

Analysis of Initial Divergence Rate of Single Near-Wall Vortex in A Parallel Vortex Field

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Program Authorized to Offer Degree:

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Abstract

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This study was conducted to gain a better understanding in the interaction between vortices in a parallel vortex field near wall. This thesis describes one of the methods predicting the initial diverging speed of a single vortex in a parallel vortex field near wall. The method uses first order potential flow theory to predict the initial speed of one of the vortices. In this study, the center vortex was evaluated to simulate an infinite vortex sheet. A parametric study was conducted to see how various factors would impact the initial vortex divergence speed. The factors include the circulation strength of the vortices, the vertical distance between the wall to the vortex cores, the distance between each vortex cores, and the perturbation distance of another vortex to create the divergence of the vortex of interest.

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Chapter 1

INTRODUCTION

1.1 Problem Statement

Earlier research found that an initially turbulent boundary layer can be re-laminarized (Dawson *et al.*) over about half of the wall surface if stationary, streamwise vortices are introduced into the flow. The vortices were stabilized by a sinusoidal wavy wall if they are positioned in the middle of each trough. The resulting flow field resembles Kelvin's cat's eyes flow pattern. In the research of Oster & Wygenaski (1982) and Roberts (1985), when a shear layer is forced to generate Kelvin's cat's eyes, the shear layer can exhibit laminar fluxes, which indicate re-laminarization of the boundary layer.

In general, vortices move with respect to nearby surfaces. If the vortex can be controlled to be stationary, the physics of the vortex become vastly different. (Dawson *et al.*). The vortex can be controlled by a solid wall. A flat wall will cause the vortices to be unstable and oscillate according to Crow (Crow, 1970) and Widnall (Widnall *et al.* 1974). Instability of the vortex and the image vortex will cause each other to oscillate and become un-stationary. The interest in the current stage of the research is determining the initial oscillating speed of vortices near a flat wall so that sufficient means of controlling the vortices can be designed to maintain stability of the vortex field.

As part of the boundary layer re-laminarization research lead by Professor Robert E. Breidenthal from the University of Washington – Aeronautics and Astronautics department, this thesis reports on research in predicting the initial departing speed of the vortex due to instability of the vortices in a parallel vortex field near wall. Earlier research involving a standing vortex has showed that the benefits of a standing vortex and the subsequent boundary layer laminarization include reduced heat flux from the fluid to the solid surface and the analogous phenomenon of reduced surface friction. This theory was further validated by recent experiments in creating standing vortices by using vortex generators and corrugated steel wall with cross sectional shape that resembles a Von Karman wavy wall (Amir) shown in Figure 1.1. The Von Karman wall

was needed partially in order to keep the vortex in its original position. This experiment showed that roughly half of the surface of the wall had a laminar boundary layer. With this result in hand, one of the challenges in the next step is to creating the parallel standing vortices on a flat wall for further evaluation of the aforementioned benefits.

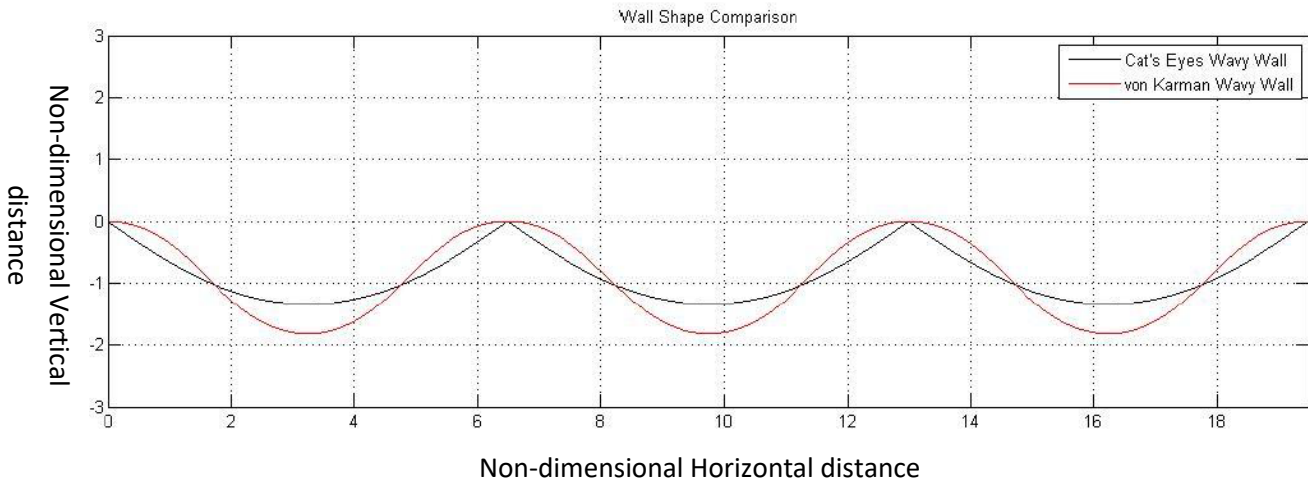


Figure 1.1 Von Karman Wavy Wall Shape (Mehmedagic)

In order to keep the standing vortices stationary in a parallel vortex field near wall, the vortices will have to be in equilibrium. Several challenges will have to be worked out due to the unstable nature of the parallel vortex field, with the main issue being stability and divergence of the vortices. Equilibrium can be achieved by setting equal spacing between the vortex cores and the distance between the vortex cores and the wall, and having same vortex strength (magnitude of circulation). Unlike having equilibrium, stability will require active control of each of the individual vortices, which requires an understanding of the initial diverging speed of the vortex cores. This analysis shows the results generated by using potential theory in trying to predict this speed under different conditions.

1.2 Analysis Background

The goal of this analysis is to simulate the velocity field of parallel vortices near wall. Potential flow theory has been proposed and widely in use for several decades. Potential flow is selected in this case for its ease of use and fast speed for gathering a huge amount of data, as the purpose

of this study is to be able to have a preliminary result of how quickly a disturbed vortex initially diverges from its nominal position. Also, a large amount of data can be easily generated on a PC rather than a multi-core super computer if the full Navier-Stokes equation with a satisfactory turbulence model was to be used.

In Saffman (1993), the complex potential presented in section 7.2 offers a mathematical description of a single vortex near wall. In fact, the model is created by adding two vortices with equal circulation strength and opposite direction of rotation. As a result, the streamline half way between the centers of the two vortices is a straight line that is perpendicular to the line connecting the two vortex cores, representing a flat wall exactly half way between the two vortices. Due to the linear nature of these vortices described by potential flow theory, multiple pairs of these vortices can be either added or subtracted in order to simulate the flow field of interest. Fig. 1.2 captures a section of the parallel vortex flow field described above. It contains a velocity magnitude field of an infinite pairs of the equal-strength and opposite-sign vortex pairs. The color blue and yellow denotes opposite ends of the velocity magnitude spectrum.

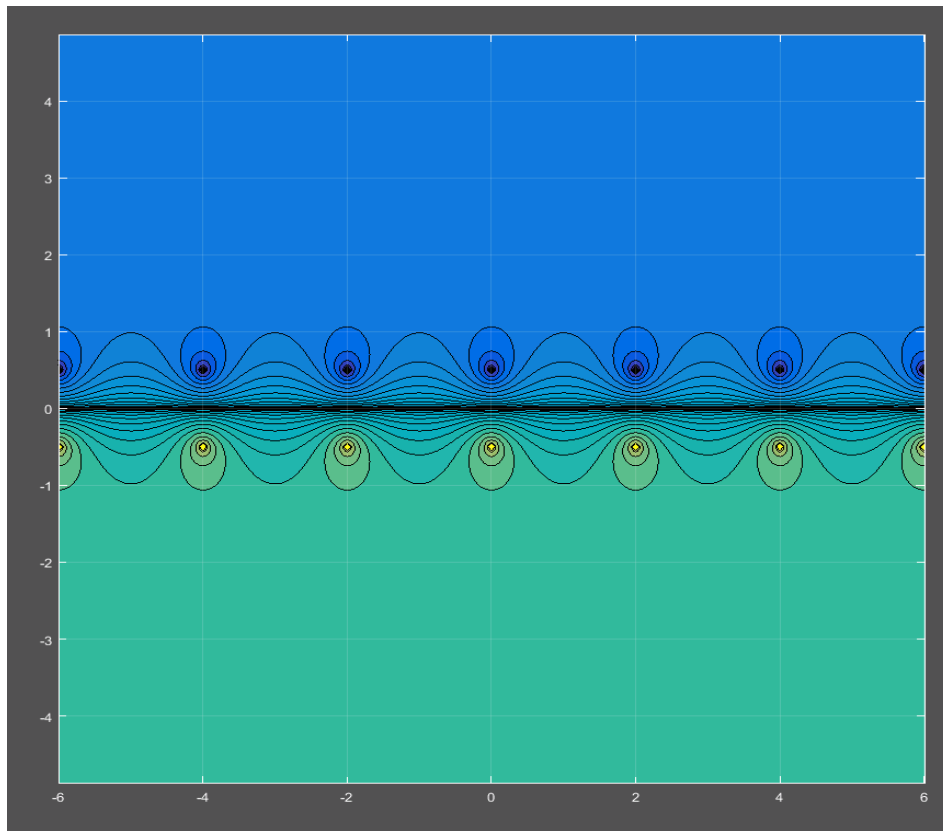


Figure 1.2: Plot of an Infinite Parallel Vortex Field Near Wall.

