I_{24} is measured as 5.5 in.



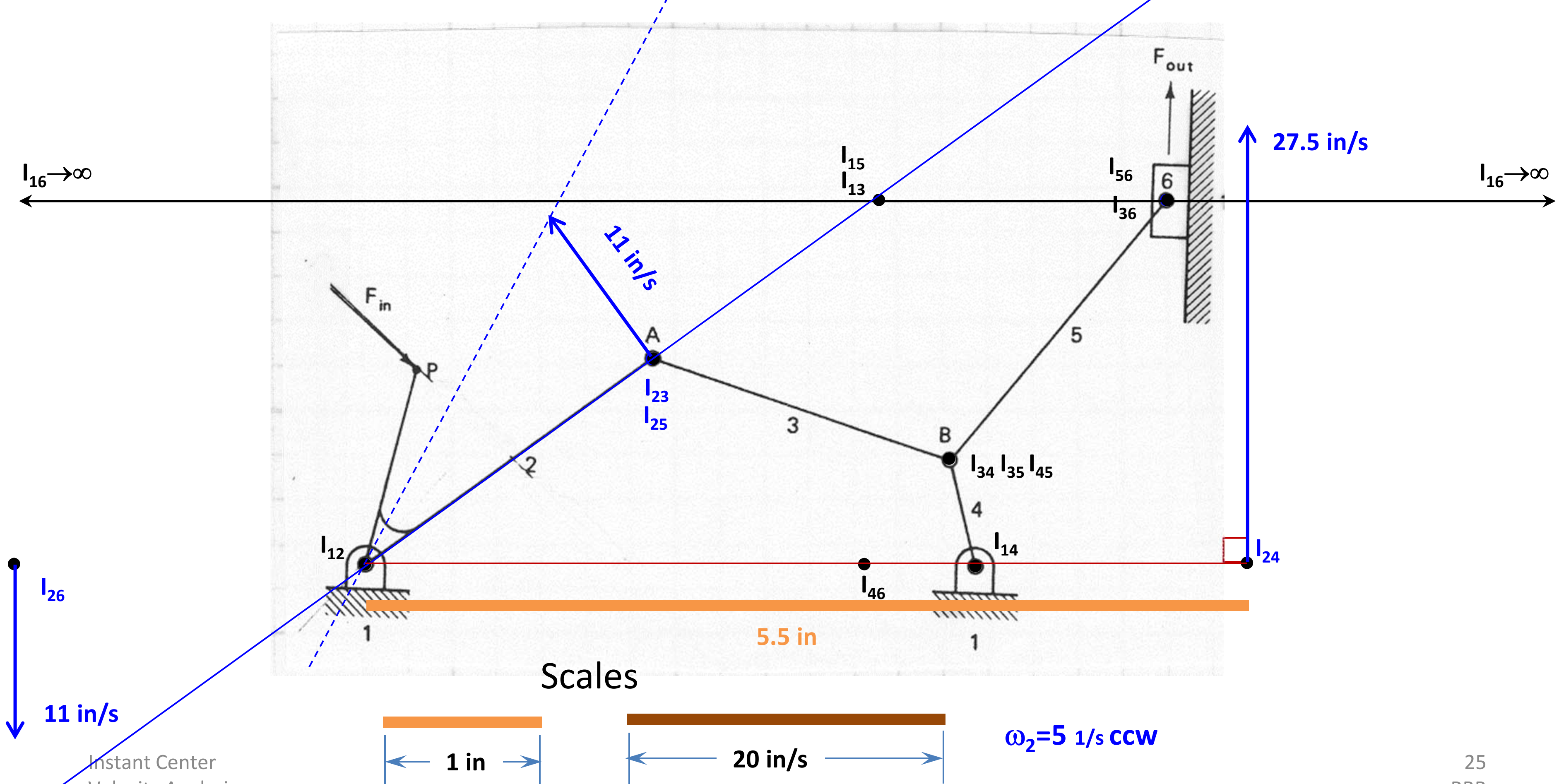
An **ALTERNATE** approach to determining the Linear Velocity of Instant Center I_2

- The distance from I_{12} to I_{24} is measured as 5.5 in.

$$v_{I_{24}} = \omega_2 \cdot r_{I_{24}I_{12}} = 5\tfrac{1}{s} \cdot 5.5in = 27.5\tfrac{in}{s}$$

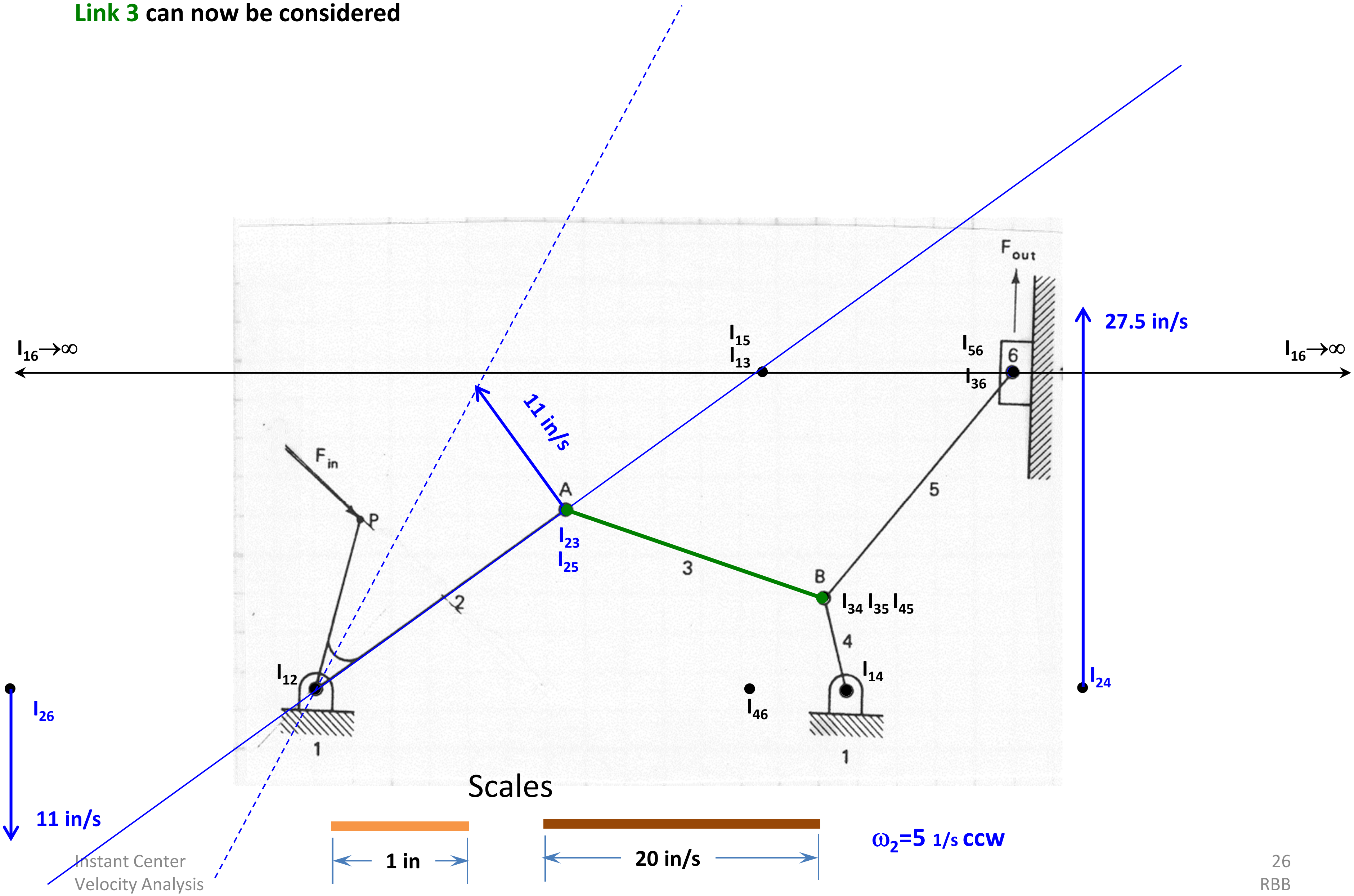
- The direction of v_{I24} is perpendicular to the line extending from I_{12} to I_{24}
- The sense is determined using the Right-Hand-Rule

BOTH APPROACHES MATCH



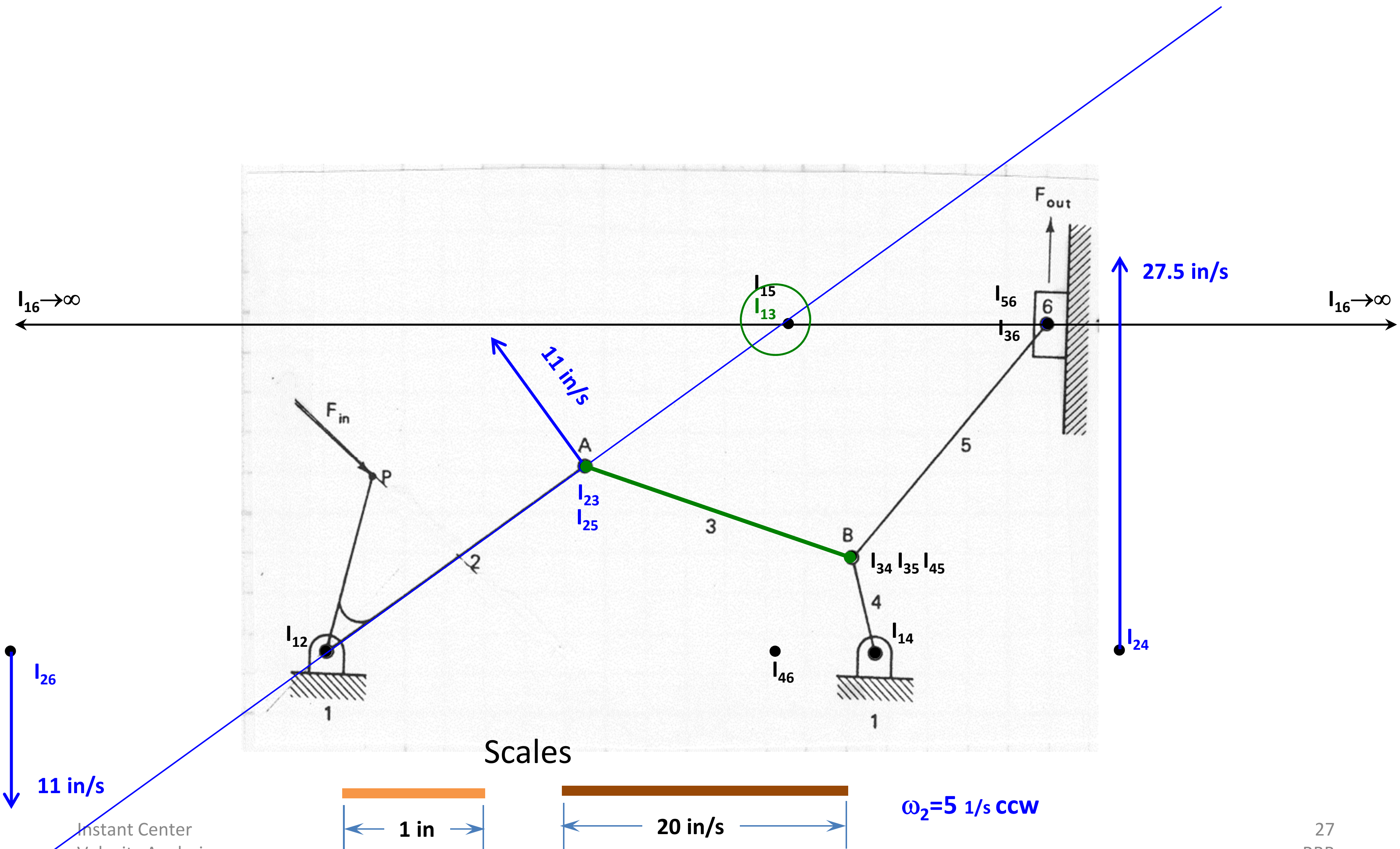
The Linear Velocity of Instant Centers I_{23}, I_{24}, I_{25}, and I_{25} have all been determined

Link 3 can now be considered



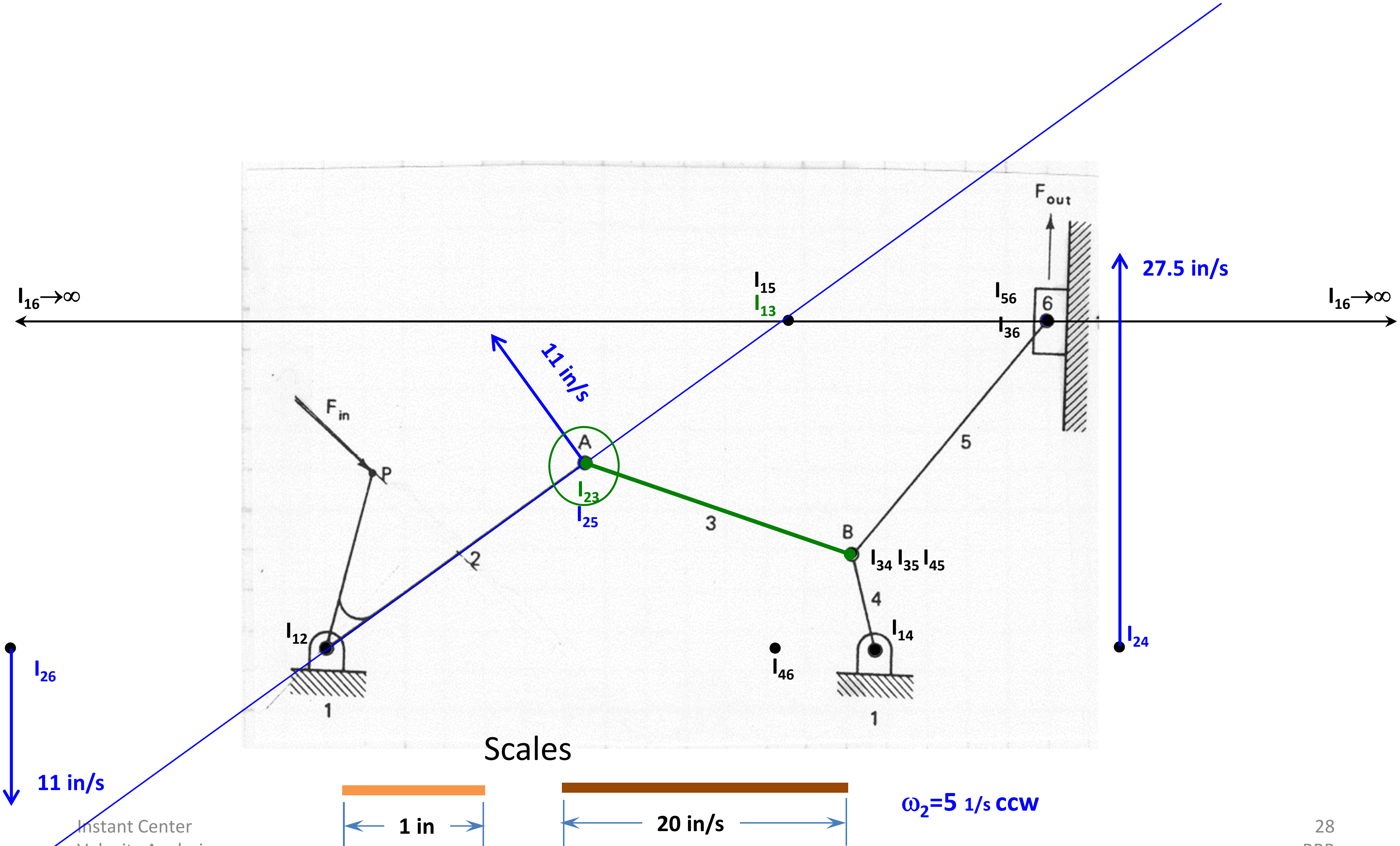
ω_2=5 1/s ccw

At this instant, Link 3 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{13}



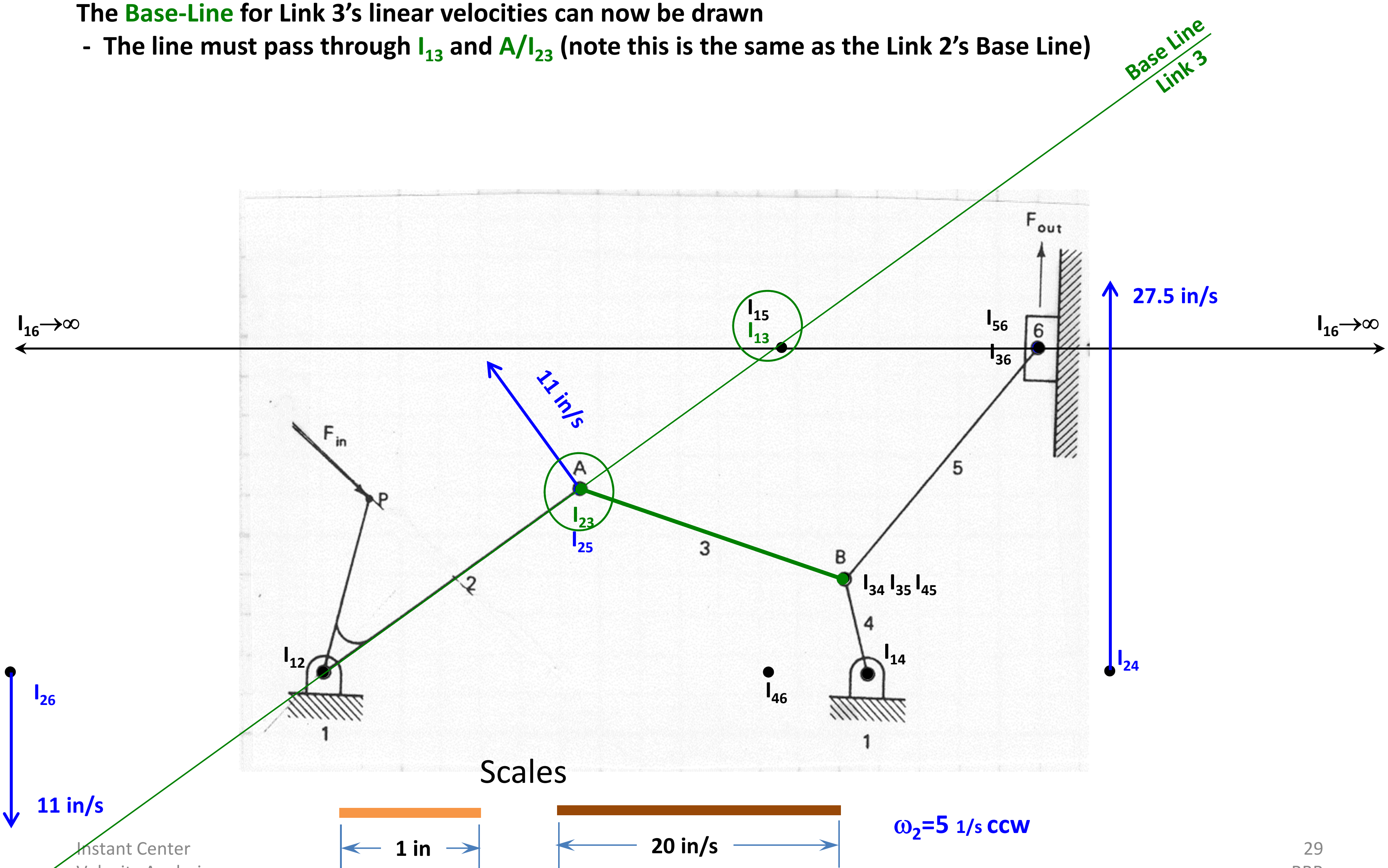
At this instant, Link 3 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{13}