In Fig. 1.2, the center horizontal line formed by the straight streamlines existing between the parallel vortex fields represents a wall. The vortex field above the center line mirrors the one on the bottom with opposite sign. The vortices are in equilibrium. They are in equilibrium because the induced velocity from one side of a vortex balances out the contribution from the other side. Therefore, the vortex will remain at their initial location as long as there is no disturbance elsewhere in the flow field. In the case that one of the vortices moves away from its equilibrium position, then the disturbance would create unbalanced induced velocity on this vortex and it will diverge and become unstable, causing the entire vortex field to become unstable. The unstable feature of the vortex field will be used to investigate the initial divergence speed of the vortices. Fig. 1.3 shows how the vortices are stable and in equilibrium.

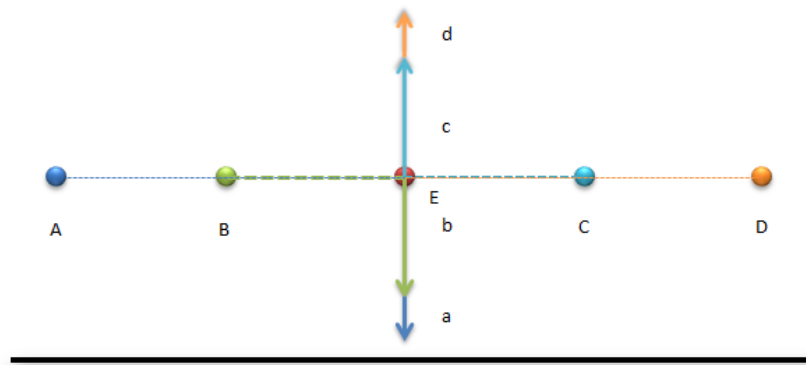


Figure 1.3: Vortex Induced Velocity Vectors – In Equilibrium

In Fig. 1.3, circles A, B, C, D, E represents five vortex cores. Vectors a, b, c, d represent induced velocity vectors by A, B, C, D on vortex E. Because the circulation strength, horizontal distances between vortex cores, and vertical distances from the wall to the vortex are the same for all vortices, the magnitude of vector c equals b, and the magnitude of a equals d. Assuming this is an infinite vortex field, and then the contribution from combination of all other vortices on either side of vortex E should cancel each other out. The same applies to all the other vortices in an infinite vortex field. Therefore, the vortex field is in equilibrium. However, once the vortex departs from its neutral position, the equilibrium will no longer exist. Under the influence of all other vortices, the induced velocity from other vortices will cause the vortex of interest (E) to diverge from its initial neutral position, as shown in Fig. 1.4. The black solid curve indicates a

possible projected trajectory of vortex E. As the equilibrium of the flow field is disrupted, vortices A through D will move as a result.

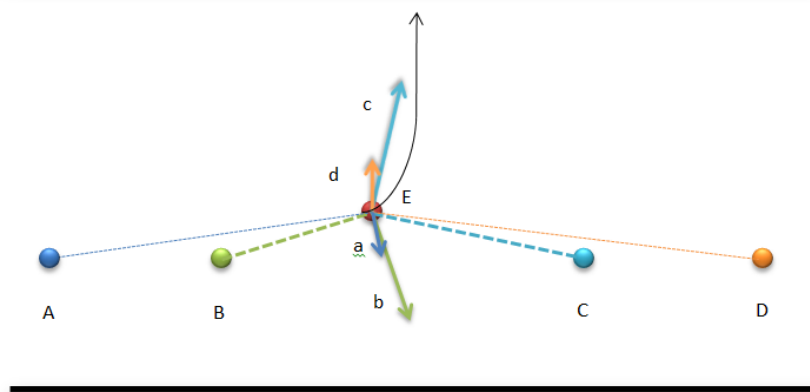


Figure 1.4: Vortex Induced Velocity Vectors – Not In Equilibrium

As the estimated trajectory suggests, the parallel vortex field will become unstable as soon as the vortex moves away from its neutral position. In order for the vortex field to return to its equilibrium state, a localized flow perturbation will have to be applied with same magnitude in opposite direction in order to maintain equilibrium in the vortex field. The initial velocity of the vortex will have to be understood in order to understand how quick of an active control is needed in order to keep the flow field in equilibrium.

Potential flow theory is used for this analysis. Potential flow theory offers a very reasonable estimation with minimal computing resources. In this analysis, the flow is assumed to be inviscid, incompressible and with its velocity irrotational. The velocity potential is denoted as ϕ . It is a function of space and time. The flow velocity, V , can be described as gradient of the velocity potential. $\vec{V} = \nabla\phi = \left\{ \frac{\partial\phi}{\partial x}, \frac{\partial\phi}{\partial y}, \frac{\partial\phi}{\partial z} \right\}$. Using Laplace's equation, $\nabla^2\phi = \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} = 0$.

A complex potential is described as $w = \phi + i\psi$. Whereas ψ is the stream function. Its definition is: $u = \frac{\partial\psi}{\partial y}, v = \frac{\partial\psi}{\partial x}$, and $\frac{dw}{dz} = u - iv$.

1.3 Analysis Methodology

Estimation of the initial vortex diverging speed is done via using the model introduced in section 1.2. In this scenario, the speed is the magnitude of the combination of induced velocity at point

E from all vortices around it as shown in Fig. 1.5. The velocity field of vortex E cannot have impact on itself, therefore, the vortices around it defines its diverging speed.

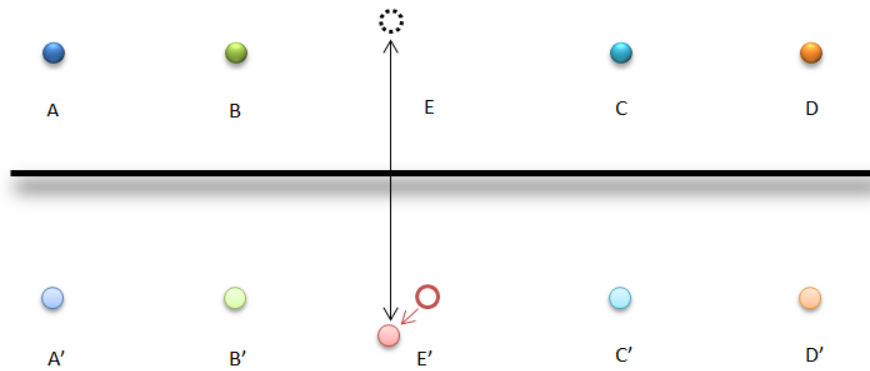


Figure 1.5: Parallel Vortex Model for Computing Initial Diverging Speed

Several parameters are assumed to have an impact on the initial diverging speed. They are:

- The horizontal distance between vortex cores, λ
- The vertical distance from the vortex cores to the wall, h
- The circulation strength of the vortices, Γ
- The perturbation distance of the opposite vortex E', Δx .

The variables mentioned above can be seen in Fig. 1.6.

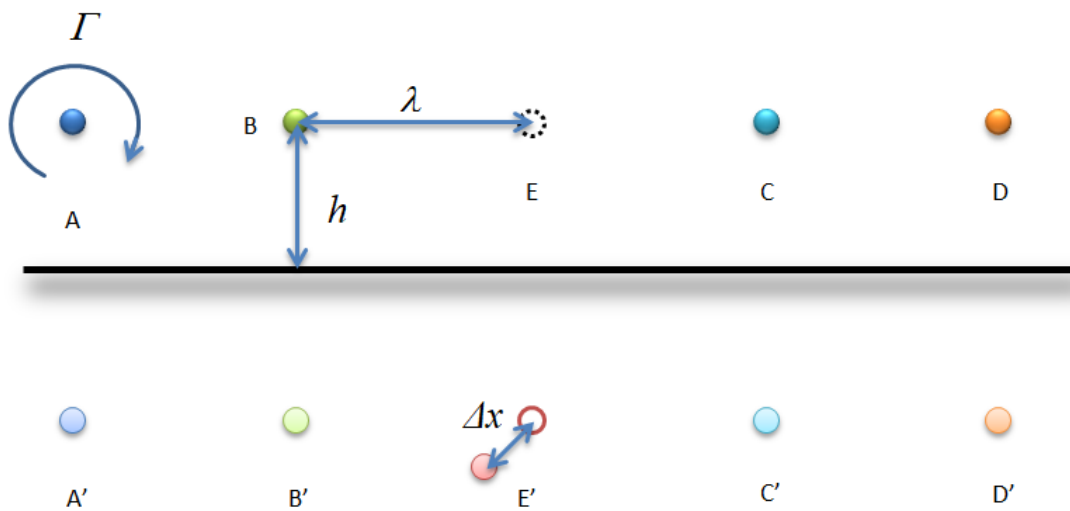


Figure 1.6: Variables in the Parallel Vortex Model for Computing Initial Diverging Speed

In both Fig. 1.5 and 1.6, the vortices have equal spacing between the vortex cores, vertical distance from the wall, and circulation strength. Vortices A', B', C', D', and E' are the opposite sign vortices from A, B, C, D, and E respectively. In this analysis, E' is perturbed by a distance

of Δx to analyze the impact to diverging speed of vortex E. Vortex E will be removed so that its own impact is not included in the results of the diverging speed. As the location of E' was thought to have an impact on resulted speed on E, the perturbation of E' is described by displacement, Δx , and angle from origin, θ .

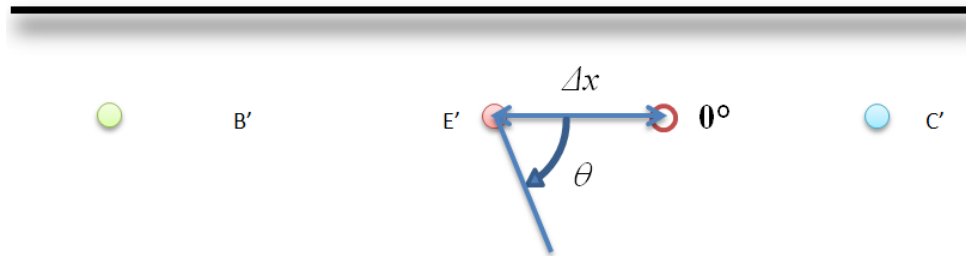


Figure 1.7: Perturbation displacement and orientation.

1.4 Process of the Analysis

The analysis is carried out in the following steps using the background knowledge presented in section 1.1 through 1.3. The analysis outlines the major steps from the initial setup of the analysis, the parametric study, and the data evaluation to reach final conclusions. These steps are:

1. Define the independent variables and the dependent variables
2. Construct the vortex field in neutral position
3. Construct the perturbed vortex field
4. Compute the difference between the initial and perturbed vortex fields
5. Parametric Study:
 - a. Vary the horizontal distance between the vortex cores
 - b. Vary the vertical distance from wall to the vortex cores
 - c. Vary the circulation strength
 - d. Vary the perturbation displacement
 - e. Vary the perturbation orientation

6. Evaluate how the diverging speed of the vortex vary with each of the independent parameters

Chapter 2

Modeling

A MATLAB code was written to evaluate the initial divergence speed of one of the vortices in the parallel vortex field near wall. The model follows the processes outlined in section 1.4. The following sections will explain the details and implementation of each of the steps.

2.1 Advantages Of MATLAB For This Analysis

MATLAB was selected for this project for its strength in floating point linear algebra operation, ease of use, and availability. Also, its extensive and powerful plotting options make it ideal in this analysis as it can offer direct visual representations that is easy to understand.

2.2 Structures of the Code and Equations Used

The MATLAB code first takes in all independent variables needed for the analysis. The parameters including circulation strength (Γ), vertical distance (h), horizontal distance (λ), perturbation distance (Δx), and number of vortex pairs on each side of the center pair of vortices. Due to the limitation on computational resources, it was found that having 4 pairs of vortex on each side was one of the best trade-off between computational time versus data quality. With 4 pairs of vortex selected on each side of the center pair of vortex, results 9 vortex pairs equally spaced in the computational space.

After the input information listed above is defined, the code then proceeds to create a 2D computation space according to the dimensions in order to resolve the simulated flow field. This is accomplished with meshgrid command in MATLAB. With the computational space defined, vortices are then added to the computational space as potential flow method allows for linear superposition. The complex potential that describes a single line vortex with strength Γ at z_0 is

$$w = -i \frac{\Gamma}{2\pi} \log(z - z_0)$$

whereas $z = x + iy$.

Adding one more element to the equation with an opposite sign vortex describes a counter rotating pair vortex that are symmetrically placed in a parallel sided channel of width b , distance $b-2h$ apart. The complex potential then becomes:

$$w = -i \frac{\Gamma}{2\pi} \log \frac{(z - i(b - h))}{z - i h} + W(z)$$

where $W(z)$ is analytic in the channel. $W(z)$ is not considered in this study as only the initial steady state solution is studied in this project.

To simulate two counter-rotating vortices, the complex potential $w = -i \frac{\Gamma}{2\pi} \log \frac{(z - i(b - h))}{z - i h}$ can be used. The wall is represented with the streamline that is parallel to the x-axis in between the two vortices. When two vortices with equal and opposite direction are placed next to one-another, the streamlines between the two vortices becomes a straight line that is perpendicular from the line connecting the vortex cores of the pair. These streamlines represent a perfectly flat wall. The flow field calculated on each side of the line represents the flow field of a vortex near a flat wall. The pair plotted out in MATLAB can be seen in Fig. 2.1

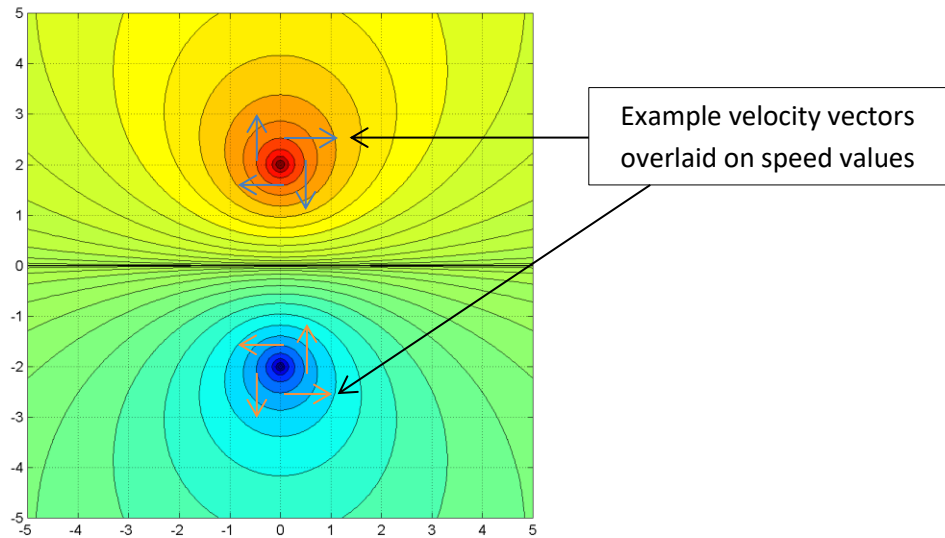


Figure 2.1: Vortex near Wall – Counter-Rotating Vortex Pairs

Adding all of the nine pairs of vortices will make up the baseline vortex field in this analysis. Fig. 2.2 shows an example of the baseline flow field.

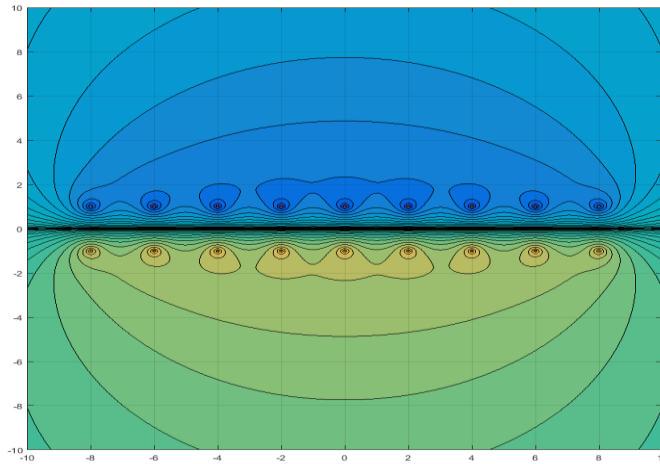


Figure 2.2: Vortex near Wall – Baseline Vortex Field (9 pairs)

Once the baseline vortex field was generated, the perturbed vortex field is generated. In order to create the new vortex field, the 4 pairs of each side of the center pair are unchanged. The only thing that would change is the removal of the center top vortex combined with perturbed center bottom vortex. The resulting flow field calculates the total change in speed at where the center top vortex used to be, thus calculating the initial diverging speed of the top center vortex. An example of the diverging vortex field can be found in Fig. 2.3 below.

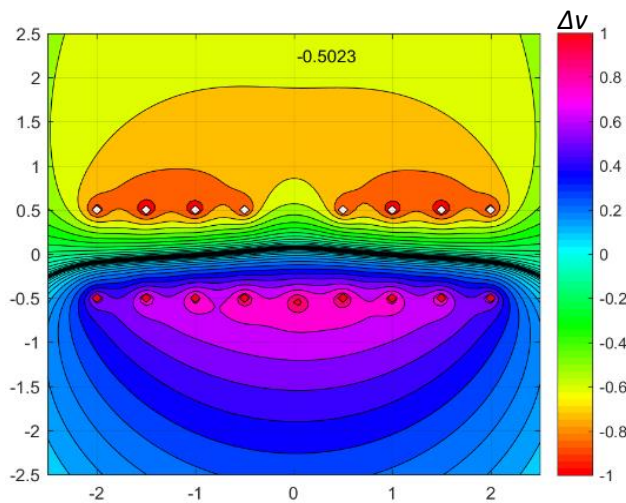


Figure 2.3: Vortex near Wall – Perturbed Vortex Field (9 pair example)

Fig. 2.3 also shows the lower center vortex in a perturbed state. The perturbation was accomplished by adjusting the values in the complex potential equation.