A known velocity on Link 3 is at A which is the same as I_{23}, $v_A = v_{I23} = 11$ in/s



At this instant, Link 3 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{13}
A known velocity on Link 3 is at A which is the same as I_{23}, $v_A = v_{I23} = 11$ in/s

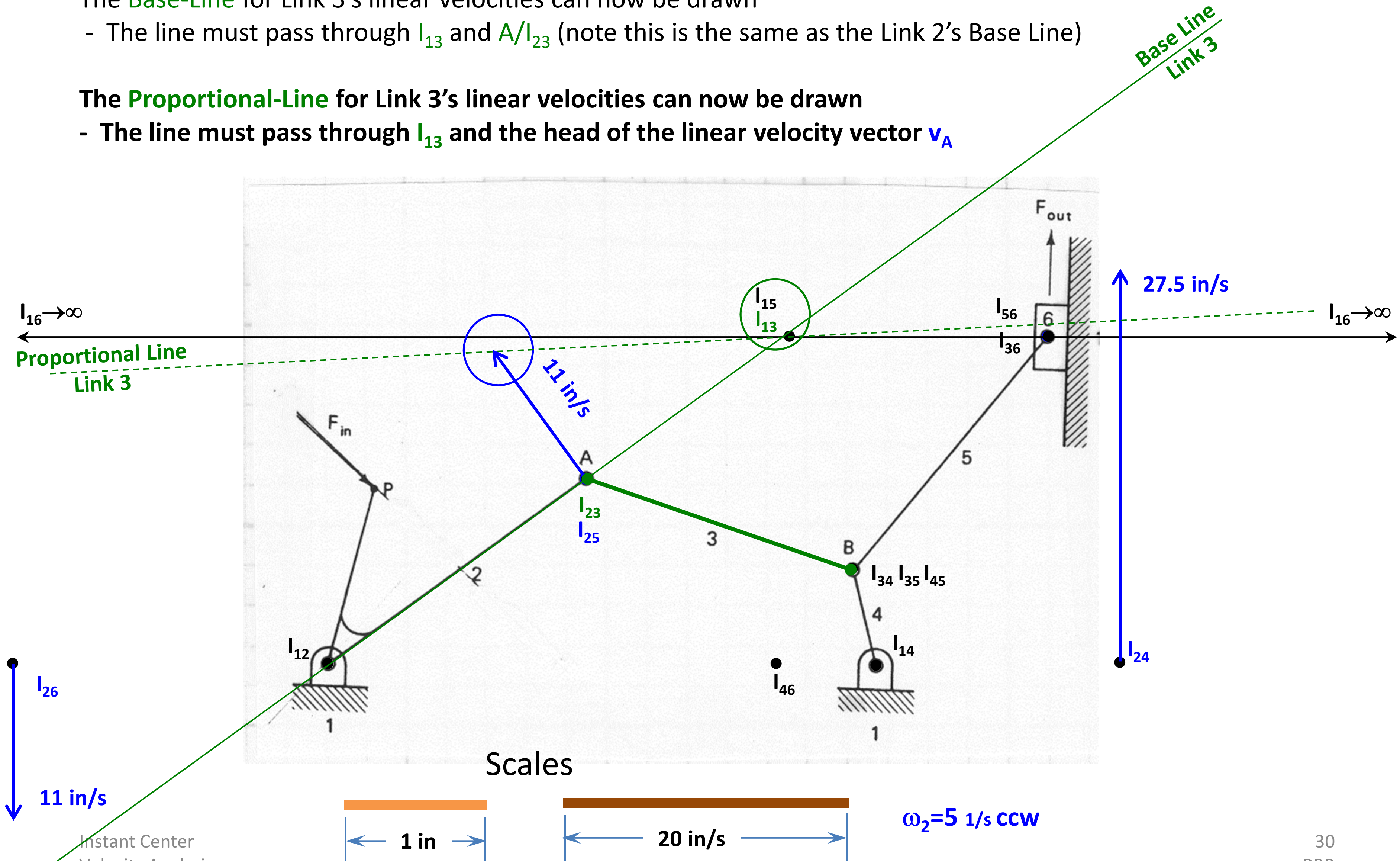
The Base-Line for Link 3's linear velocities can now be drawn
- The line must pass through I_{13} and A/I_{23} (note this is the same as the Link 2's Base Line)



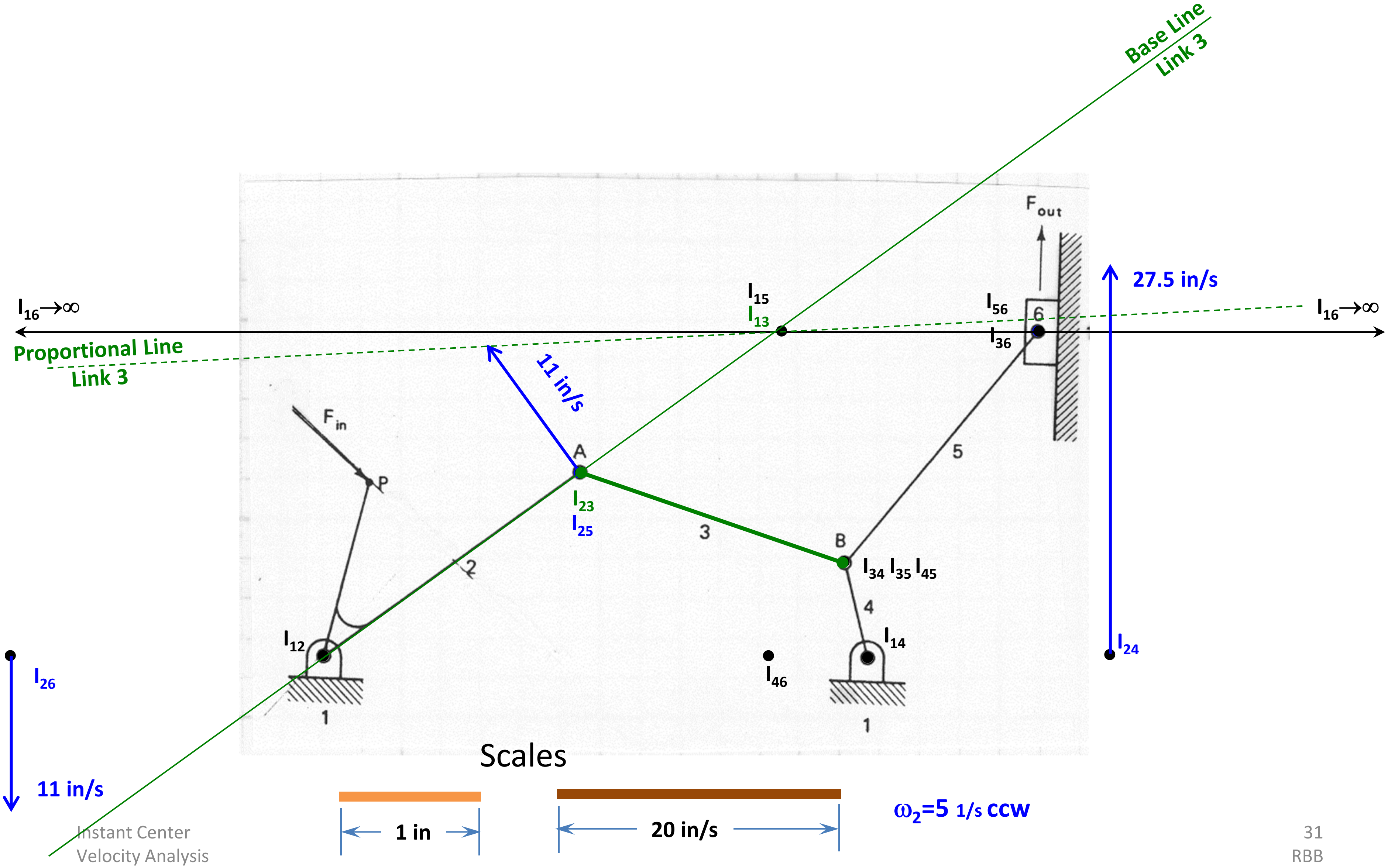
At this instant, Link 3 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{13}
A known velocity on Link 3 is at A which is the same as I_{23}, $v_A=v_{I23}=11$ in/s

The Base-Line for Link 3's linear velocities can now be drawn
- The line must pass through I_{13} and A/I_{23} (note this is the same as the Link 2's Base Line)

The Proportional-Line for Link 3's linear velocities can now be drawn
- **The line must pass through I_{13} and the head of the linear velocity vector v_A**

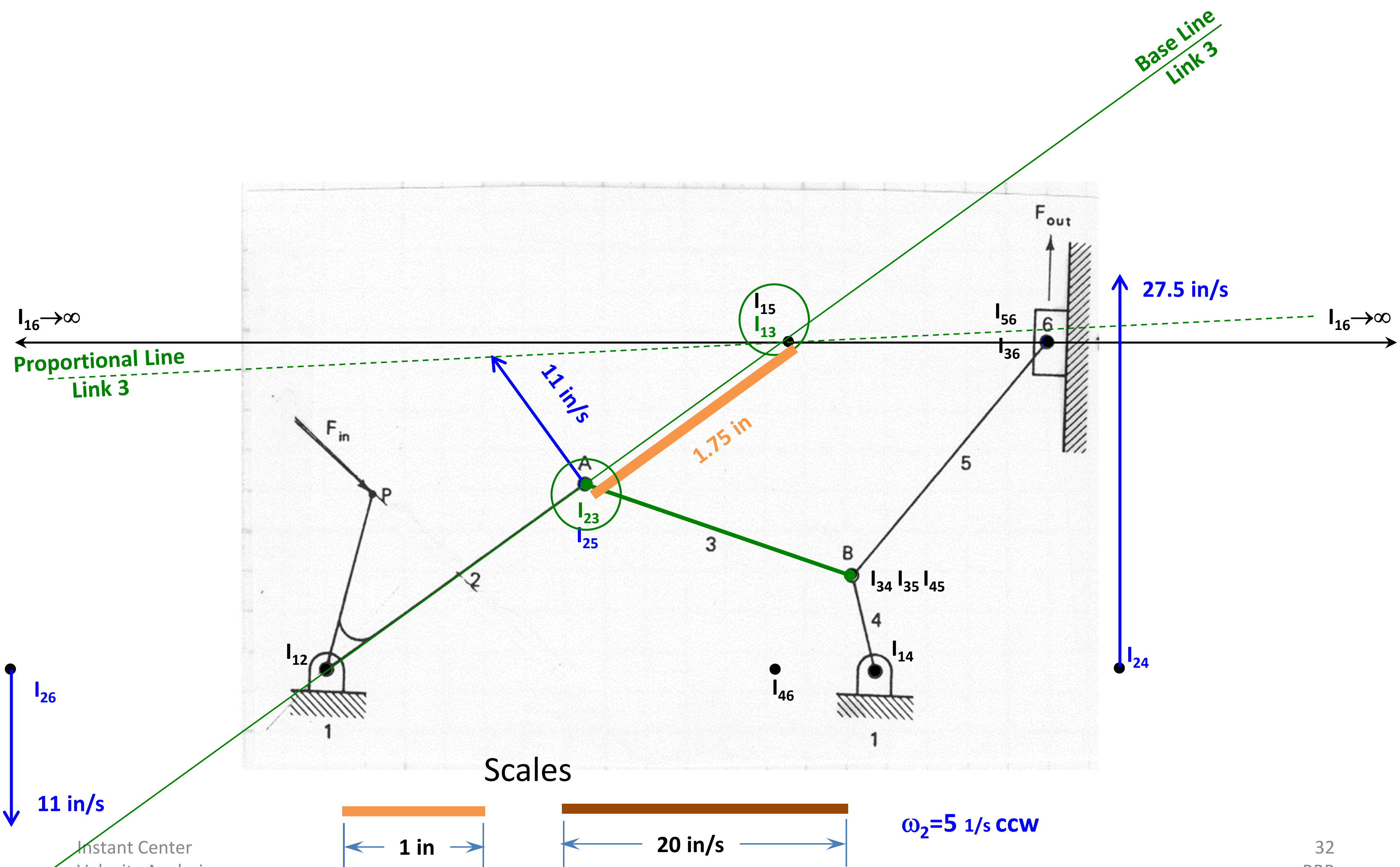


The angular velocity of Link 3, ω_3, can now be calculated



The angular velocity of Link 3, ω_3, can now be calculated

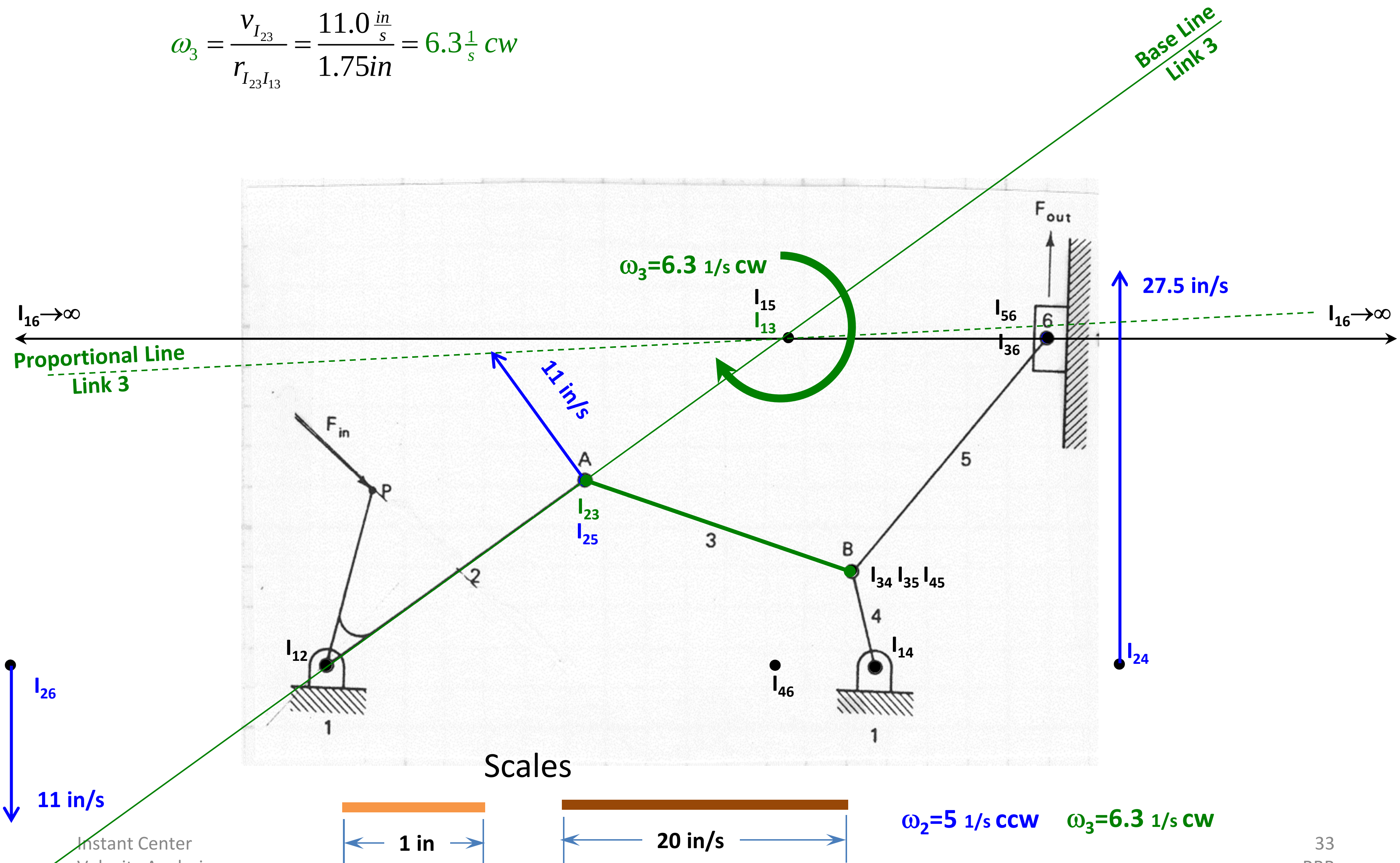
- The distance from I_{13} to A/I_{23} is measured, r_{I13I23}=1.75 in



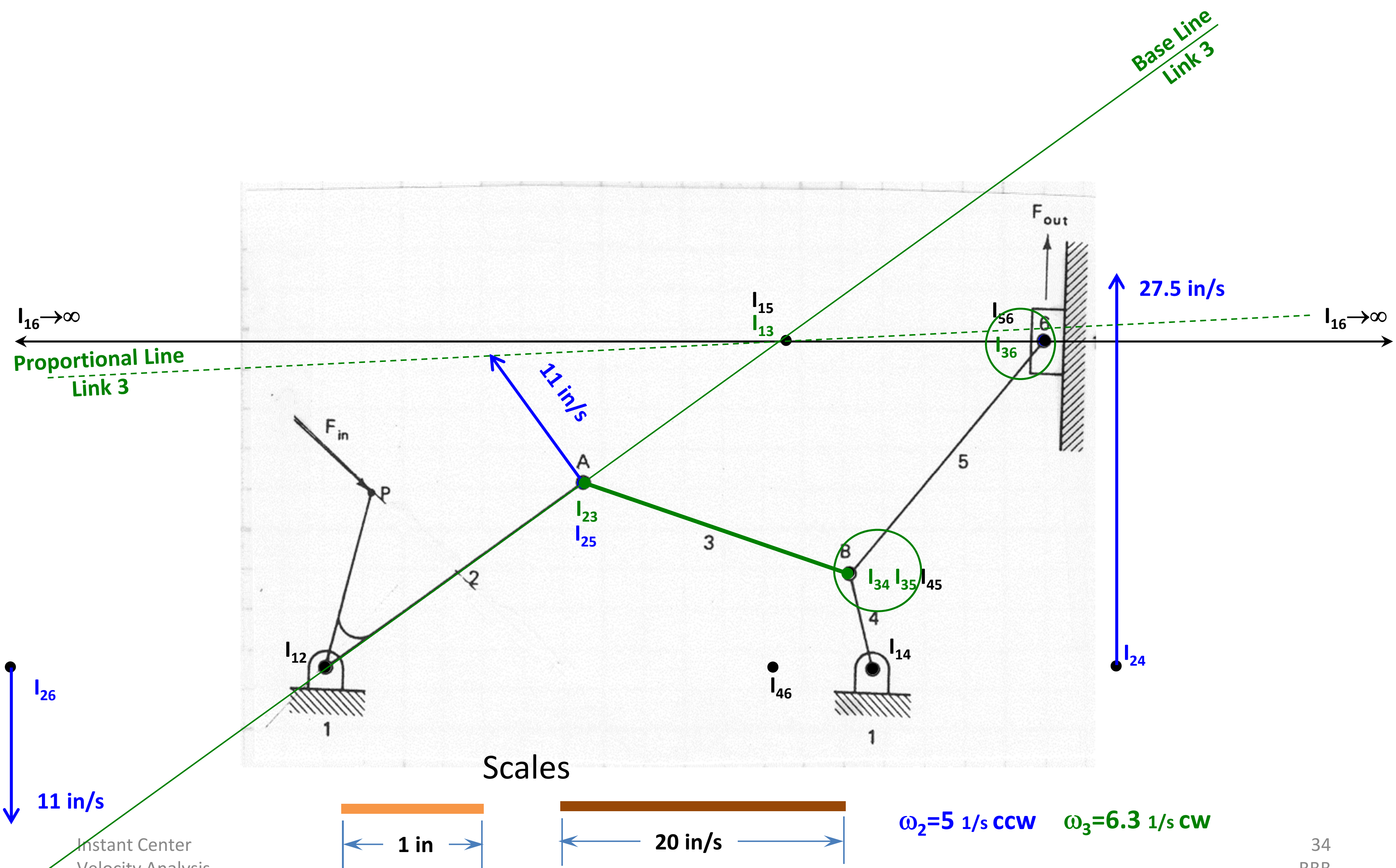
The angular velocity of Link 3, ω_3, can now be calculated