The original form of the complex potential equation is

$$w = -i \frac{\Gamma}{2\pi} \log \frac{(z - i(b - h))}{z - i h} + W(z)$$

The perturbation is added to the above equation and becomes:

$$w_{perturbed} = -i \frac{\Gamma}{2\pi} \log \frac{(z - i(b - h + Dvl) - Dhl)}{z - i(h + Dvu) - Dhu} + W(z)$$

Where:

Dvl – positive displacement in the horizontal axis for the lower vortex

Dhl – positive displacement in the vertical axis for the lower vortex

Dvu – positive displacement in the horizontal axis for the upper vortex

Dhu – positive displacement in the vertical axis for the upper vortex

In the perturbation study, since the upper vortex was removed, the denominator of the log expression is removed. Thus, the values of *Dvu* and *Dhu* are zero. The numerator of the log expression defines the lower vortex position. *Dvl* and *Dhl* are adjusted accordingly for each value of Δx and θ to move the lower vortex to its appropriate perturbed position. *Dvl* and *Dhl* are linear displacement in the vertical and horizontal axes. The value Δx is displacement from original vortex core to the new position. Therefore, *Dvl* and *Dhl* are calculated accordingly in each case depending on the value of Δx and θ .

Therefore, the complex potential of the perturbed center lower vortex becomes:

$$w_{perturbed} = -i \frac{\Gamma}{2\pi} \log(z - i(b - h + Dvl) - Dhl)$$

2.3 Setup of the parametric study

The parametric study investigates how each of the independent variables would affect the outcome of the analysis. As mentioned earlier, the variables include relative position of the vortex to the wall (vertical distance from the wall, and distance between the vortex cores), the circulation or vortex strength, and perturbation orientation and distance. Different combinations of the parameters were analyzed with the MATLAB code to simulate different vortex fields. The results are shown and analyzed in the following sections.

2.4 Acquiring the Results

Obtaining the results in this analysis is done both visually and numerically. To see the results of the flow field visually, the final computational space is simply plotted out. The plotting is accomplished by using command `contourf`. `Contourf` displays isolines calculated from the user specified matrix and fills the space between the isolines using constant colors from the colormap. Color bars were also included to indicate the magnitude for the values each color represent.

All plotting in this paper shows the imaginary part in the complex potential, which is the magnitude of the velocity in the 2-dimensional computational space. Each solid black line represents a streamline.

The values presented in this paper are hypothetical in nature; they only represent a relative magnitude system that can be applied to the specific unit system and physical medium of interest. As the magnitude of the complex potential is presented and plotted, the negative values represent decrease in the magnitude of delta-velocity, whereas positive values represent increase in the magnitude delta-velocity.

All of the plots shown in chapter are results from the initial frame of the flow field, as the parameter of interest is initial divergent speed of the upper center vortex that is horizontally symmetric to the disturbed vortex about $y = 0$.

Chapter 3

PARAMETRIC ANALYSIS USING THE MATLAB MODEL

In order to understand how each of the independent parameters affects the result, a parametric study was conducted. The following sections show the results and subsequent analysis that evaluates how the flow field gets affected by varying the parameters.

3.1 Variation and effect of each independent variables

The independent variables include the relative position of the vortex to the wall (vertical distance from the wall, and distance between the vortex cores), the circulation or vortex strength, and the perturbation orientation and distance. These parameters are designated as h for vertical distance, λ for distance between the vortex cores, Γ for circulation, θ for perturbation orientation, and Δx for perturbation distance respectively.

The baseline values selected for each of the variable is:

$$\Gamma = 1.0$$

$$\lambda = 2.0$$

$$h = 0.5 - \text{physical distance}$$

$$\Delta x = 0.2 - \text{physical distance}$$

$$\theta = 0^\circ \text{ to } 315^\circ \text{ in } 45^\circ \text{ increments}$$

The parametric study varies each of the parameters to fully understand how velocity field is impacted by each of them. The following values are selected for each of the variables:

$$\Gamma = [0.1, 0.25, 0.5, 1.0]$$

$$\lambda = [0.5, 1.0, 2.0]$$

$$h = [0.5, 1.0]$$

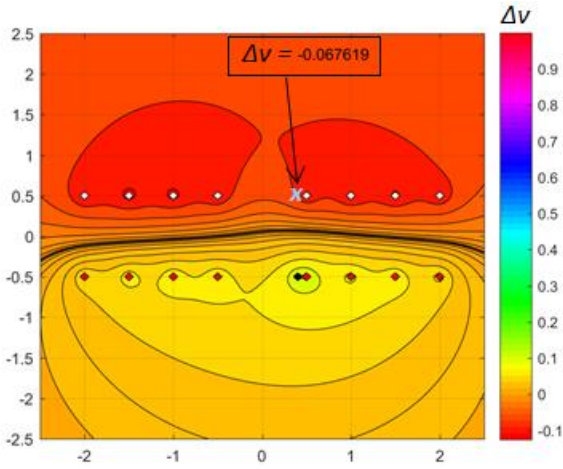
$$\Delta x = [0.05, 0.1, 0.2, 0.3, 0.4]$$

The ratio of λ and h offers an aspect ratio of the spacing between the vortex cores and their distances to the wall. The aspect ratio (λ/h) assessed are 0.5, 1, 2 and 4. The ratio of Δx relative to the smaller of λ and h gives an indication of magnitude of the perturbation. In this study, the ratios are 0.1, 0.2, 0.4, 0.6 and 0.8.

3.2 Variation of Vortex Strength

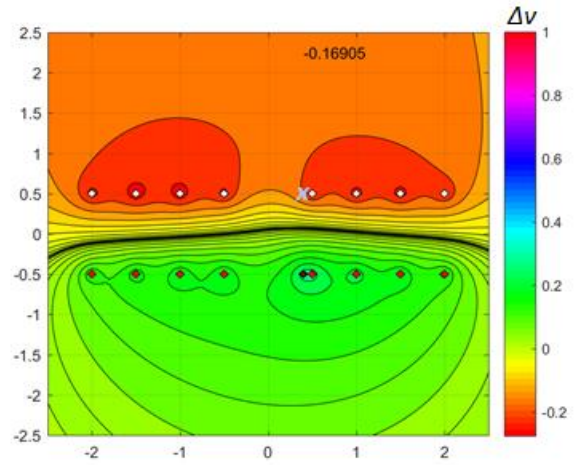
The complex potential equation $w = -i \frac{\Gamma}{2\pi} \log \frac{(z-i(b-h))}{z-i h}$ indicates that there is a linear relationship between the magnitude of the circulation and the resulting speed change from the perturbation. The plots below all have λ of 0.5, h of 0.5 and Δx of 0.4. The only difference between them is in circulation strength (Γ).

The Γ values in the plots below are 0.1, 0.25, 0.5, and 1. In these particular cases, θ is zero, meaning the perturbation is only in the positive horizontal axis direction. The computed Δv was shown to be -0.0676 for Γ of 0.1, -0.1691 for Γ of 0.25, -0.3381 for Γ of 0.5, and -0.6762 for Γ of 1. This set of data shows that the variation in Γ has a linear relationship with Δv . Also, while the magnitude of the velocity field changed, the plots show that the velocity distribution remains the same.



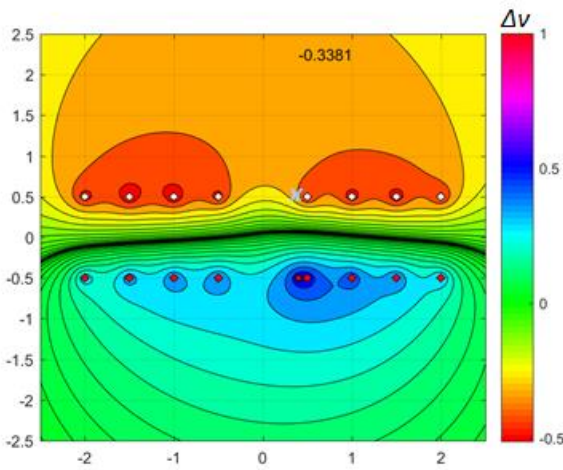
$\Gamma = 0.1$. $\lambda = 0.5, h = 0.5, \Delta x = 0.4, \vartheta = 0^\circ$

$\Delta v = -0.0676 (x1)$



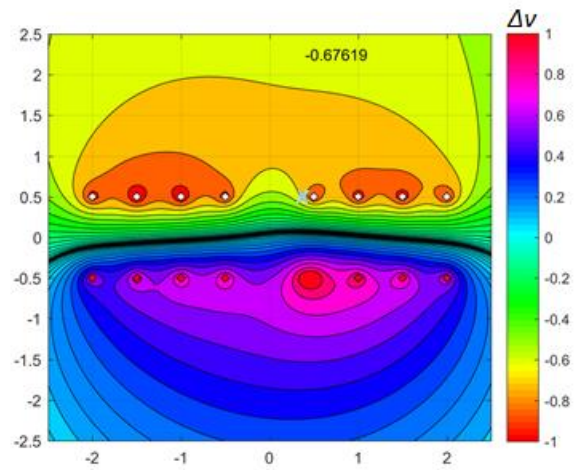
$\Gamma = 0.25$. $\lambda = 0.5, h = 0.5, \Delta x = 0.4, \vartheta = 0^\circ$

$\Delta v = -0.1691 (x2.5)$



$\Gamma = 0.5$. $\lambda = 0.5, h = 0.5, \Delta x = 0.4, \vartheta = 0^\circ$

$\Delta v = -0.3381 (x5)$



$\Gamma = 1.0$. $\lambda = 0.5, h = 0.5, \Delta x = 0.4, \vartheta = 0^\circ$

$\Delta v = -0.6762 (x10)$

Figure 3.1: Speed contour data plot with varying Γ

The conclusions above agree with the complex potential equation. All other cases ran for the parametric study consistently showed the same relationship as the example case discussed.

3.3 Variation of Vertical distance from wall

The vertical distance from the vortex core to the wall is defined in the imaginary part of the complex potential equation: $w = -i \frac{\Gamma}{2\pi} \log \frac{(z-i(b-h))}{z-ih}$. The results below in Fig. 3.2 indicate that as the vertical distance from the vortex to wall is increased by 100%, the raise in Δv exceeded that the magnitude increase for the distance. In these two cases, Γ is 0.25, λ is 1, Δx is 0.2, and θ is 90° . In the data plot on the left, h is 0.5, while the plot on the right has h of 1.0.

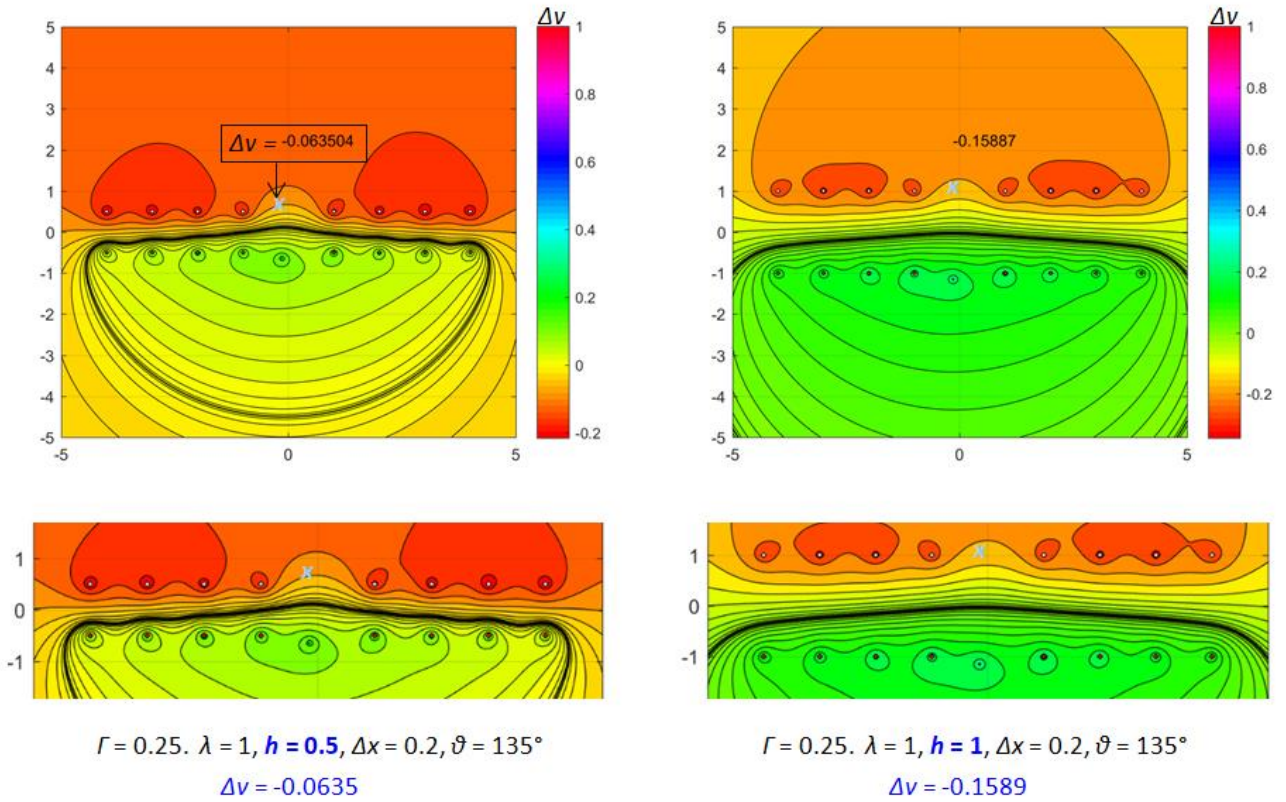
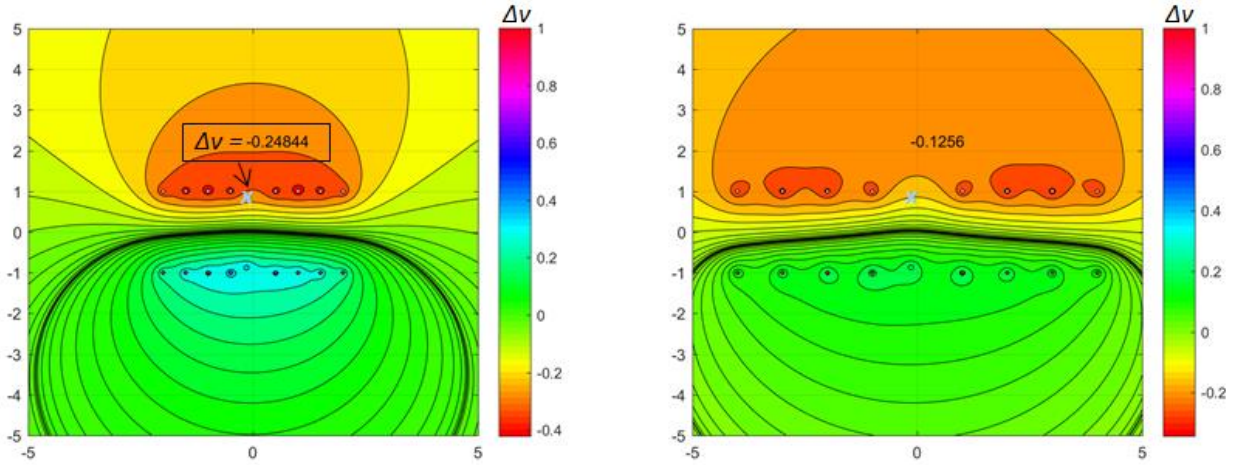


Figure 3.2: Speed contour data plot with varying h

3.4 Variation of Horizontal distance between vortices

The horizontal distance from the vortex core to the wall is defined in the real part of the complex potential equation: $w = -i \frac{\Gamma}{2\pi} \log \frac{(z-i(b-h))}{z-i h}$. The results below in Fig. 3.3 indicate that as the horizontal distances between the vortex core increases, the value of Δv decreases proportionally. In these cases, Γ is 0.25, Δx is 0.2, and θ is 225° . With λ of 0.5, the resulting Δv is -0.2484. With λ of 1.0, the resulting Δv is -0.1256. Between these two cases, λ increased by 100%, the magnitude of Δv decreased by 51%. As λ increased to 2.0, the magnitude of Δv further reduced to -0.059. This 400% increase in λ resulted in Δv 's magnitude reduction of 76%. One explanation for this phenomenon is that the influences of the nearby vortices are greater as they are physically closer to the center vortex pair. Moving them closer horizontally along the way increases the instability of the flow field and magnifies the effect of any disturbances in the vortex field.

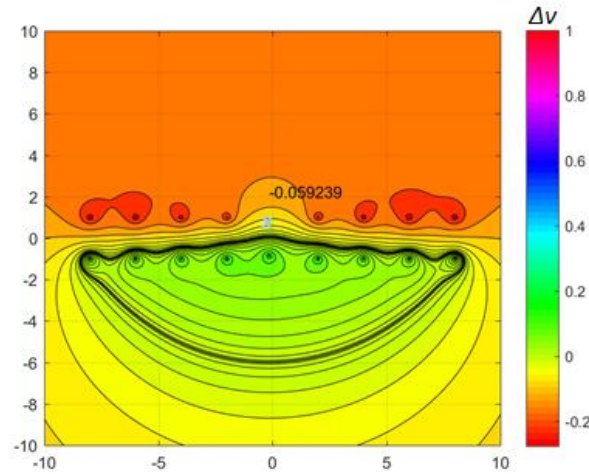


$\Gamma = 0.25, \lambda = 0.5, h = 1, \Delta x = 0.2, \vartheta = 225^\circ$

$\Delta v = -0.2484$

$\Gamma = 0.25, \lambda = 1, h = 1, \Delta x = 0.2, \vartheta = 225^\circ$

$\Delta v = -0.1256$



$\Gamma = 0.25, \lambda = 2, h = 1, \Delta x = 0.2, \vartheta = 225^\circ$

$\Delta v = -0.0592$

Figure 3.3: Speed contour data plot with varying Γ

3.5 Variation of Perturbation Distance and Direction

The variation of distances and directions are analyzed together, as both parameters contribute to changes caused by varying the magnitude and orientation of Δx . As mentioned earlier, Δx values of 0.05, 0.1, 0.2, 0.3 and 0.4 were used in this analysis. The angle associated with the perturbation is defined as the angle from the positive horizontal axis, with clockwise as the positive direction. The perturbation was studied from 0° to 360° in 45° increments. One complete case is presented in this section to thoroughly analyze the effects of perturbation distance and direction. ($\Gamma = 1.0, h = 0.5, \lambda = 0.5$)

In the results shown in Fig. 3.4, the perturbation in the horizontal axis is shown. The perturbed positions are -0.4, -0.3, -0.2, -0.1, -0.05, +0.05, +0.1, +0.2, +0.3, +0.4 along the horizontal axis. The θ for the positions that are positive in the horizontal axis is 0° , whereas the negative positions have θ of 180° . The results show that Δv is symmetric to the vertical axis where the center pair vortices are. With Γ of 1.0, h and λ both at 0.5, the values of Δv ranged from -0.676 to -0.463. The value of Δv is -0.676 when Δx is ± 0.4 . Δv is -0.560 when Δx is ± 0.3 . Δv is -0.501 when Δx is ± 0.2 . Δv is -0.470 when Δx is ± 0.1 . Δv is -0.463 when Δx is ± 0.05 . This observation is consistent with the theory defined earlier in this paper that the magnitude of the induced velocity on the point of interest is proportional to the Δx . With Δx being the same, the vortex induced speed is the same no matter the direction of the point of reference.