- The distance from I_{13} to A/I_{23} is measured, r_{I13I23}=1.75 in
- **The linear velocity at A/I_{23}, v_A=v_{I23}=11 in/s is divided by r_{I13I23}**

$$\omega_3 = \frac{v_{I_{23}}}{r_{I_{23}I_{13}}} = \frac{11.0\,\frac{in}{s}}{1.75in} = 6.3\tfrac{1}{s}\,cw$$

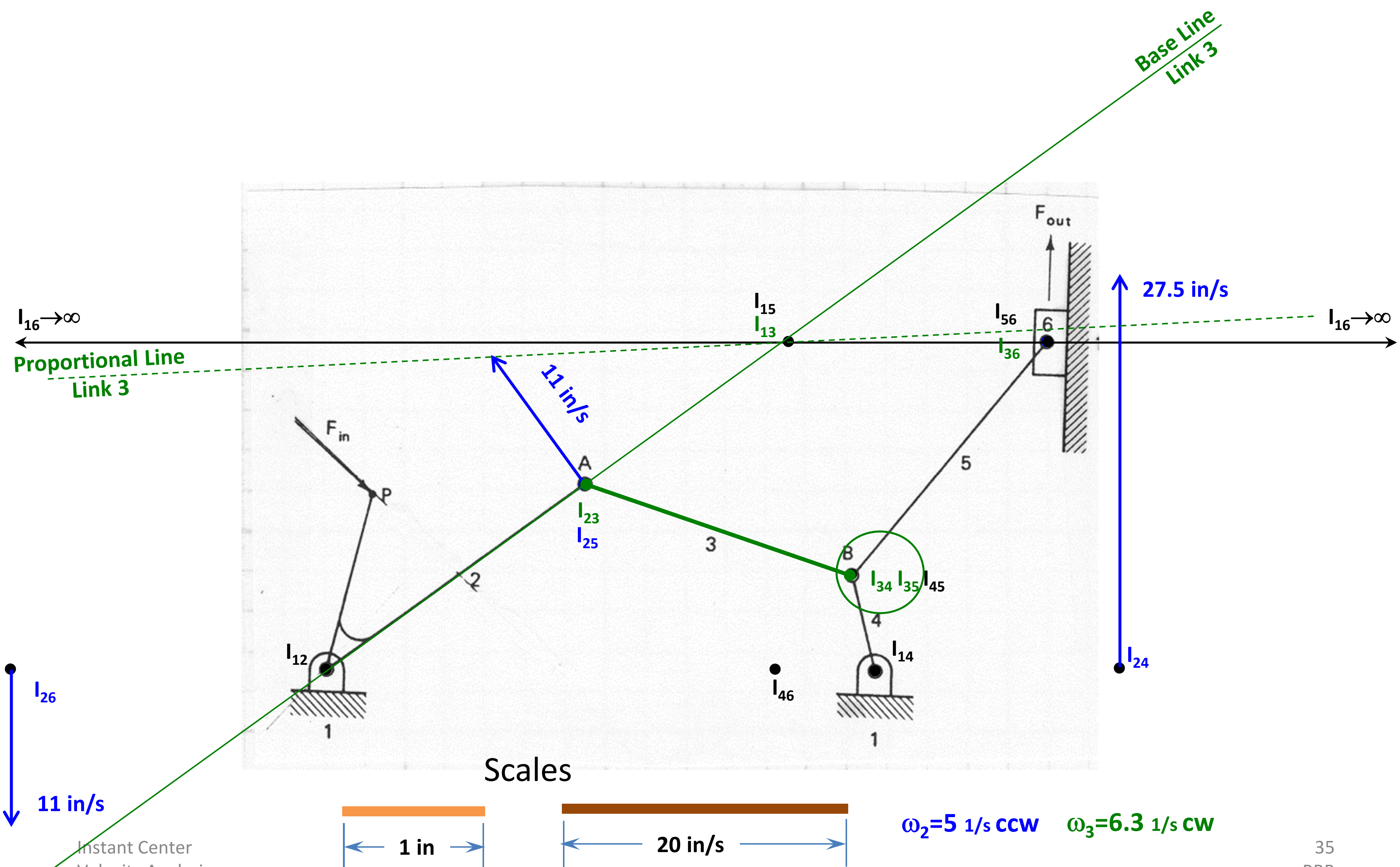


The linear velocities of Instant Centers I_{34}, I_{35}, and I_{36} can now be found



ω_2=5 1/s ccw ω_3=6.3 1/s cw

Starting by finding the LINEAR VELOCITIES of Instant Centers I_{34}, and I_{35}
Instant Centers I_{34}, and I_{35} are both at point B

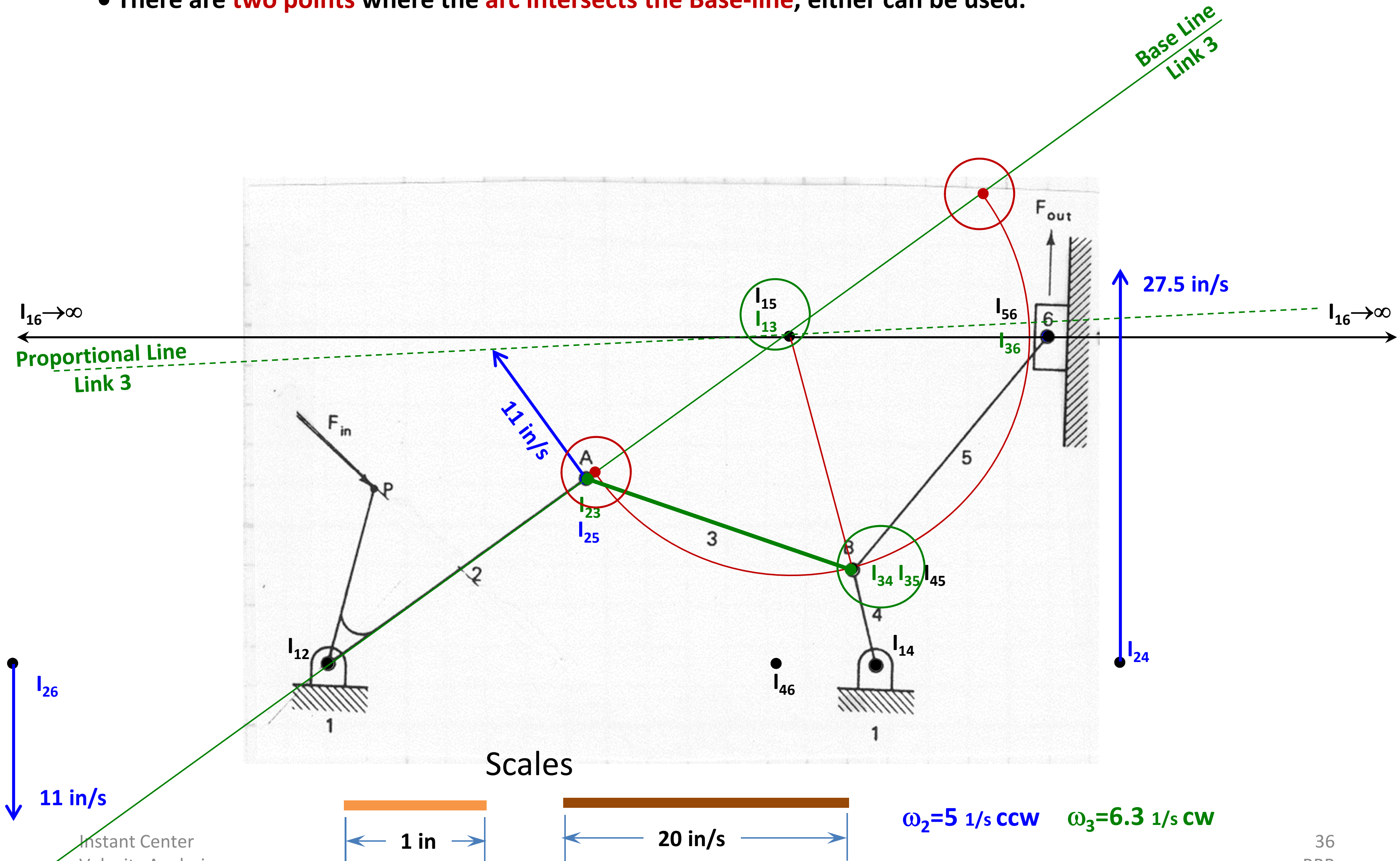


Starting by finding the LINEAR VELOCITIES of Instant Centers I_{34}, and I_{35}

Instant Centers I_{34}, and I_{35} are both at point B

- Scribing an arc centered at I_{13}, Starting at B/I_{34}/I_{35}, and terminating at the Link 3 Base-Line

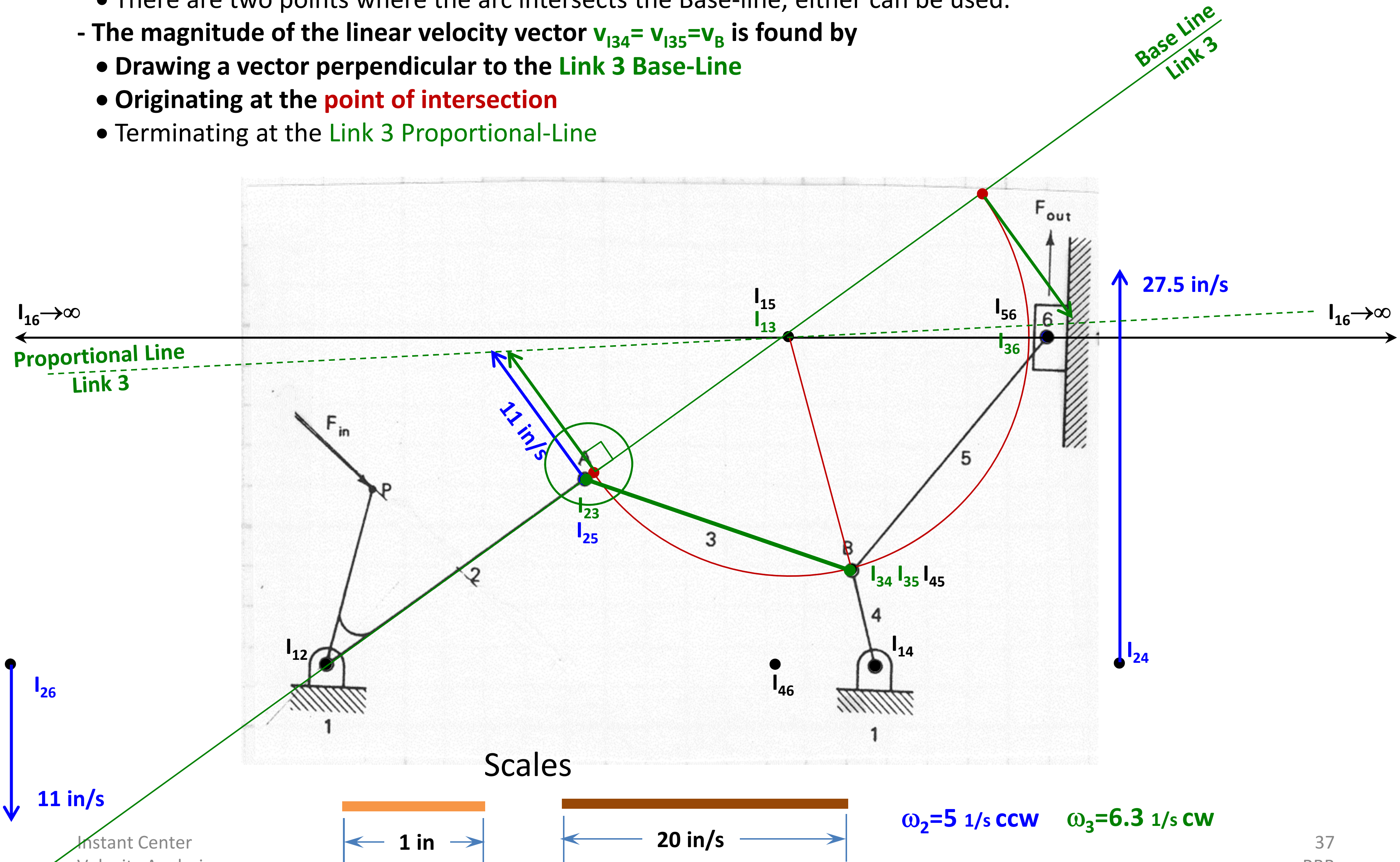
- **There are two points where the arc intersects the Base-line, either can be used.**



Starting by finding the LINEAR VELOCITIES of Instant Centers I_{34}, and I_{35}

Instant Centers I_{34}, and I_{35} are both at point B

- Scribing an arc centered at I_{13}, Starting at B/I_{34}/I_{35}, and terminating at the Link 3 Base-Line
  - There are two points where the arc intersects the Base-line, either can be used.
- **The magnitude of the linear velocity vector $v_{I34}= v_{I35}=v_B$ is found by**
  - **Drawing a vector perpendicular to the Link 3 Base-Line**
  - **Originating at the point of intersection**
  - Terminating at the Link 3 Proportional-Line

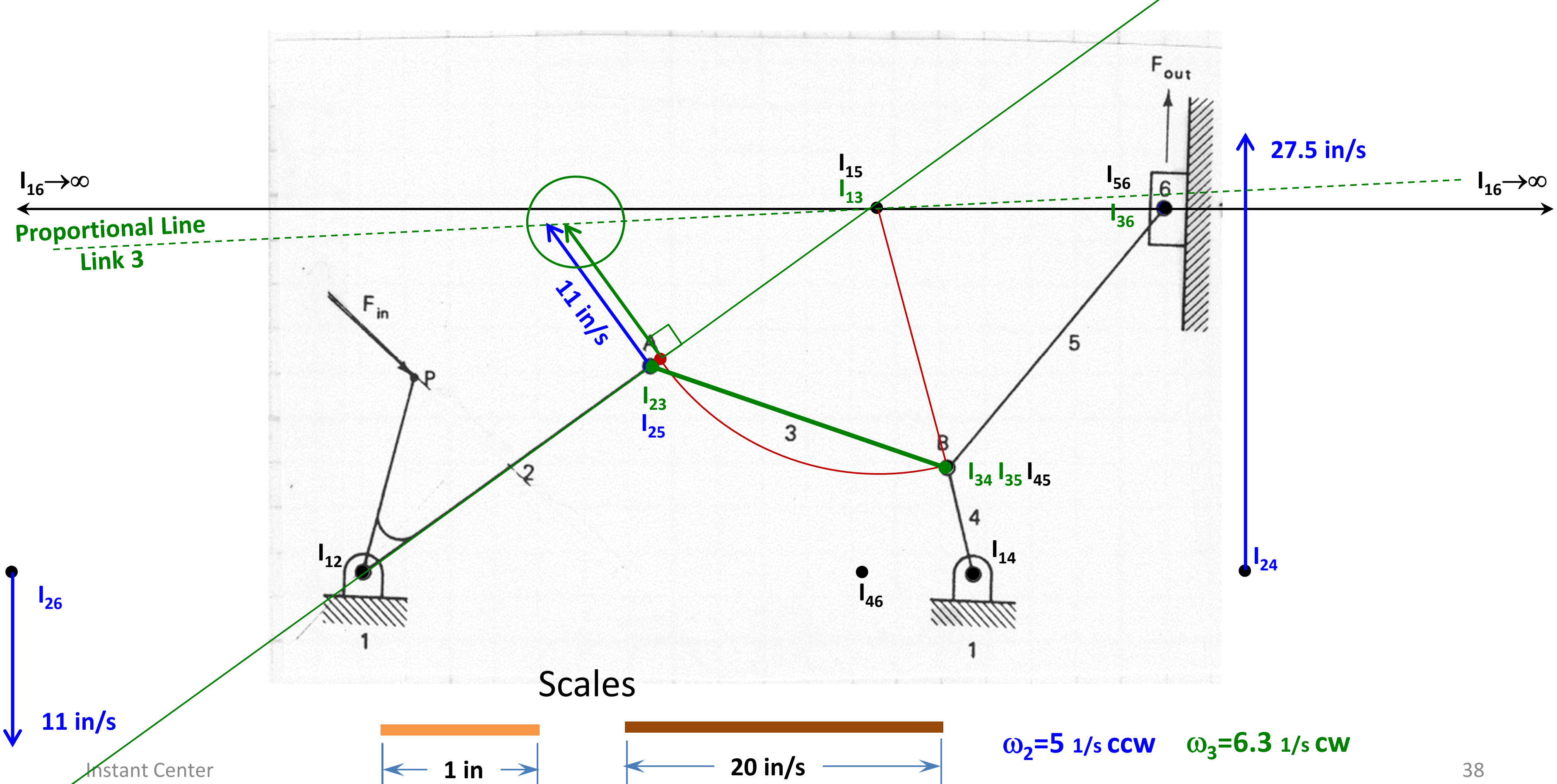


ω_2=5 1/s ccw ω_3=6.3 1/s cw

Starting by finding the LINEAR VELOCITIES of Instant Centers I_{34}, and I_{35}

Instant Centers I_{34}, and I_{35} are both at point B

- Scribing an arc centered at I_{13}, Starting at B/I_{34}/I_{35}, and terminating at the Link 3 Base-Line
  - There are two points where the arc intersects the Base-line, either can be used.
- **The magnitude of the linear velocity vector $v_{I34}= v_{I35}=v_B$ is found by**
  - Drawing a vector perpendicular to the Link 3 Base-Line
  - Originating at the point of intersection
  - **Terminating at the Link 3 Proportional-Line**

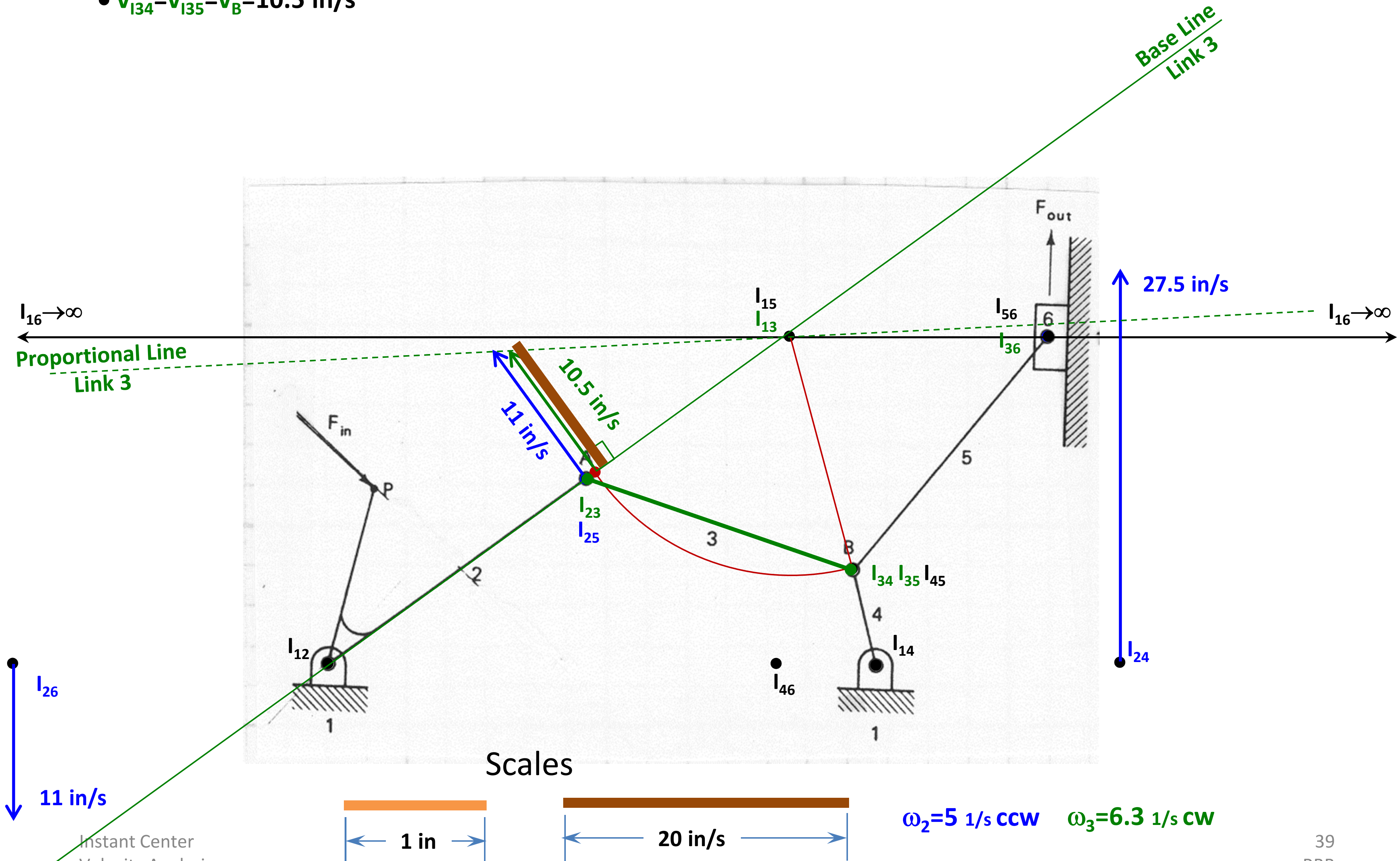


ω_2=5 1/s ccw ω_3=6.3 1/s cw

Starting by finding the LINEAR VELOCITIES of Instant Centers I_{34}, and I_{35}

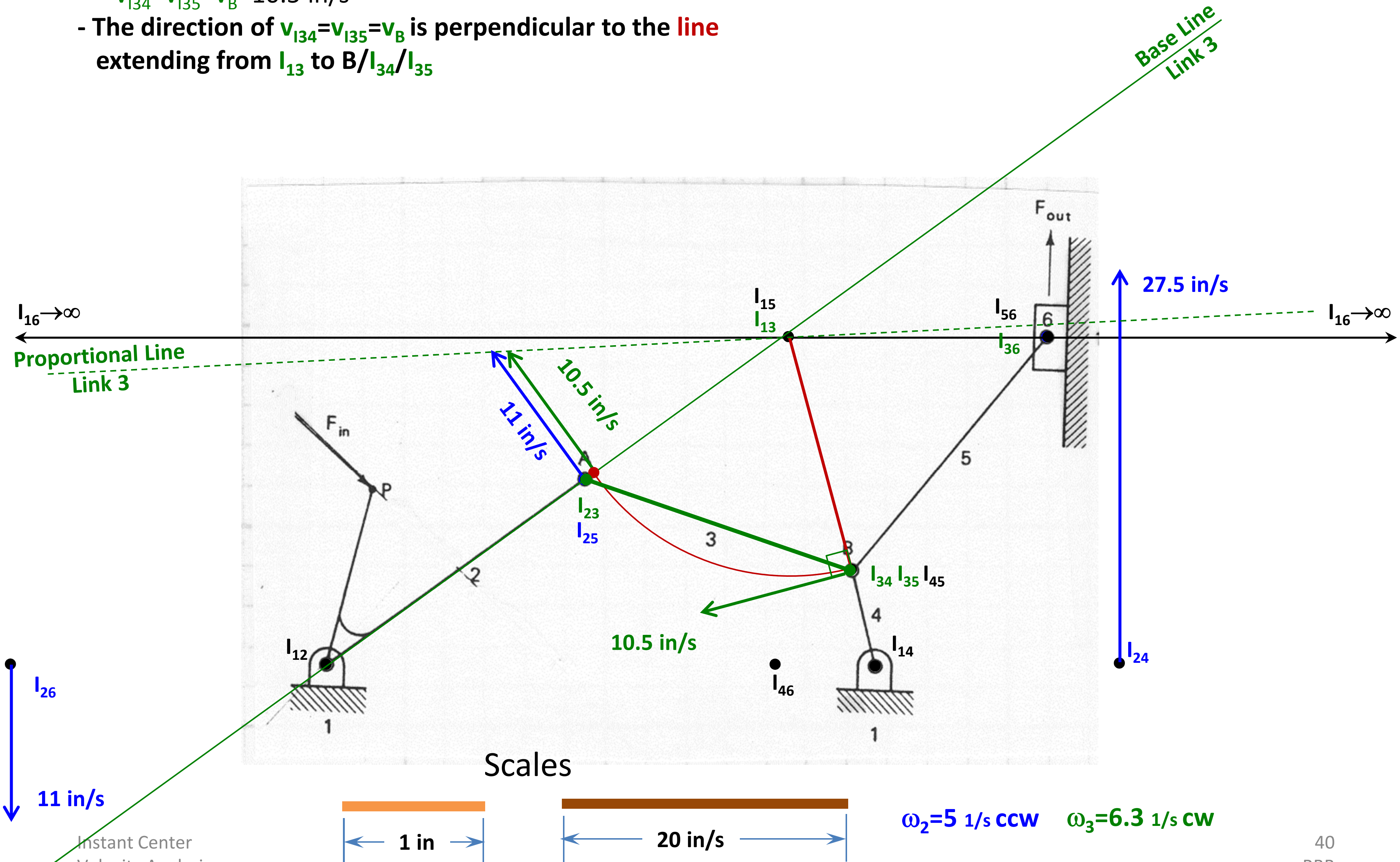
- The magnitude of the linear velocity vector $v_{I34}=v_{I35}=v_B$ is found by

- **Measuring the scaled length of the vector drawn**
- **$v_{I34}=v_{I35}=v_B$=10.5 in/s**

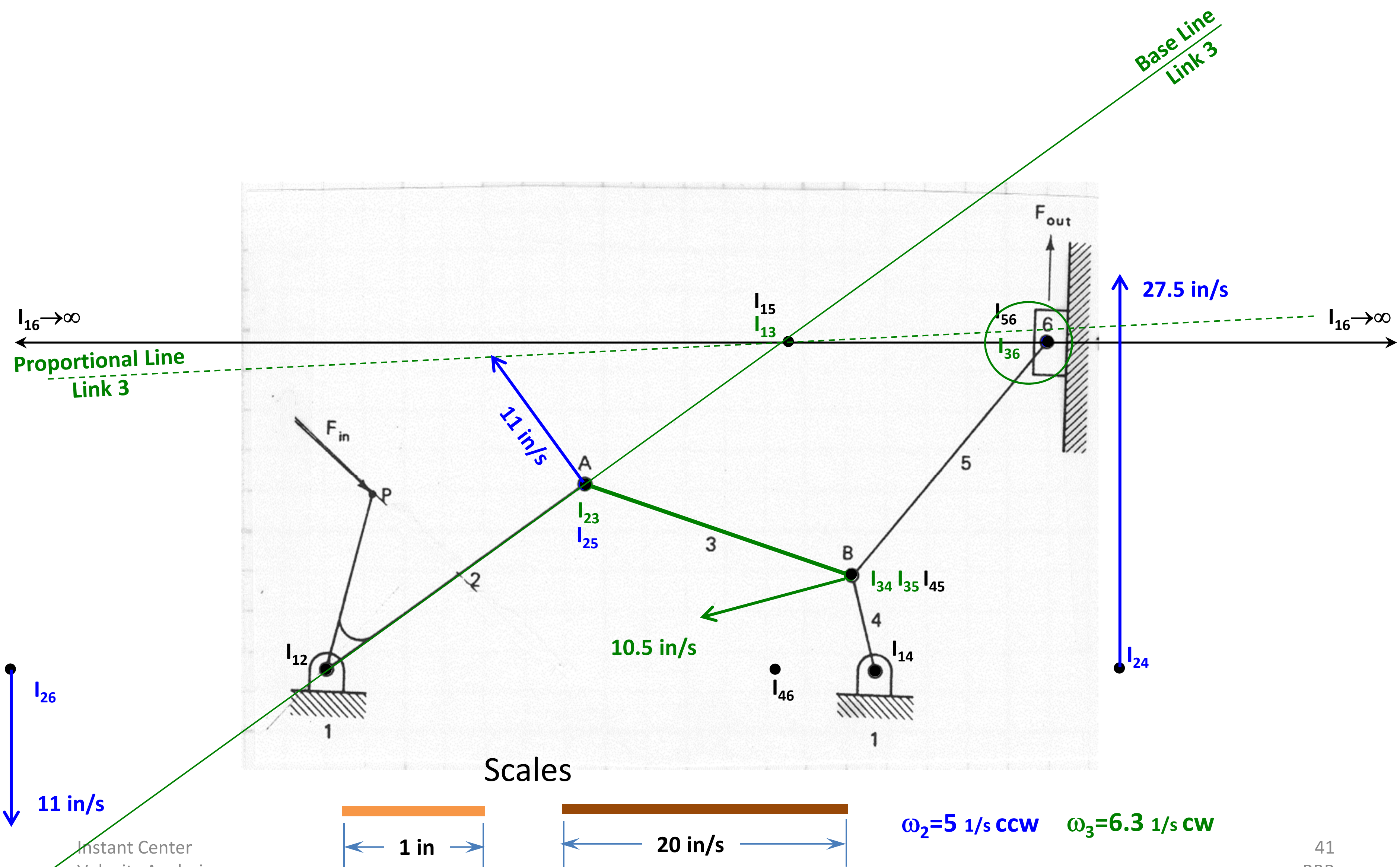


Starting by finding the LINEAR VELOCITIES of Instant Centers I_{34}, and I_{35}

- The magnitude of the linear velocity vector $v_{I34}=v_{I35}=v_B$ is found by
  - Measuring the scaled length of the vector drawn
  - $v_{I34}=v_{I35}=v_B=10.5$ in/s
- **The direction of $v_{I34}=v_{I35}=v_B$ is perpendicular to the line extending from I_{13} to B/I_{34}/I_{35}**



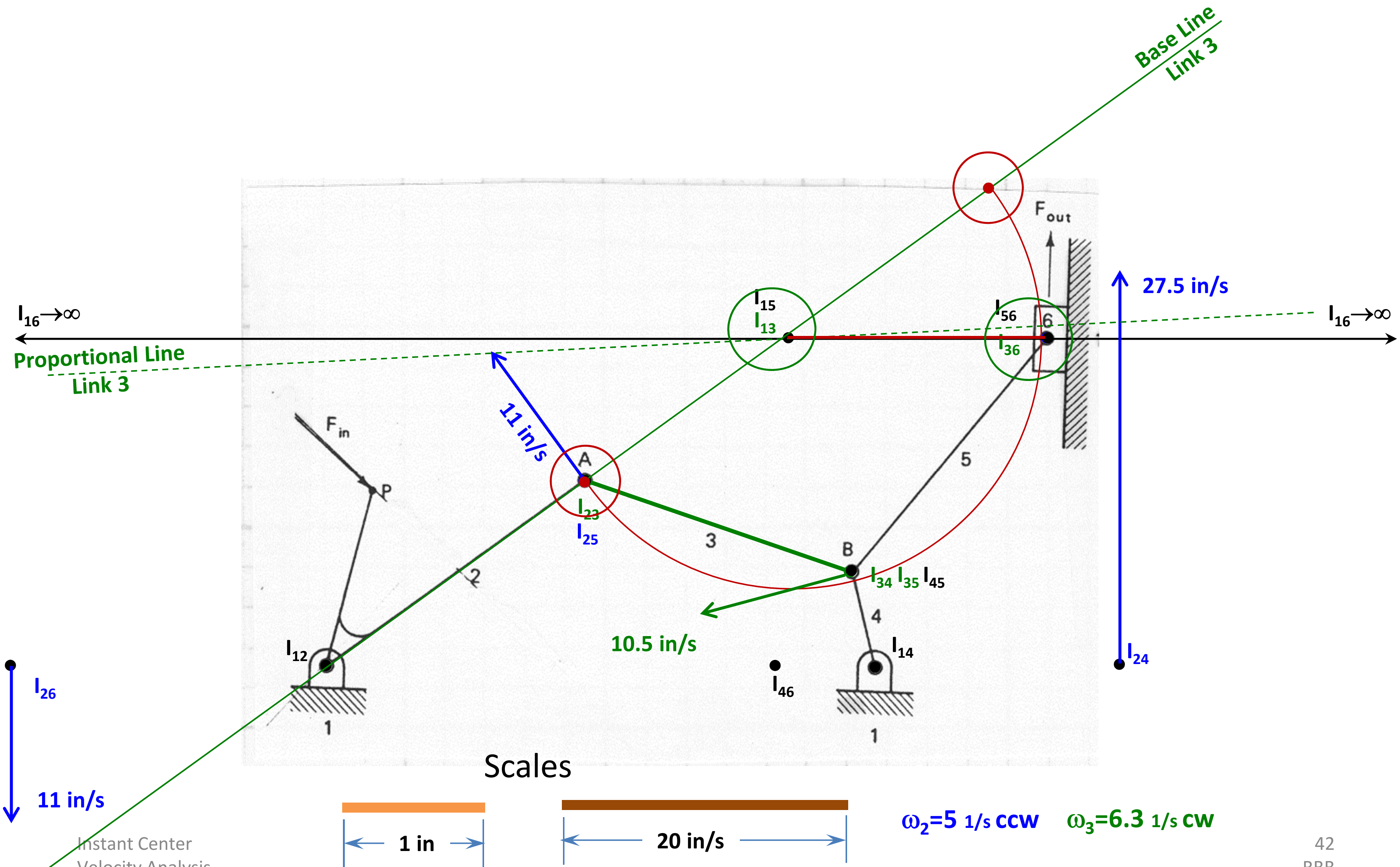
Now the LINEAR VELOCITY of Instant Centers I_{36} can be found



ω_2=5 1/s ccw ω_3=6.3 1/s cw

Starting by finding the LINEAR VELOCITY of Instant Centers I_{36}

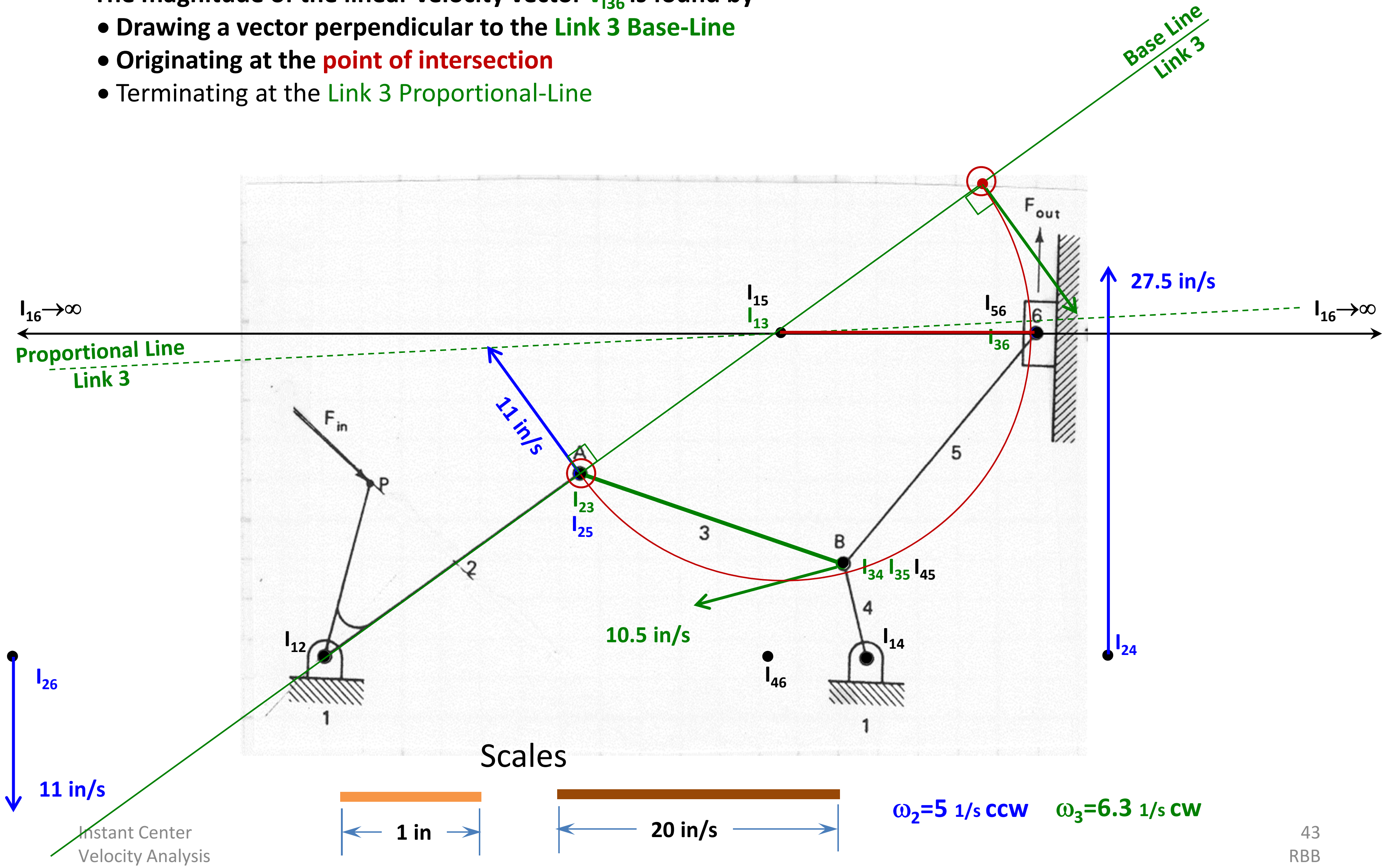
- **Scribing an arc centered at I_{13}, Starting at I_{36}, and terminating at the Link 3 Base-Line**
  - **There are two points where the arc intersects the Base-line, either can be used.**