In the results shown in Fig. 3.5, perturbation in the vertical axis is shown. The perturbed positions are -0.4, -0.3, -0.2, -0.1, -0.05, +0.05, +0.1, +0.2, +0.3, +0.4 along the vertical axis. The θ for the positions that are positive in the horizontal axis is 270° , whereas the negative positions have θ of 90° . The results show that as the bottom vortex gets closer to the flat wall, Δv 's magnitude becomes less. This observation is consistent with the results from adjusting the vertical distance from the vortices to the flat wall. Table 3.1 has the results from the cases shown in Fig. 3.5.

Table 3.1: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 90^\circ/270^\circ$

Δx	-0.4	-0.3	-0.2	-0.1	-0.05	0.05	0.1	0.2	0.3	0.4
Δv	-0.657	-0.631	-0.593	-0.537	-0.502	-0.502	-0.358	-0.229	-0.068	0.147

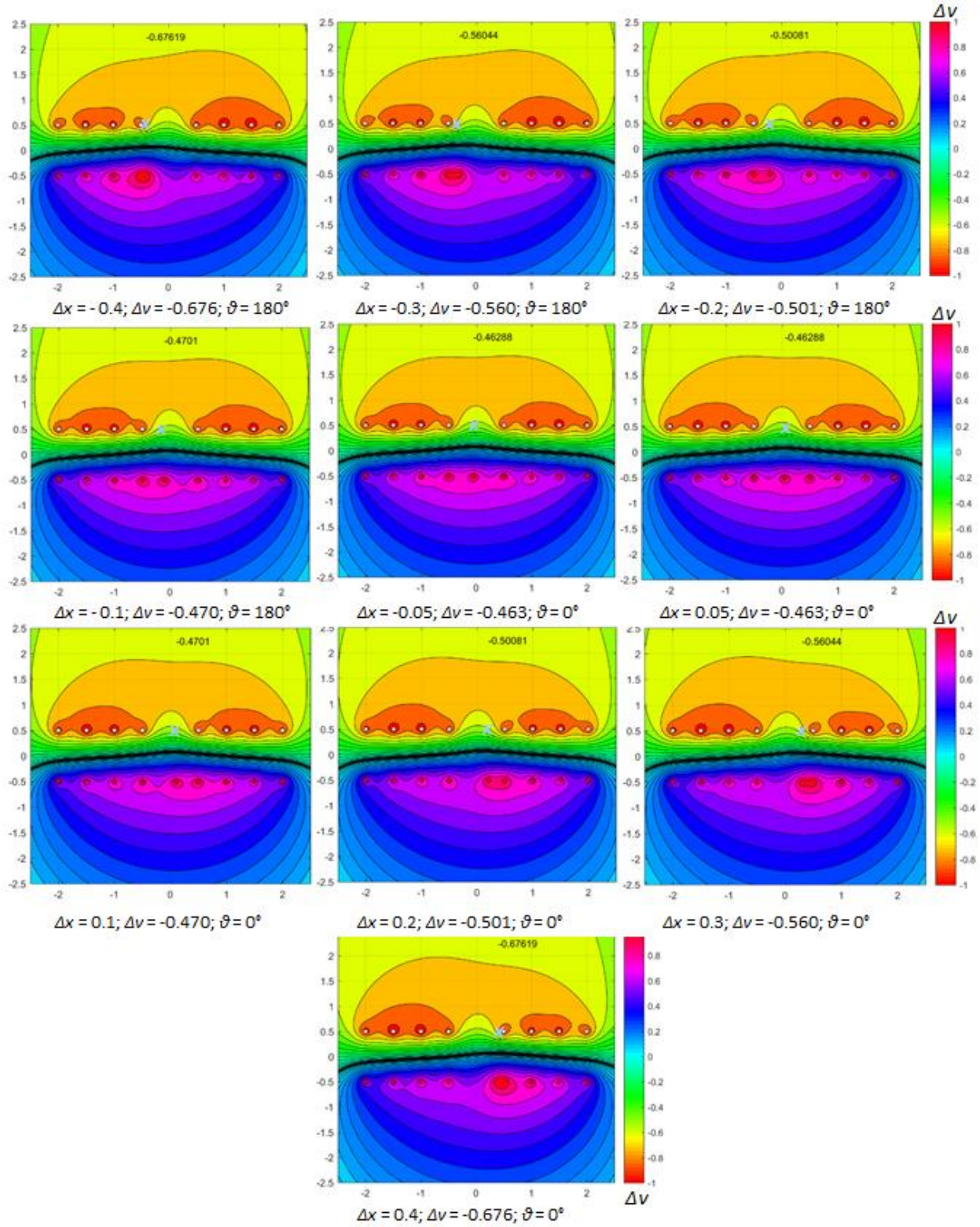


Figure 3.4: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 0^\circ/180^\circ$

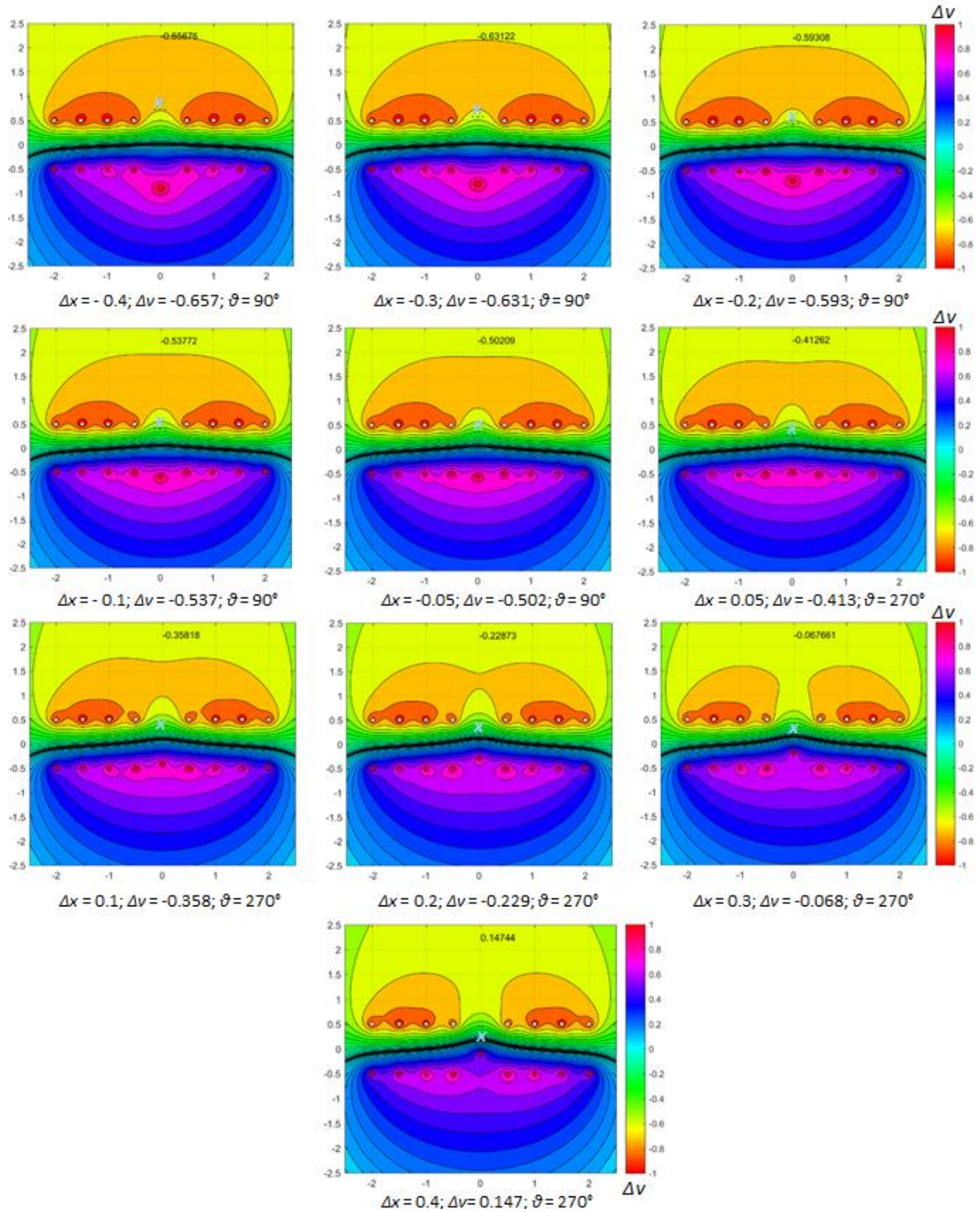


Figure 3.5: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 90^\circ/270^\circ$

In Figs. 3.6 and 3.7, the perturbations are in the diagonal directions. Fig. 3.6 contains results with perturbation in the $135^\circ/315^\circ$ axis, and Fig. 3.7 contains results with perturbation in the $45^\circ/225^\circ$ axis.