ω_2=5 1/s ccw ω_3=6.3 1/s cw

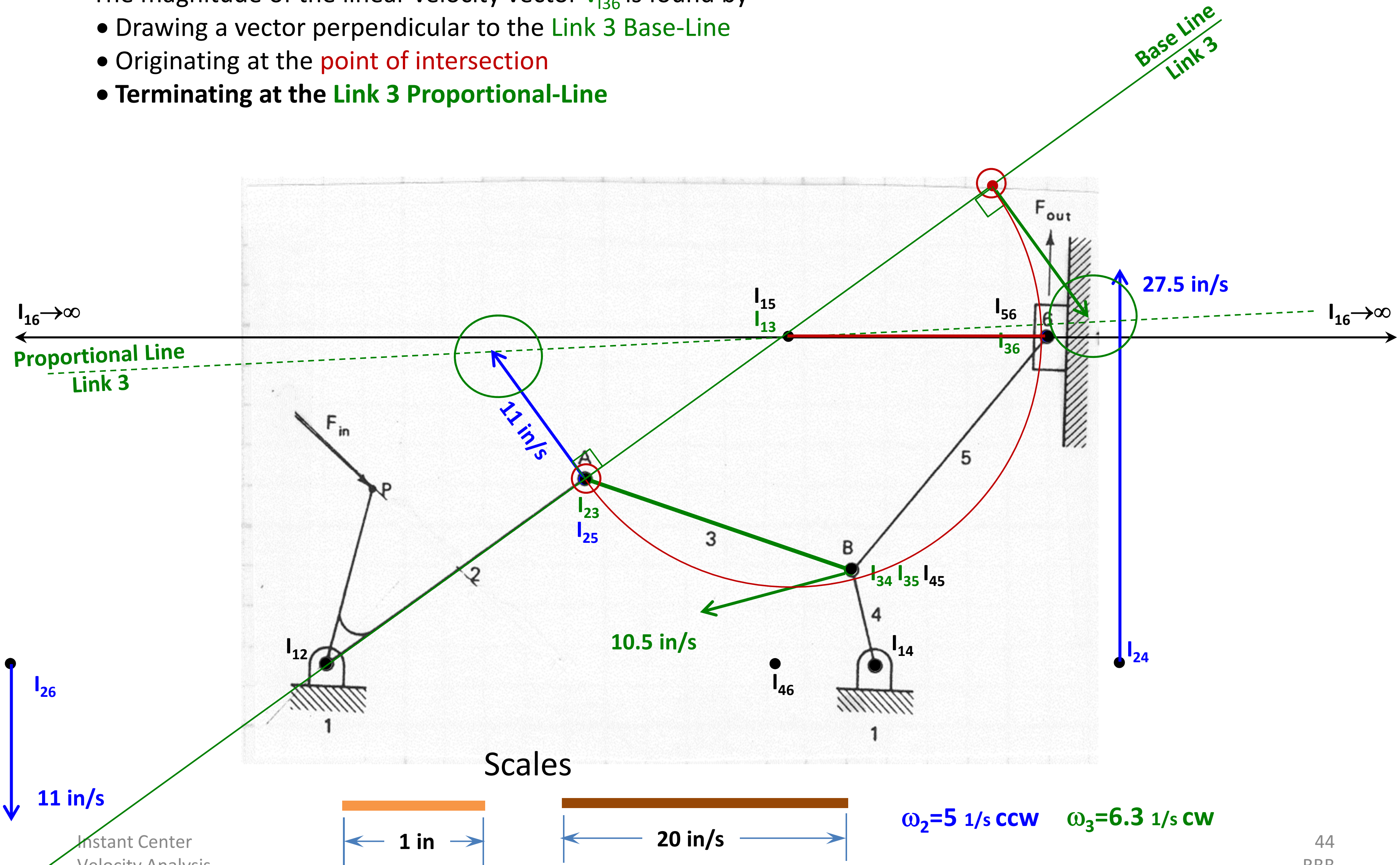
Starting by finding the LINEAR VELOCITY of Instant Centers I_{36}

- Scribing an arc centered at I_{13}, Starting at I_{36}, and terminating at the Link 3 Base-Line
  - There are two points where the arc intersects the Base-line, either can be used.
- **The magnitude of the linear velocity vector v_{I36} is found by**
  - **Drawing a vector perpendicular to the Link 3 Base-Line**
  - **Originating at the point of intersection**
  - Terminating at the Link 3 Proportional-Line



Starting by finding the LINEAR VELOCITY of Instant Centers I_{36}

- Scribing an arc centered at I_{13}, Starting at I_{36}, and terminating at the Link 3 Base-Line
  - There are two points where the arc intersects the Base-line, either can be used.
- The magnitude of the linear velocity vector v_{I36} is found by
  - Drawing a vector perpendicular to the Link 3 Base-Line
  - Originating at the point of intersection
  - **Terminating at the Link 3 Proportional-Line**



Scales

1 in

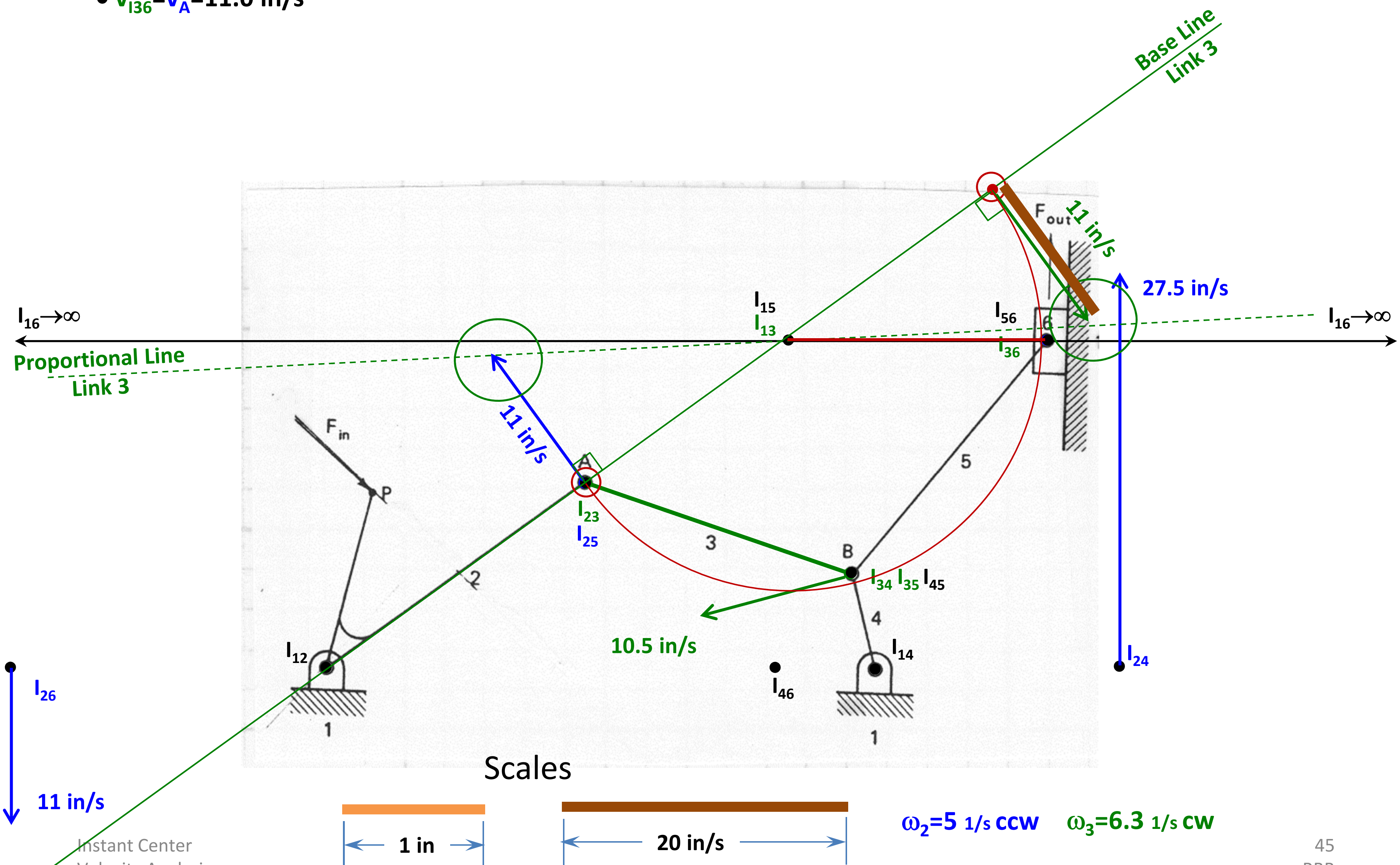
20 in/s

ω_2=5 1/s ccw ω_3=6.3 1/s cw

Starting by finding the LINEAR VELOCITY of Instant Centers I_{36}

- The magnitude of the linear velocity vector v_{I36} is found by

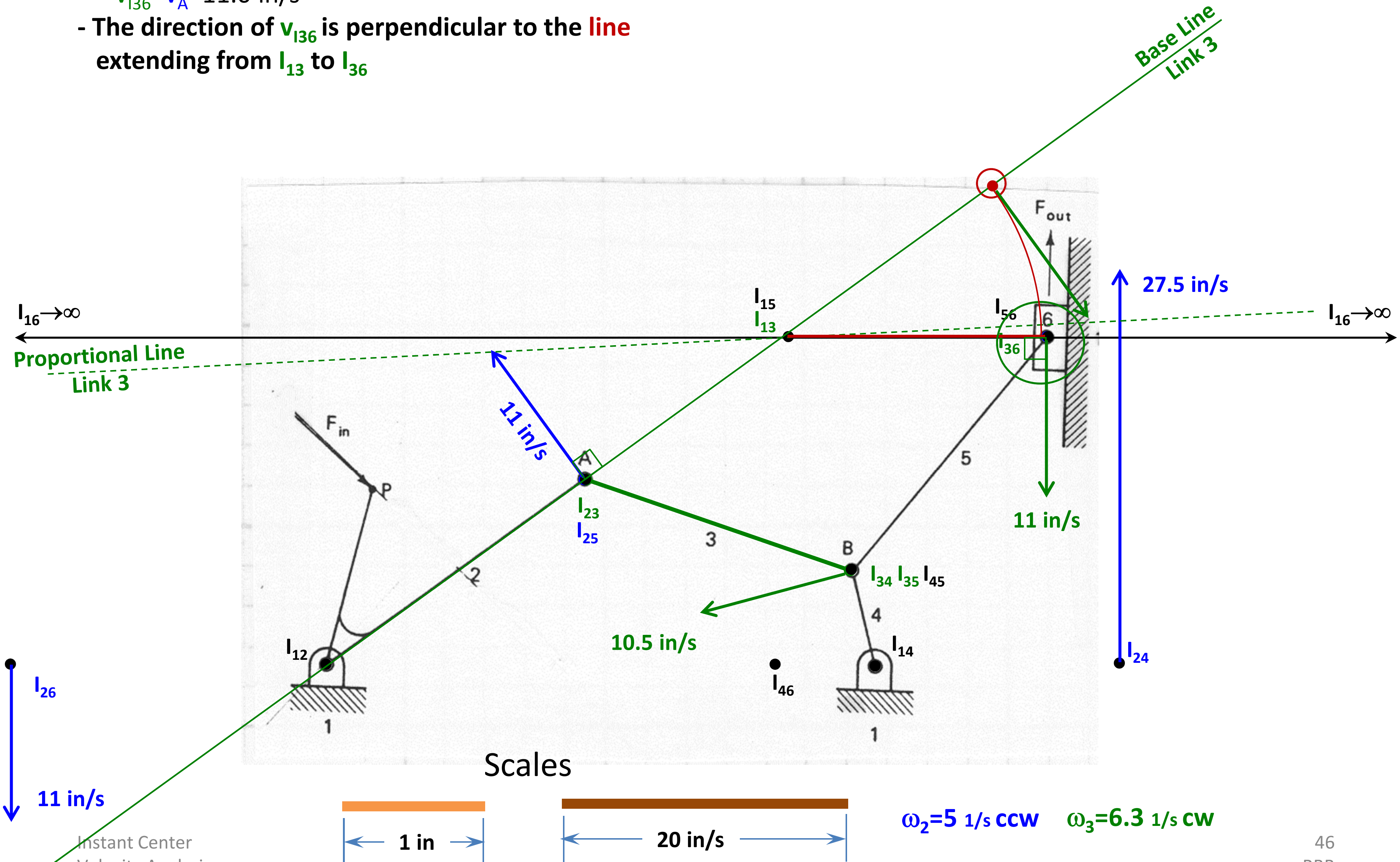
- **Measuring the scaled length of the vector drawn or $v_{I36}=v_A$**
- **$v_{I36}=v_A=11.0$ in/s**



$\omega_2=5$ 1/s ccw **$\omega_3=6.3$ 1/s cw**

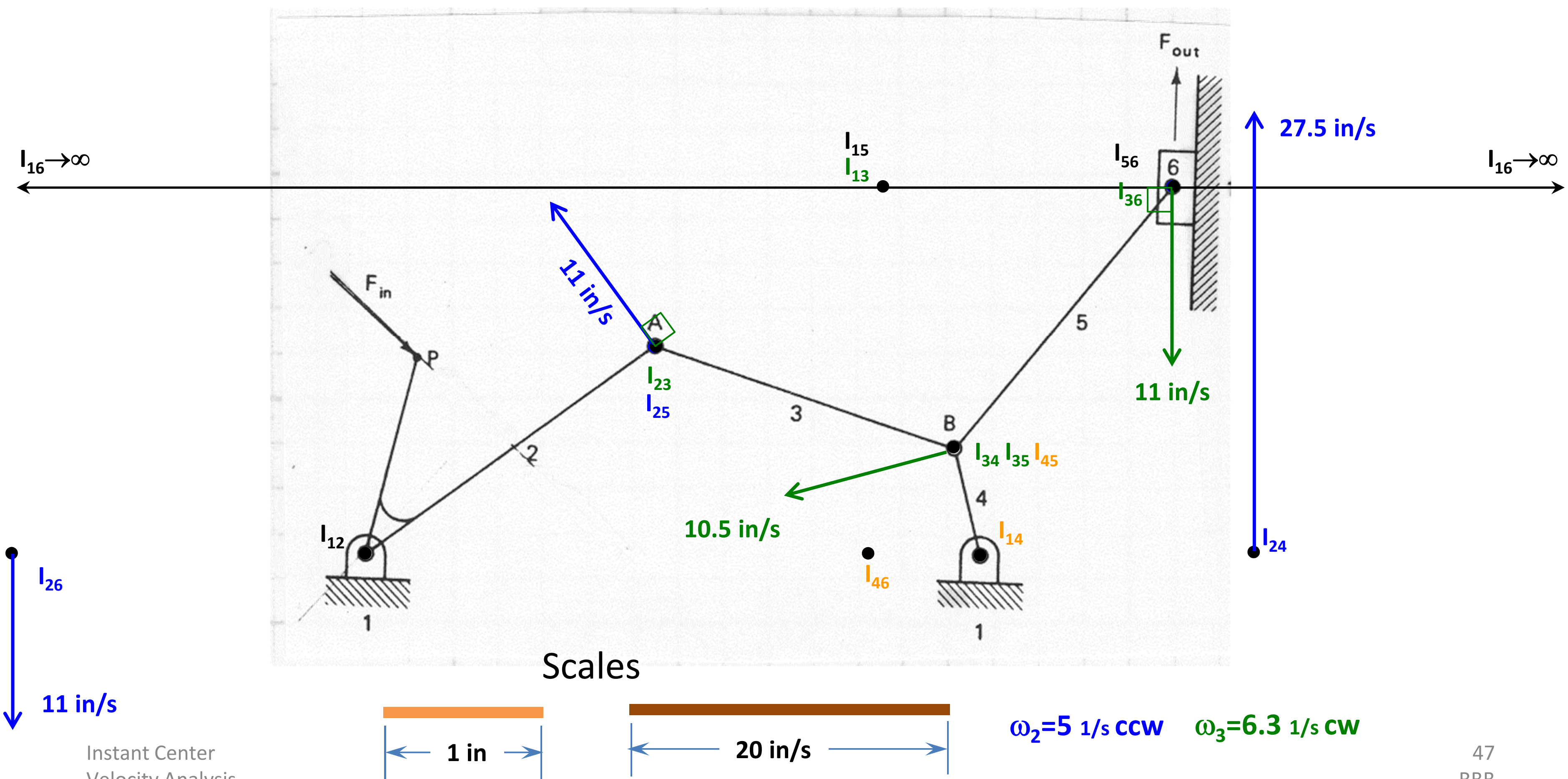
Starting by finding the LINEAR VELOCITY of Instant Centers I_{36}

- The magnitude of the linear velocity vector v_{I36} is found by
  - Measuring the scaled length of the vector drawn or $v_{I36}=v_A$
  - $v_{I36}=v_A=11.0$ in/s
- **The direction of v_{I36} is perpendicular to the line extending from I_{13} to I_{36}**



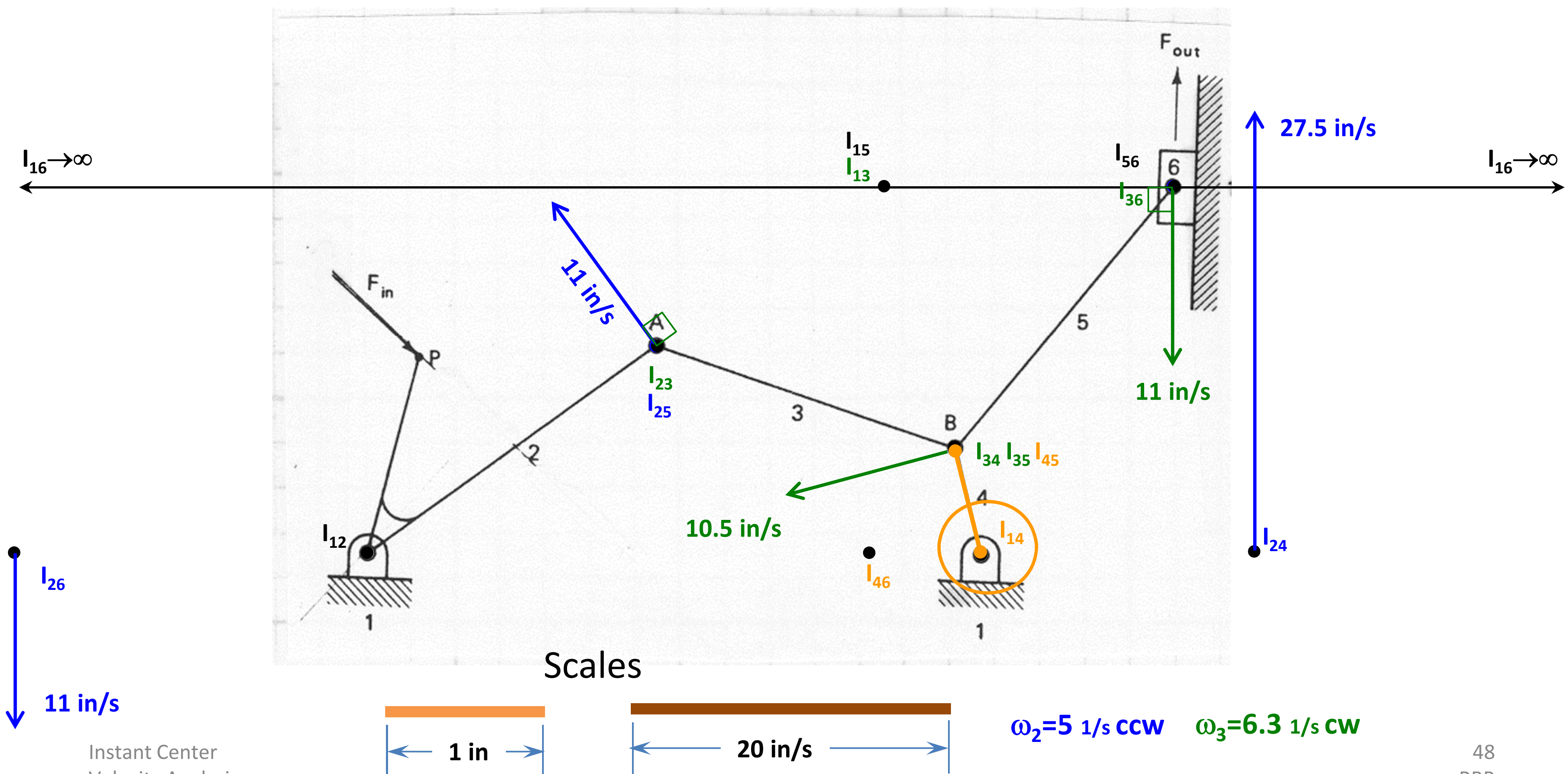
$\omega_2=5$ 1/s ccw $\omega_3=6.3$ 1/s cw

Now Link 4 and its associated Instant Centers can be considered.



ω_2=5 1/s ccw ω_3=6.3 1/s cw

At this instant, Link 4 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{14}

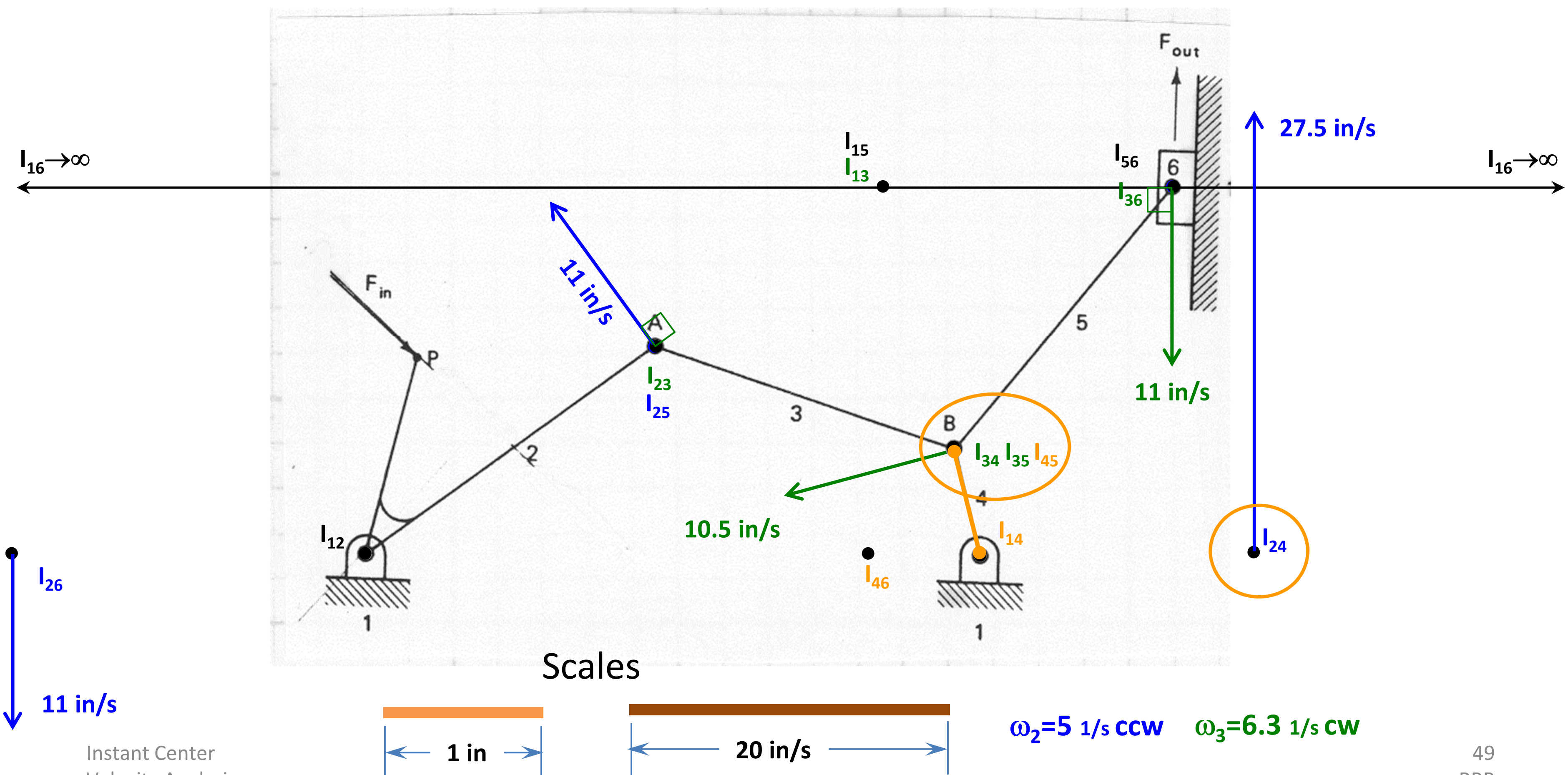


ω_2=5 1/s ccw ω_3=6.3 1/s cw

At this instant, Link 4 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{14}

There are two locations on the expanded Link 4 that that have known velocities, B/I_{45} and I_{24}

- $v_B = v_{I45} = 10.5$ in/s
- $v_{I24} = 27.5$ in/s



$\omega_2 = 5$ 1/s ccw $\omega_3 = 6.3$ 1/s cw

At this instant, **Link 4** appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{14}

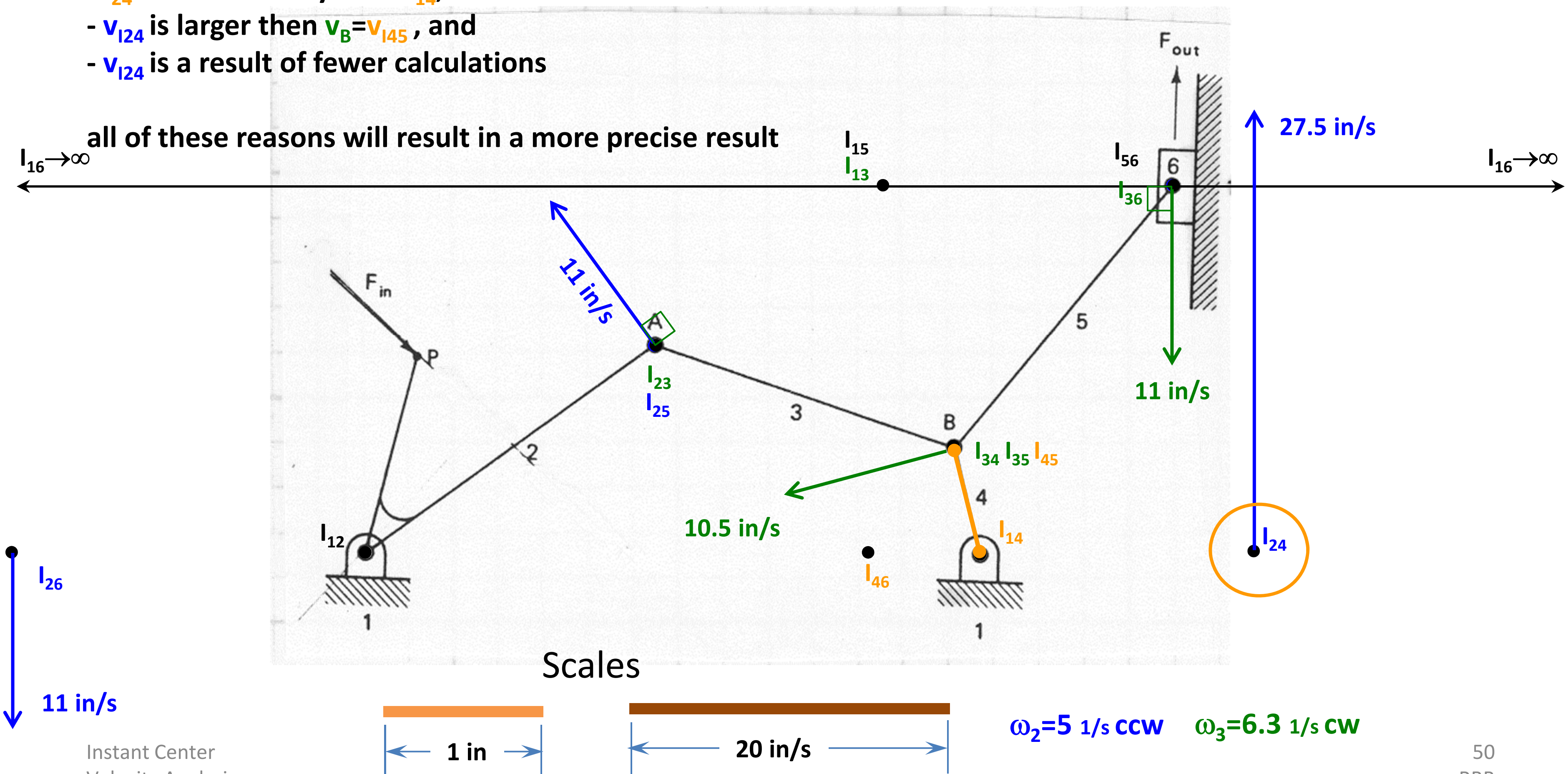
There are two locations on the expanded Link 4 that that have known velocities, B/I_{45} and I_{24}

- $v_B = v_{I45} = 10.5$ in/s
- $\mathbf{v_{I24} = 27.5}$ **in/s**

The calculation of the angular velocity ω_4 will be conducted using v_{I24} because

- **I_{24} is further away from I_{14}, and**
- **v_{I24} is larger then $v_B = v_{I45}$, and**
- **v_{I24} is a result of fewer calculations**

all of these reasons will result in a more precise result

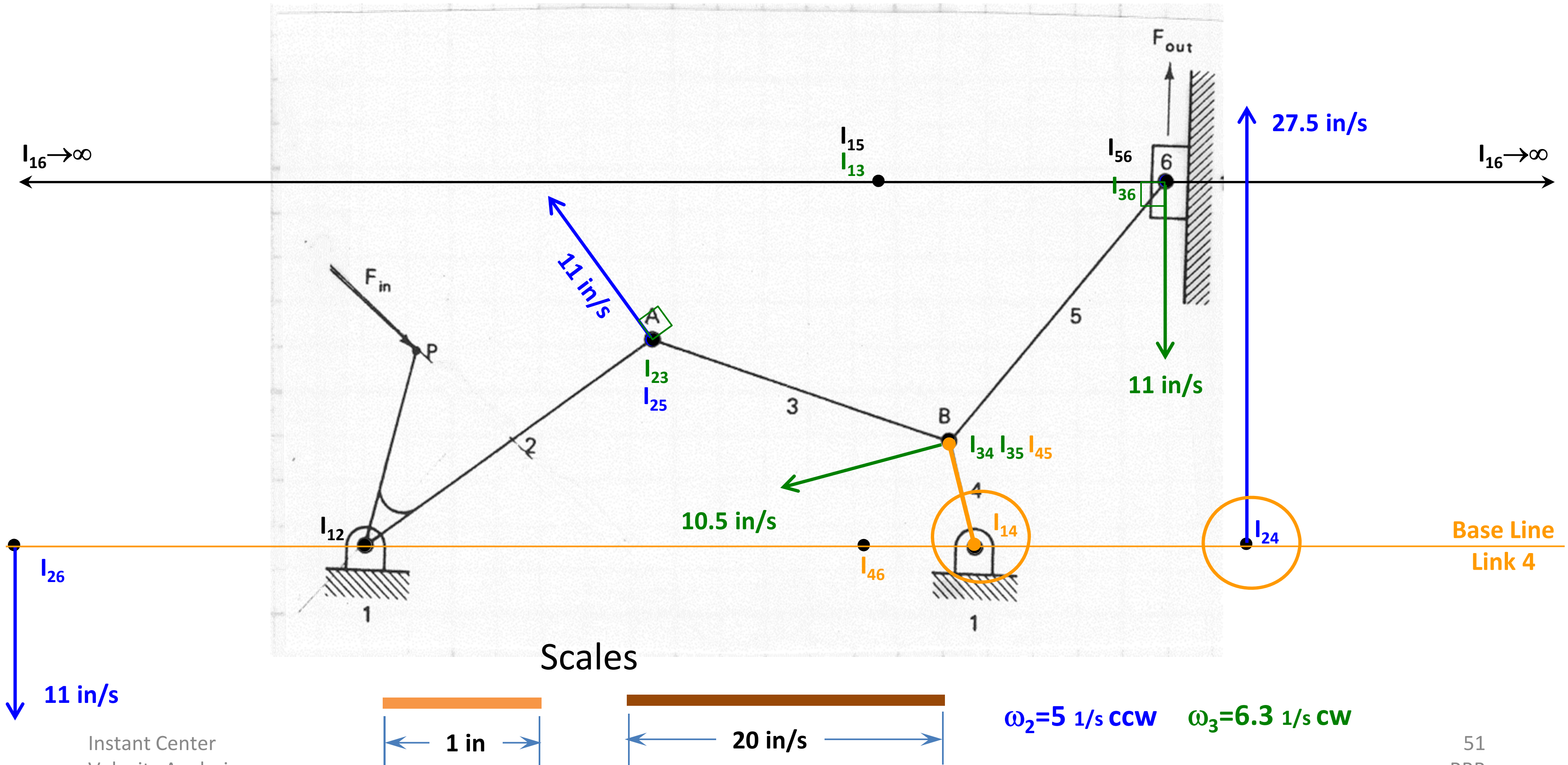


At this instant, Link 4 appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{14}

A known velocity on Link 4 is v_{I24}=27.5 in/s

The Base-Line for Link 4's linear velocities can now be drawn

- **The line must pass through I_{14} and I_{24}**



ω_2=5 1/s ccw ω_3=6.3 1/s cw

At this instant, **Link 4** appears to be rotating, with respect to the ground (Link 1), about Instant Center I_{14}

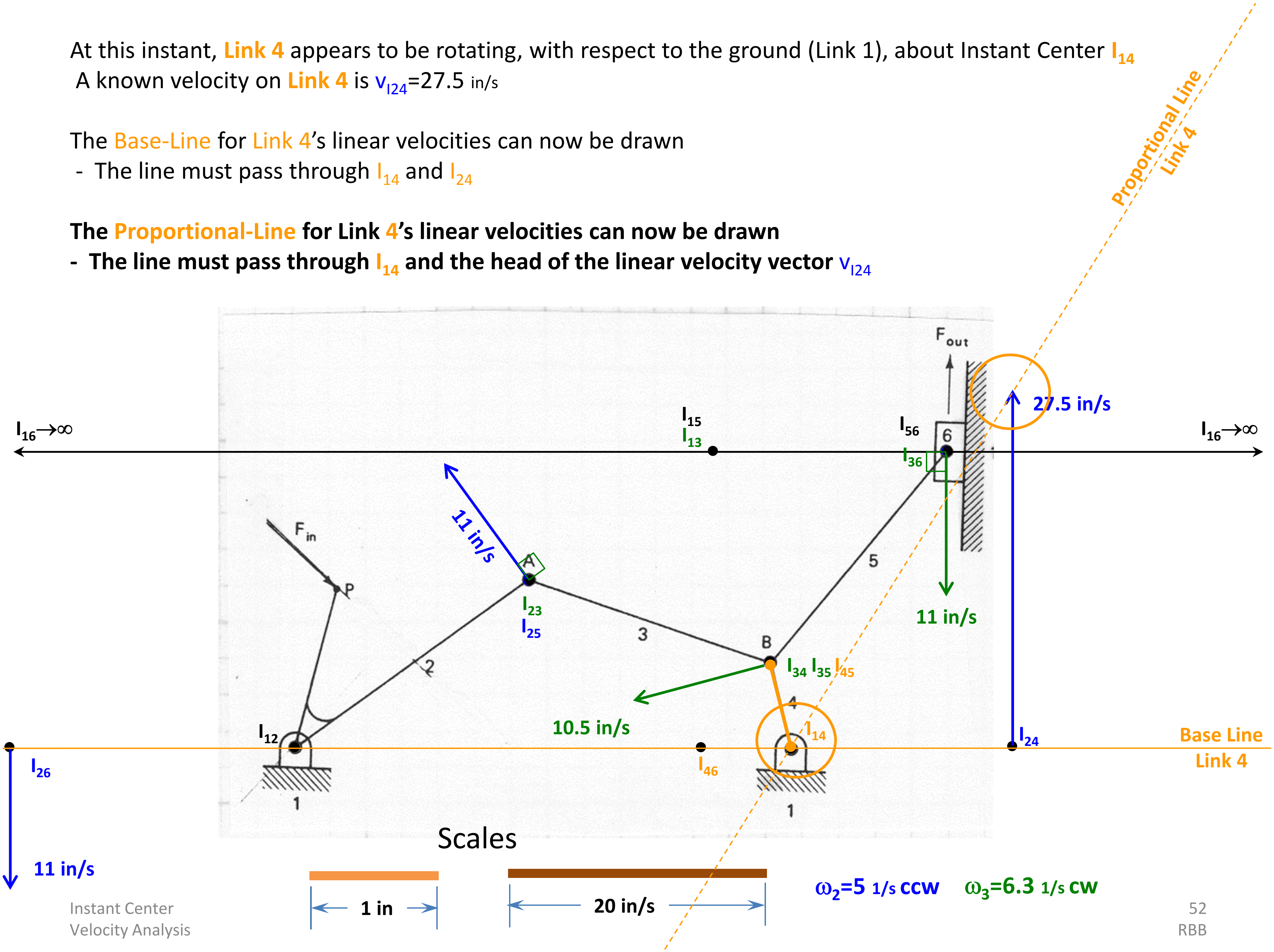
A known velocity on **Link 4** is v_{I24}=27.5 in/s

The Base-Line for Link 4's linear velocities can now be drawn

- The line must pass through I_{14} and I_{24}

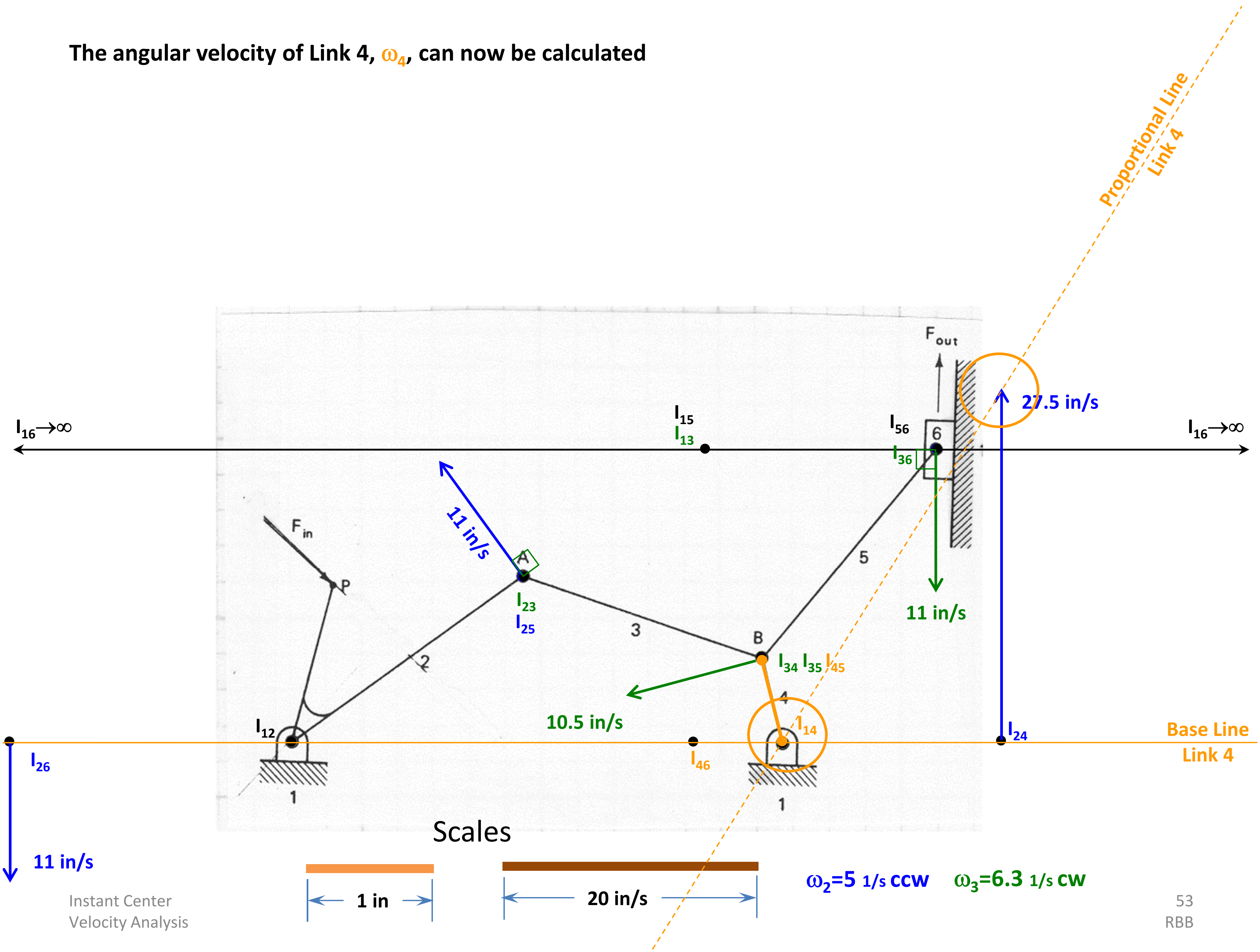
The Proportional-Line for Link 4's linear velocities can now be drawn