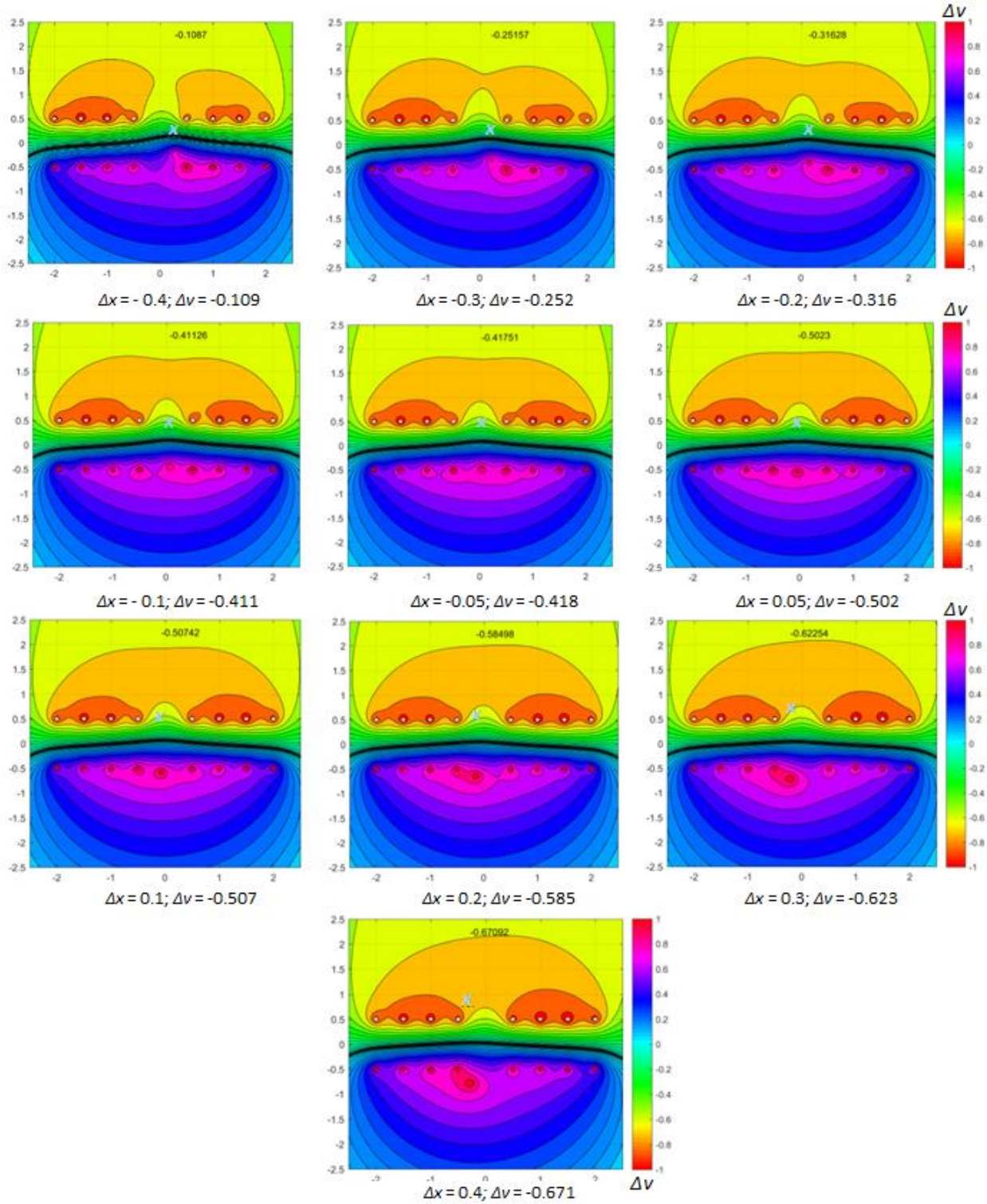


Figure 3.6: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 135^\circ/315^\circ$

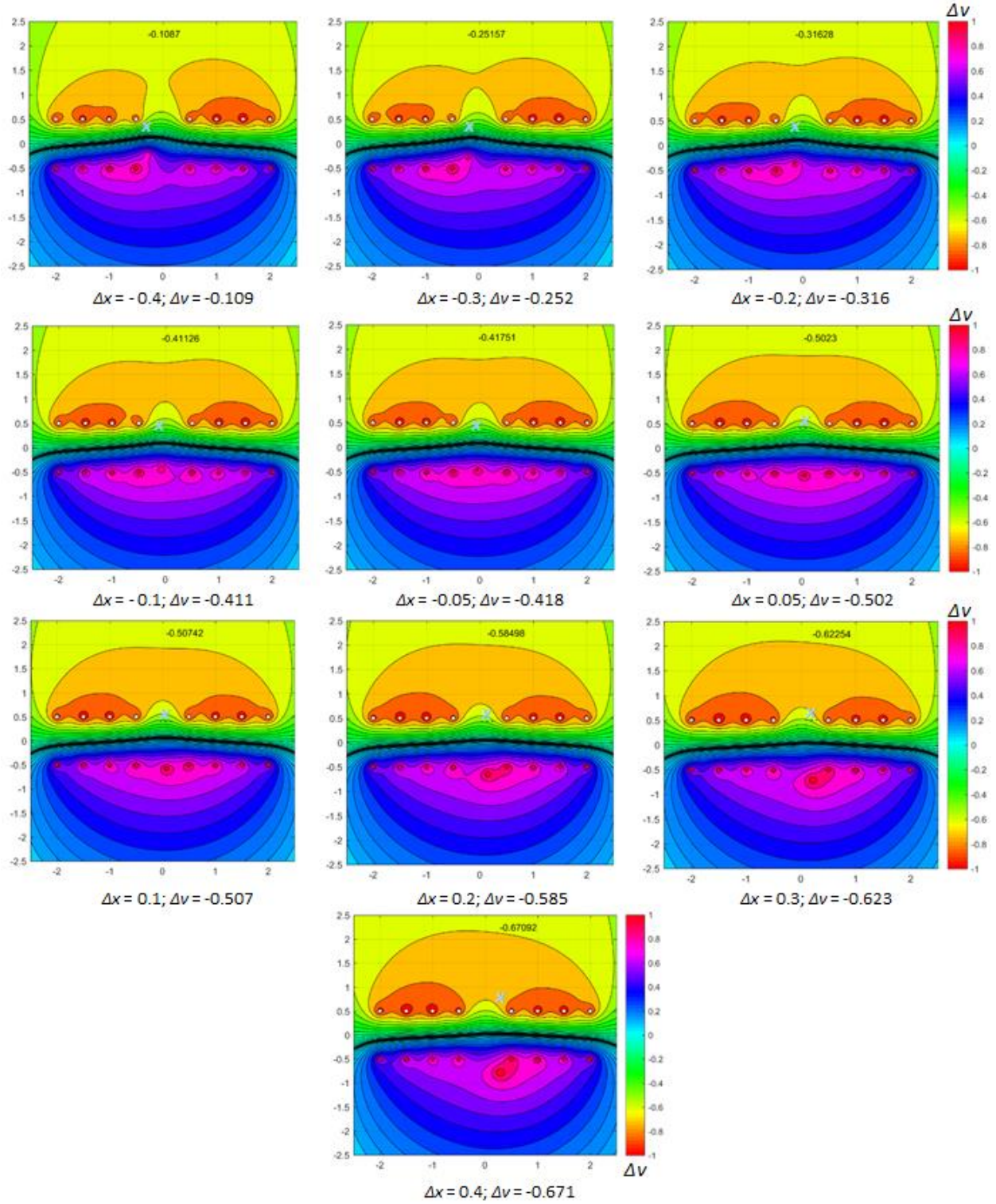


Fig. 3.7: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 45^\circ/225^\circ$

In Fig. 3.6, the negative Δx direction is defined by θ of 315° ; the positive Δx direction is in θ of 135° . In Fig. 3.7, the negative Δx direction is defined by θ of 225° ; the positive Δx direction is in θ of 45° . In these two figures, the results showed with perturbation in both diagonal axes, the

results have the same values. This shows perturbation on either side of the vertical axis is symmetric. Upon further inspection of the results in table 3.2 and 3.3, the data is consistent with the results shown in Figs. 3.4, and 3.5.

Table 3.2: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 135^\circ/315^\circ$

Δx	-0.4	-0.3	-0.2	-0.1	-0.05	0.05	0.1	0.2	0.3	0.4
Δv	-0.109	-0.252	-0.316	-0.411	-0.418	-0.502	-0.507	-0.585	-0.623	-0.671

Table 3.3: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\theta = 45^\circ/225^\circ$

Δx	-0.4	-0.3	-0.2	-0.1	-0.05	0.05	0.1	0.2	0.3	0.4
Δv	-0.109	-0.252	-0.316	-0.411	-0.418	-0.502	-0.507	-0.585	-0.623	-0.671

In Fig. 3.8, perturbation distance of $\Delta x = 0.4$ is presented in the same plot in all eight different directions analyzed. The Δv values from changing θ can be found in Table 3.4.