- **The line must pass through I_{14} and the head of the linear velocity vector** v_{I24}



ω_2=5 1/s ccw ω_3=6.3 1/s cw

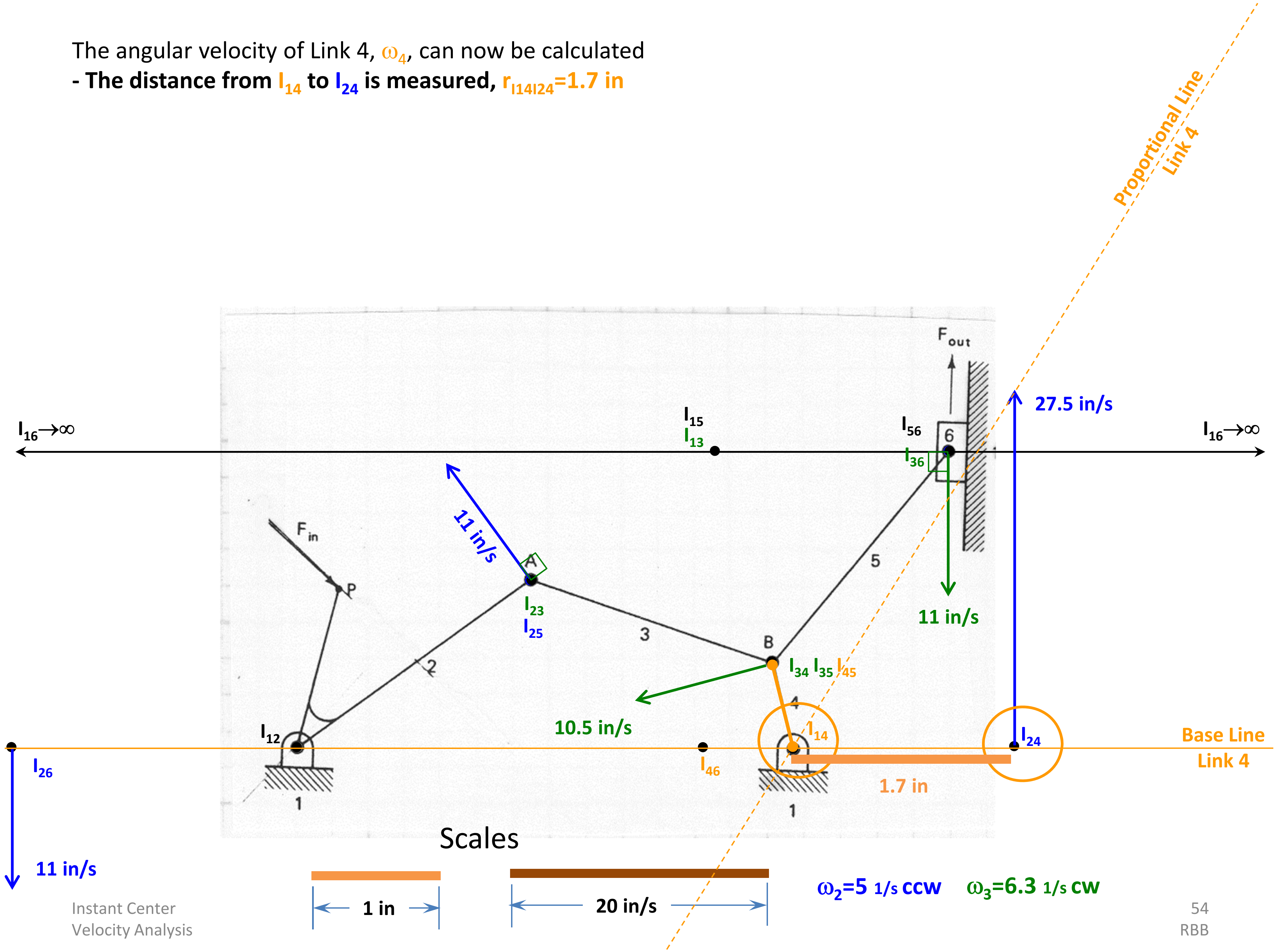
The angular velocity of Link 4, ω_4, can now be calculated



ω_2=5 1/s ccw ω_3=6.3 1/s cw

The angular velocity of Link 4, ω_4, can now be calculated

- The distance from I_{14} to I_{24} is measured, r_{I14I24}=1.7 in

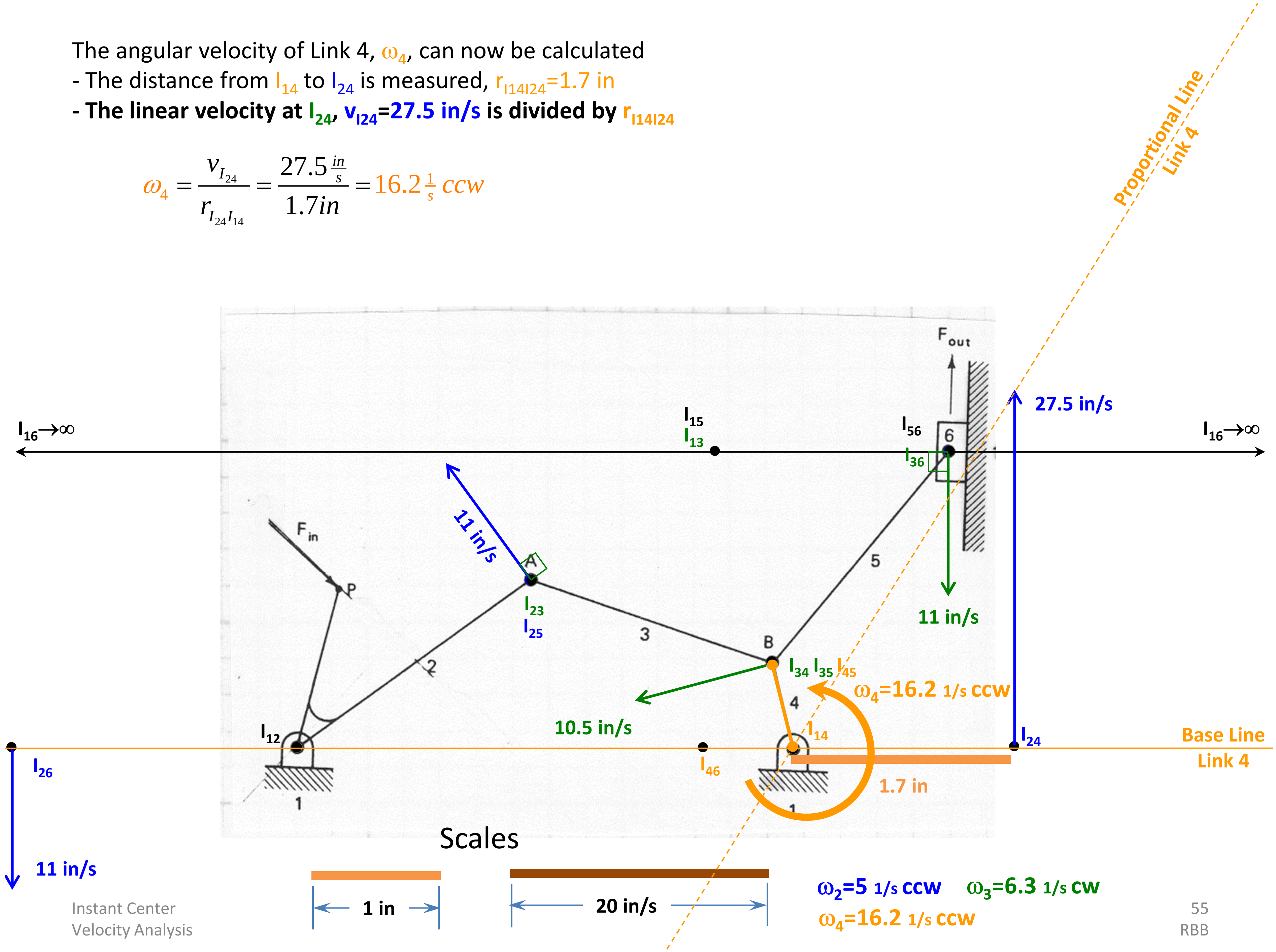


ω_2=5 1/s ccw ω_3=6.3 1/s cw

The angular velocity of Link 4, ω_4, can now be calculated

- The distance from I_{14} to I_{24} is measured, r_{I14I24}=1.7 in
- **The linear velocity at I_{24}, v_{I24}=27.5 in/s is divided by r_{I14I24}**

$$\omega_4 = \frac{v_{I_{24}}}{r_{I_{24}I_{14}}} = \frac{27.5\,\frac{in}{s}}{1.7in} = 16.2\,\tfrac{1}{s}\,ccw$$



ω_2=5 1/s ccw ω_3=6.3 1/s cw

ω_4=16.2 1/s ccw

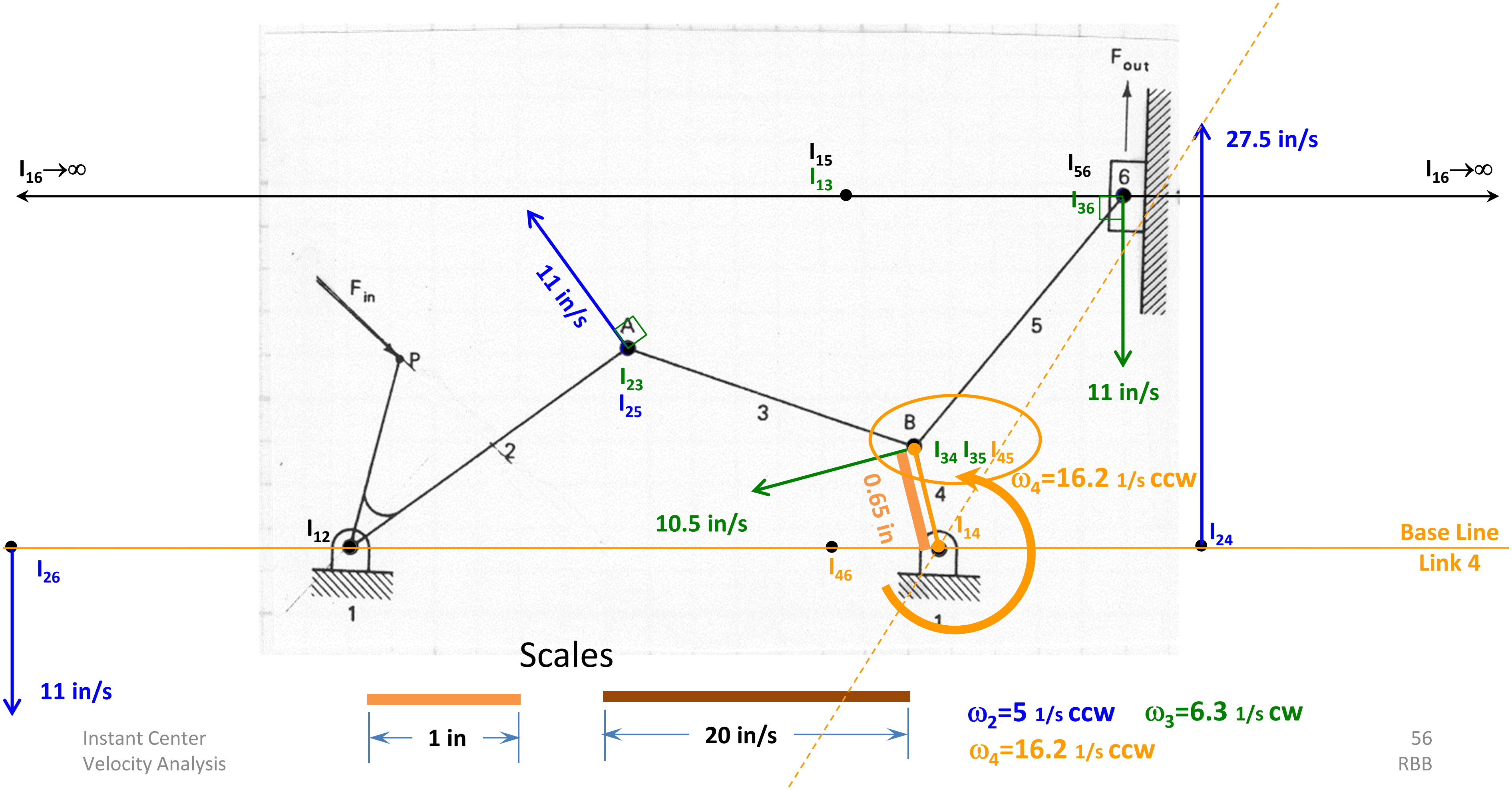
The angular velocity of Link 4, ω_4, could ALTERNATELY be calculated using

- The distance from I_{14} to I_{45}/B/I_{34}/I_{35} is measured, r_{I14I45}=0.65 in

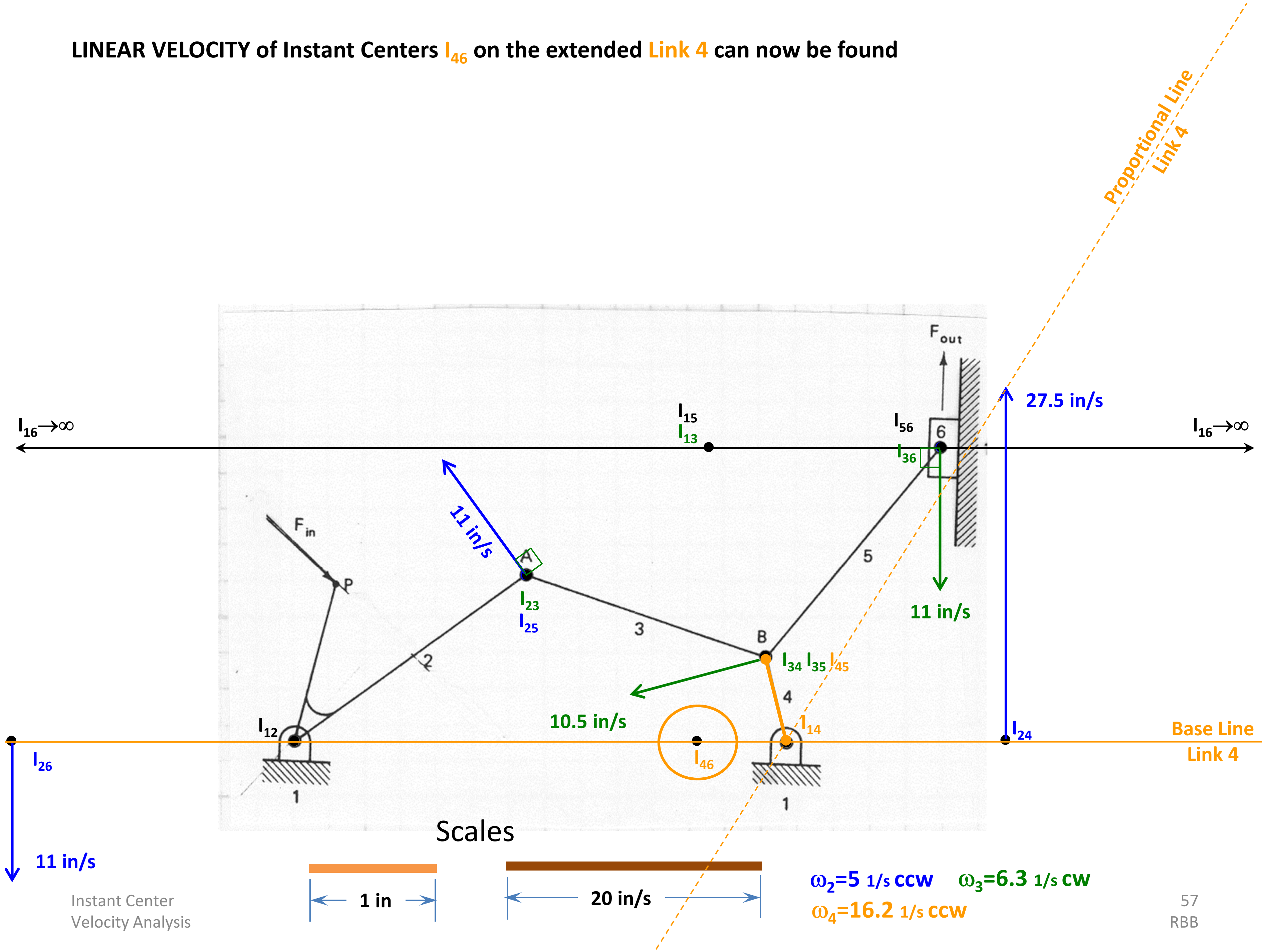
- The linear velocity at I_{45}, $v_{I45}=v_{I35}=v_{I34}=v_B$=10.5 in/s is divided by r_{I14I24}

$$\omega_4 = \frac{v_{I_{45}}}{r_{I_{45}I_{14}}} = \frac{10.5\,\frac{in}{s}}{0.65 in} = 16.2\,\tfrac{1}{s}\ ccw$$

Same result.



LINEAR VELOCITY of Instant Centers I_{46} on the extended Link 4 can now be found



Scales

1 in

20 in/s

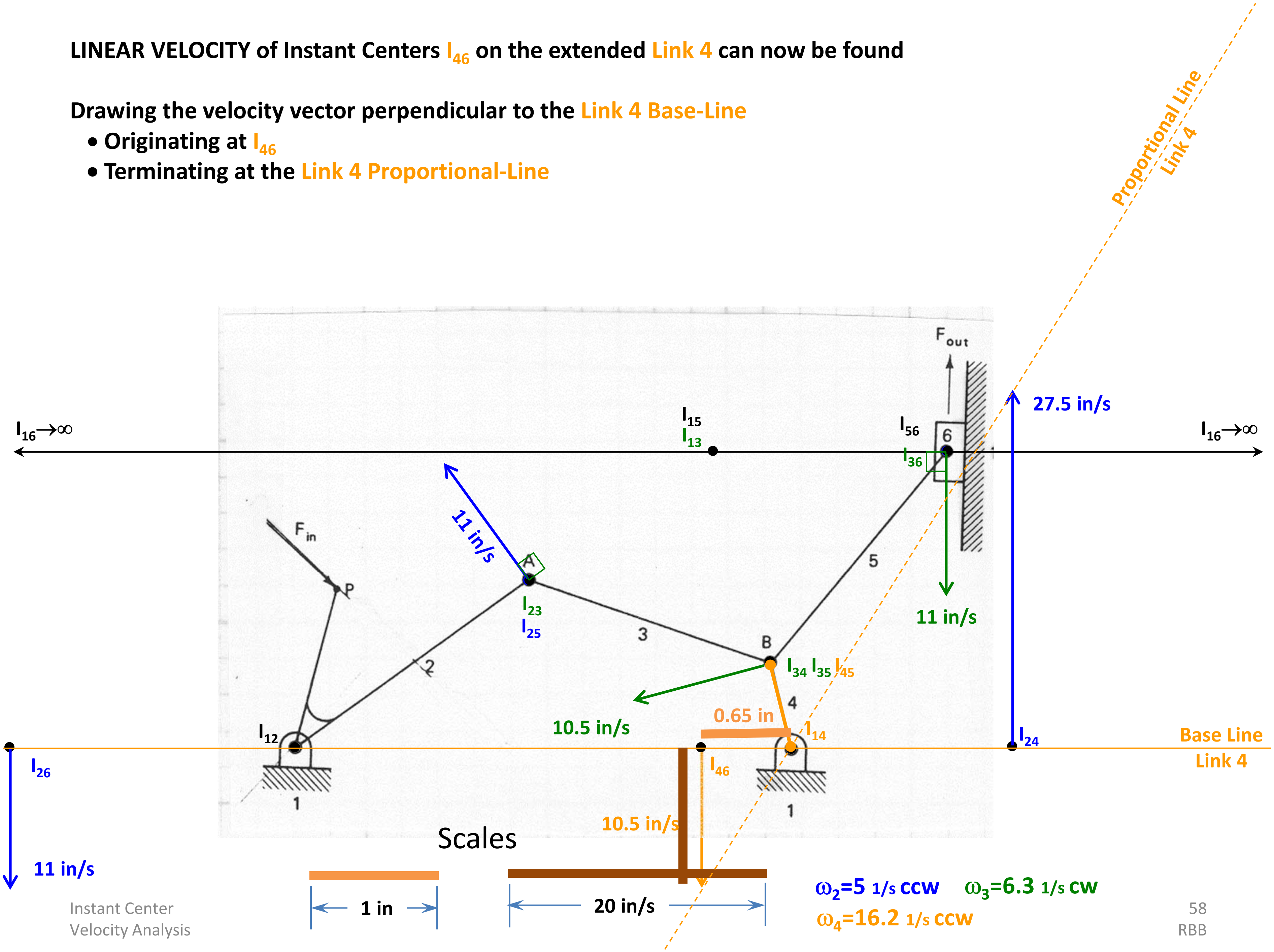
ω_2=5 1/s ccw ω_3=6.3 1/s cw

ω_4=16.2 1/s ccw

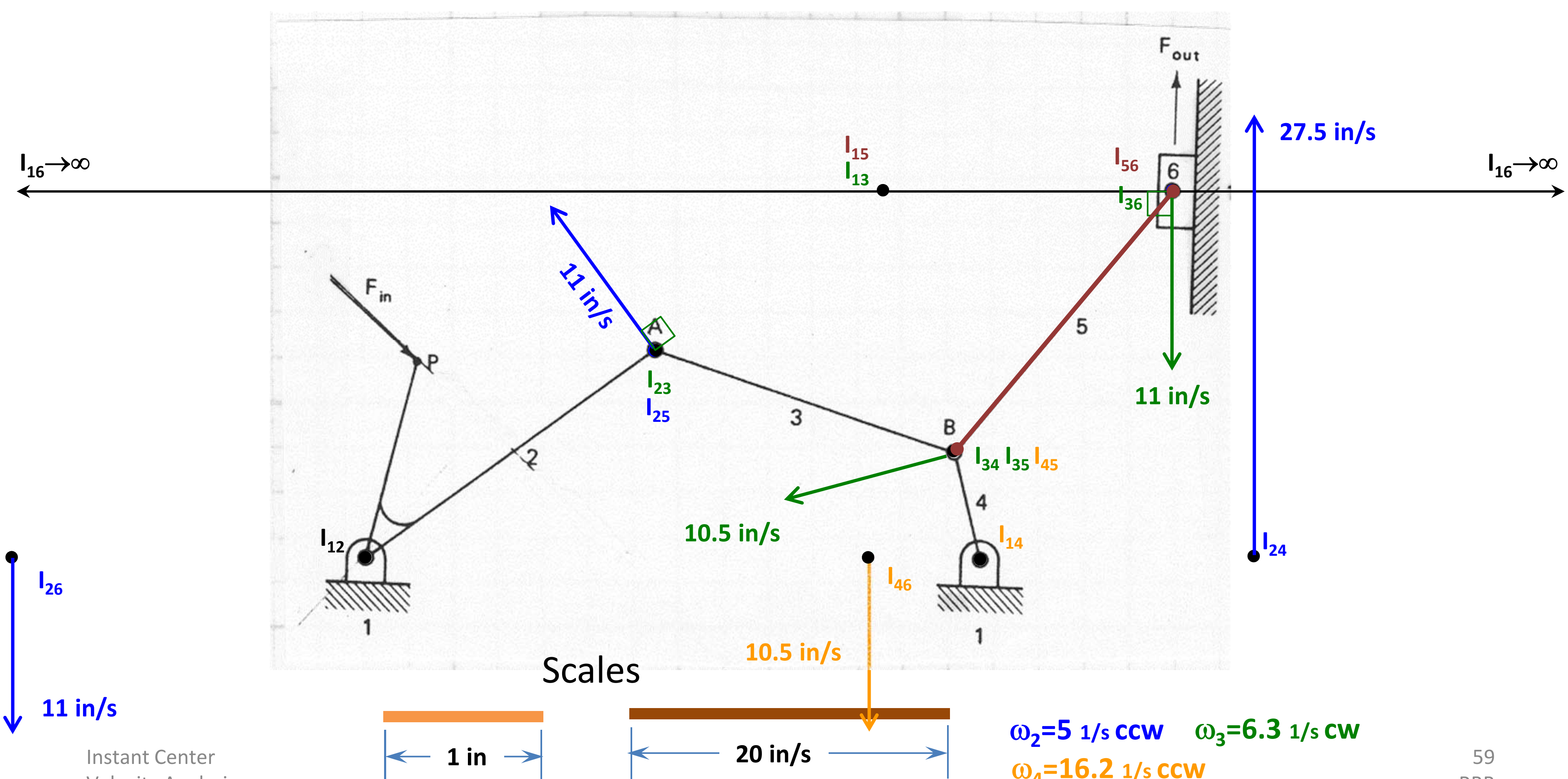
LINEAR VELOCITY of Instant Centers I_{46} on the extended Link 4 can now be found

Drawing the velocity vector perpendicular to the Link 4 Base-Line

- **Originating at I_{46}**
- **Terminating at the Link 4 Proportional-Line**



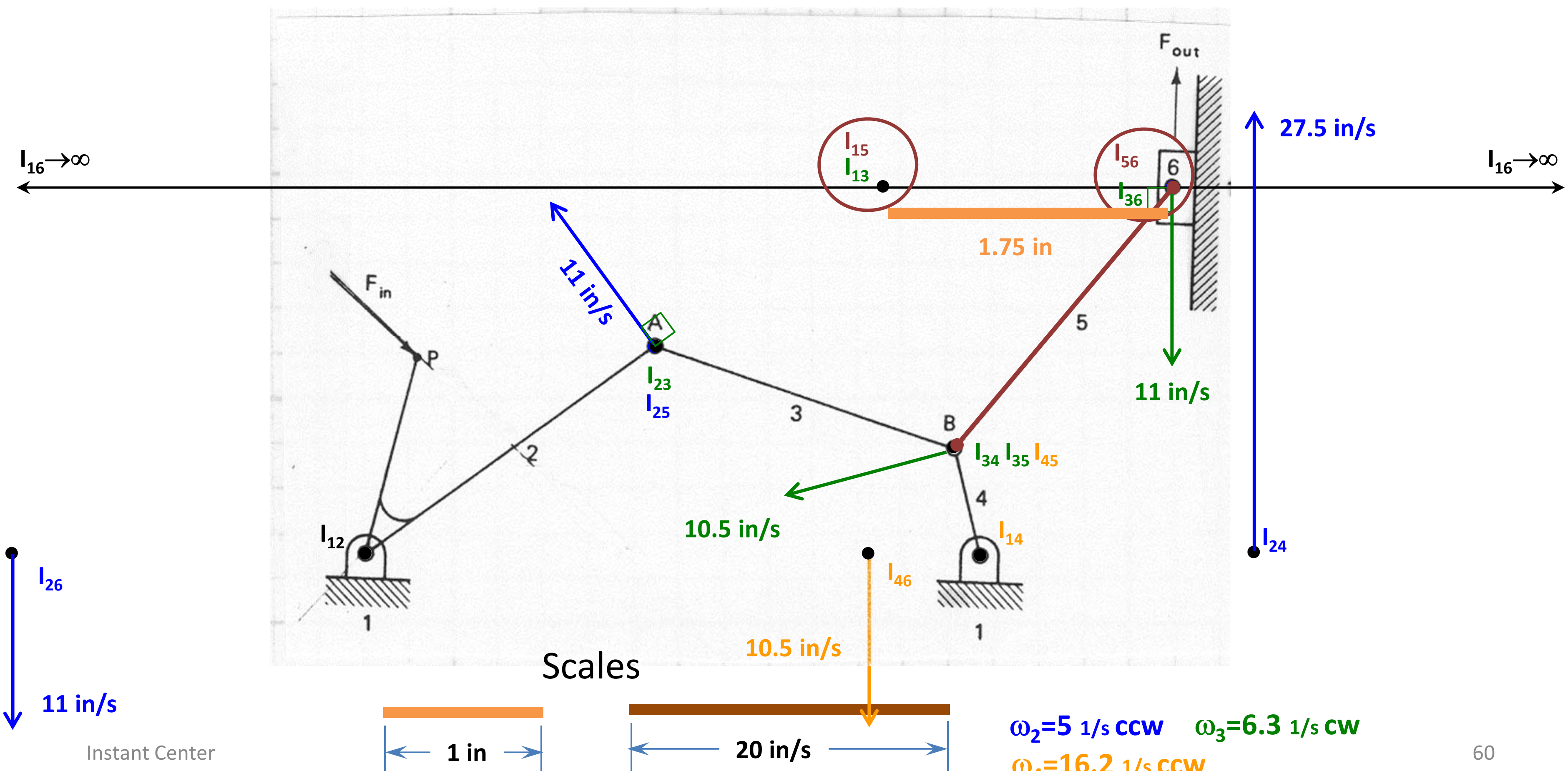
Finally, the ANGULAR VELOCITY of Link 5 can be found



ω_2=5 1/s ccw ω_3=6.3 1/s cw
ω_4=16.2 1/s ccw

Finally, the ANGULAR VELOCITY of Link 5 can be found

- The distance from I_{15} to I_{56}/I_{36} is measured, r_{I15I56}=1.75 in



ω_2=5 1/s ccw ω_3=6.3 1/s cw

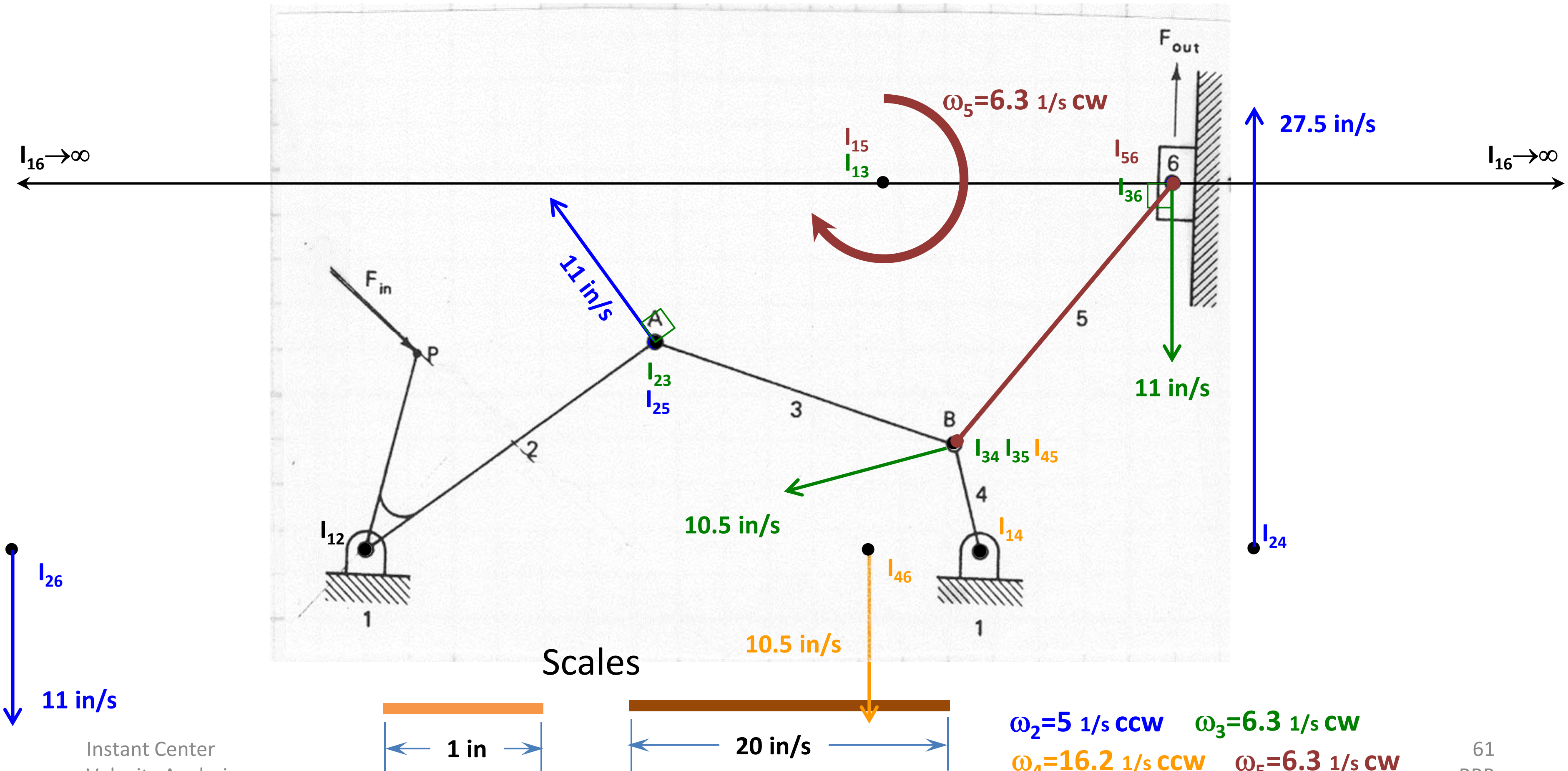
ω_4=16.2 1/s ccw

Finally, the ANGULAR VELOCITY of Link 5 can be found

- The distance from I_{15} to I_{56}/I_{36} is measured, r_{I15I56}=1.75 in

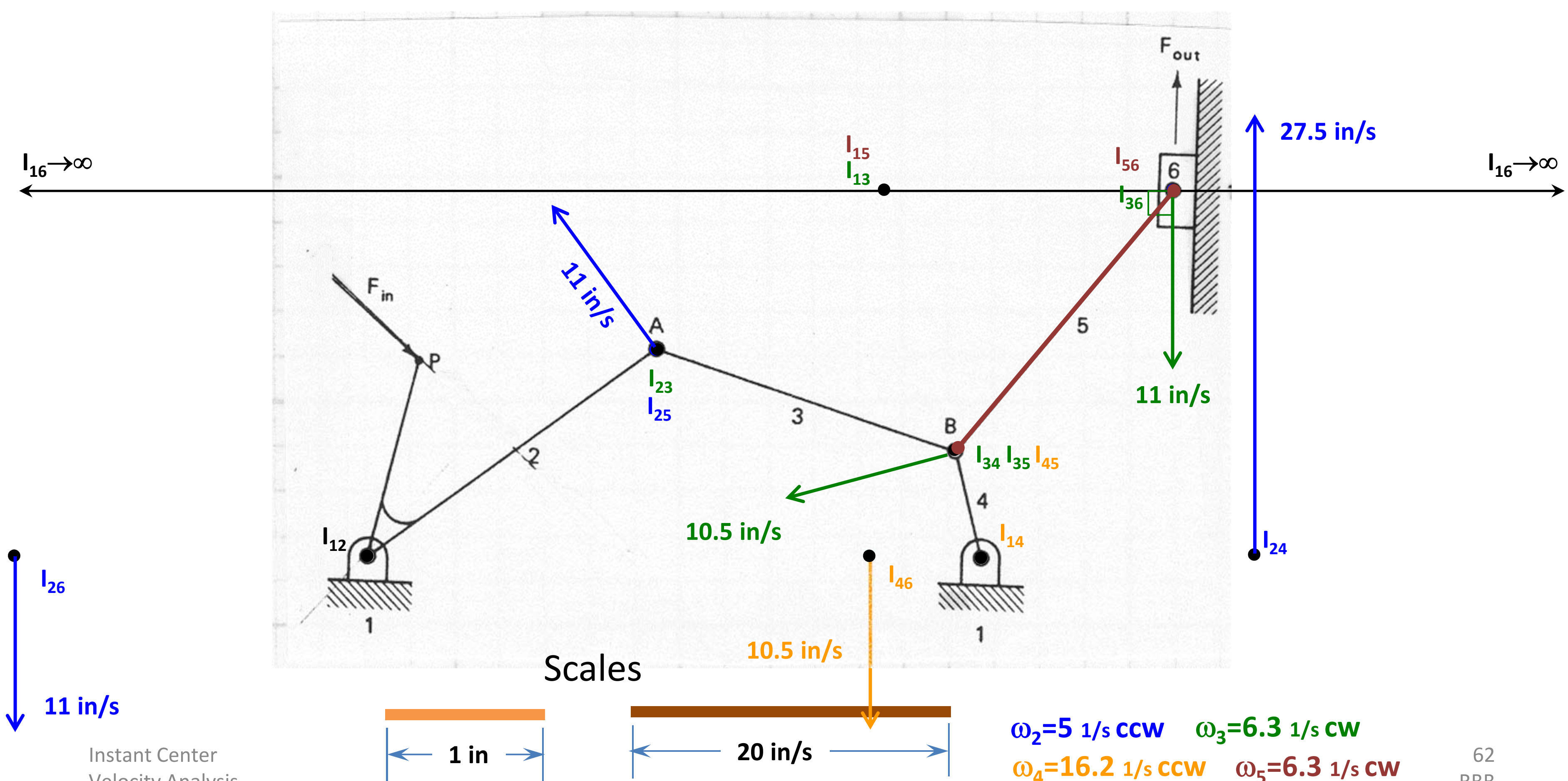
- The linear velocity at I_{56}/I_{36}, v_{I56}=v_{I36}=11 in/s is divided by r_{I15I56}

$$\omega_4 = \frac{v_{I_{56}}}{r_{I_{56}I_{15}}} = \frac{11\frac{in}{s}}{1.75in} = 6.3\tfrac{1}{s}\ ccw$$



ω_2=5 1/s ccw ω_3=6.3 1/s cw
ω_4=16.2 1/s ccw ω_5=6.3 1/s cw

All LINEAR VELOCITIES of the INSTANT CENTERS and all the ANGULAR VELOCITIES of this mechanism have been determined. The diagram below illustrates the instant center solution to his problem.



ω_2=5 1/s ccw ω_3=6.3 1/s cw
ω_4=16.2 1/s ccw ω_5=6.3 1/s cw