Table 3.4: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\Delta x = 0.4$

θ	0°	45°	90°	135°	180°	225°	270°	315°
Δv	-0.676	-0.671	-0.657	-0.671	-0.676	-0.109	-0.147	-0.109

The values in Fig. 3.8 show Δv is symmetric about the vertical axis. 45° has the same Δv value as 135° . 225° has the same result as 315° . The largest magnitude of Δv occurred when θ is 0° and 180° , which is in the neutral position. This is once again consistent with the previous observation.

Another parameter of interest for this study is the ratio between Δx and Δv , tau (τ). ($\tau = \Delta x / \Delta v$, *unit is in time*) With perturbation distance Δx remaining constant, τ varies by the orientation of the perturbation. In the case above with $\Delta x = 0.4$, the τ values are listed in table 3.5. A plot of the variation in τ can be found in Fig. 3.9.

Table 3.5: Perturbation Time Constant Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\Delta x = 0.4$

ϑ	0°	45°	90°	135°	180°	225°	270°	315°
Δv	-0.676	-0.671	-0.657	-0.671	-0.676	-0.109	-0.147	-0.109
Δx	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
τ	-0.592	-0.596	-0.609	-0.596	-0.592	-3.670	-2.721	-3.670

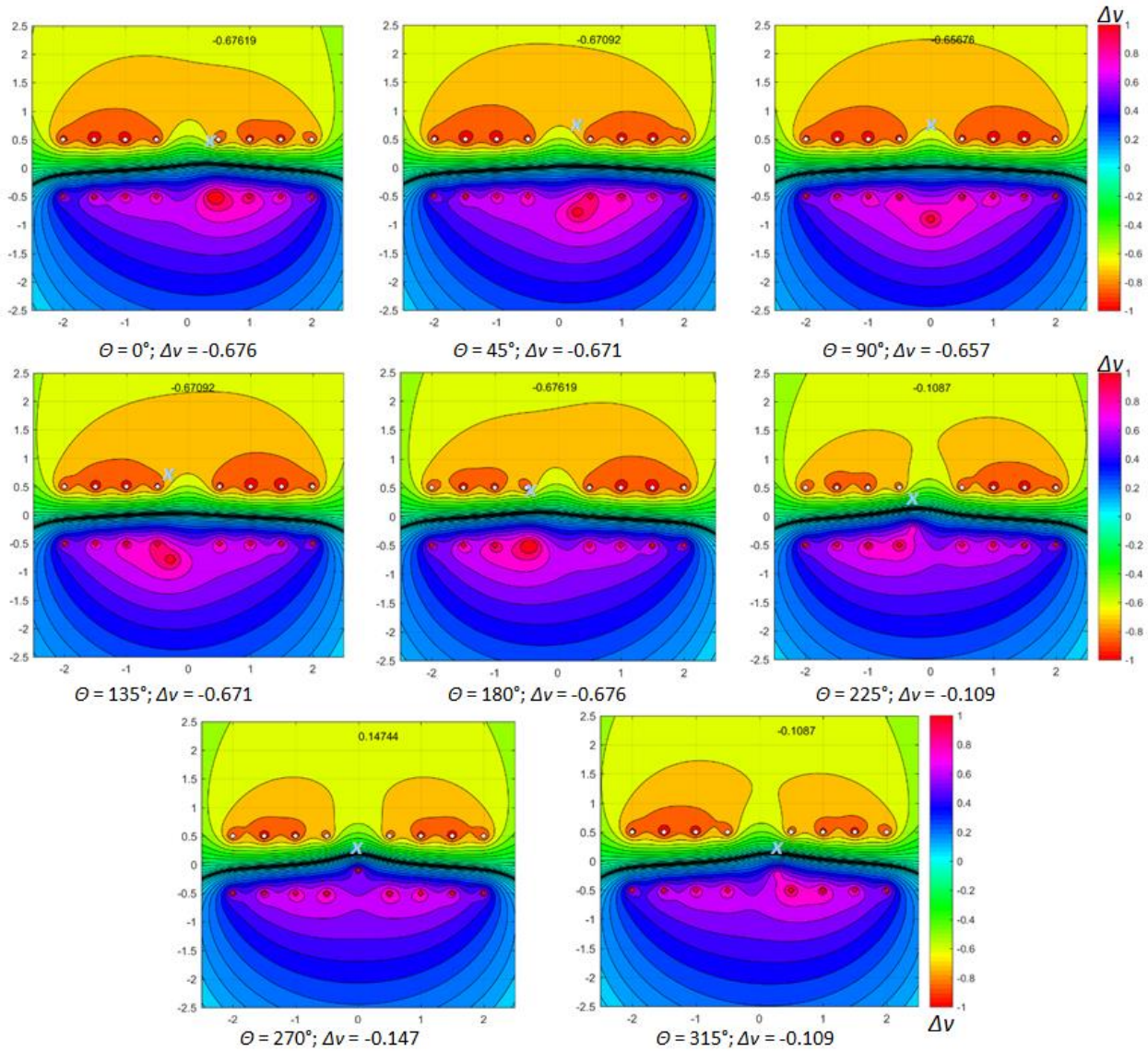


Figure 3.8: Perturbation Study Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\Delta x = 0.4$

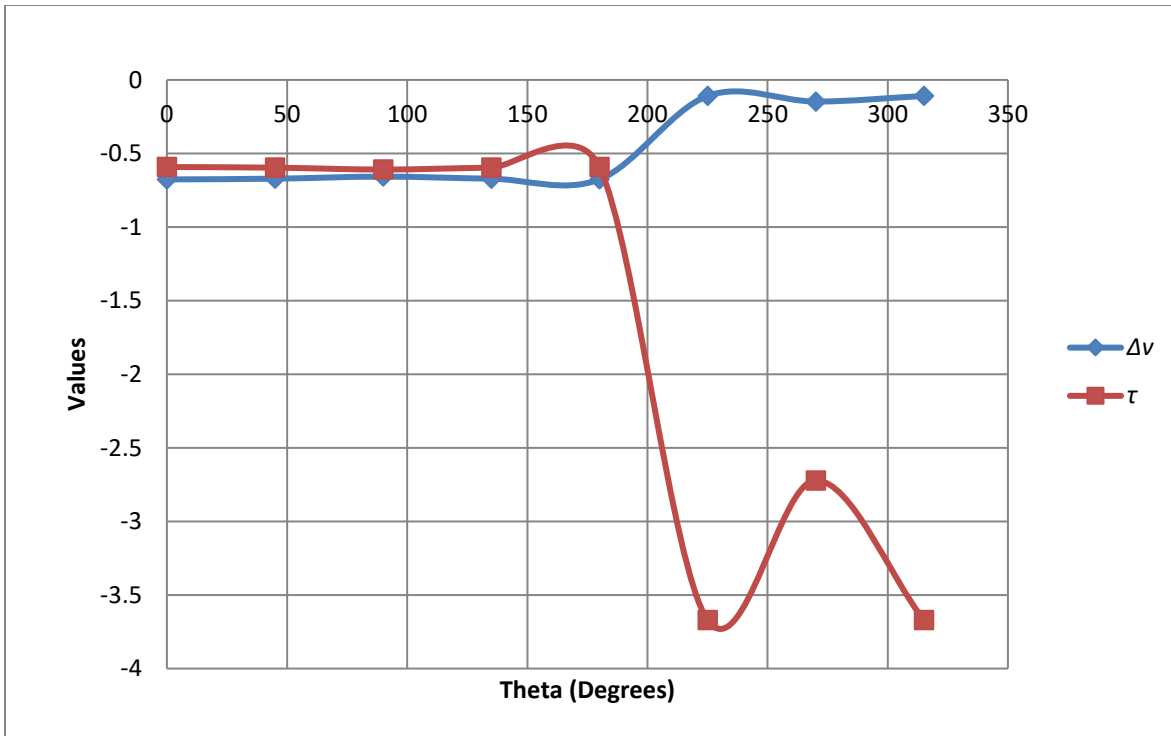


Figure 3.9: Perturbation Time Constant Results with $\Gamma = 1$, $h = 0.5$, $\lambda = 0.5$, $\Delta x = 0.4$

Due to the fact that the vortex core of interest is very close to the wall at above 200° , the results are not as valid as the results from 0 to 180° . The greatest change in magnitude of Δv occurred at 0° and 180° .

Chapter 4

SUMMARY AND CONCLUSIONS

4.1 Conclusions and Further Research Opportunities

Using the complex potential equation suggested by Professor P. G. Saffman offers a reasonable estimation of the parallel vortex field near a flat wall simulating laminar and stable vortices. The steady state solution of equation 7.2 in Saffman (1993) offers flow field that allows the initial diverging speed of a vortex to be calculated. The initial diverging speed of a vortex in a flow field in equilibrium can be simulated by creating two row of counter-rotating vortices, removing one of the vortices, and perturb the opposite signed vortex of the one that was just removed.

Three general trends were observed from analyzing the results from this study:

- 1) The resulting Δv from Δx on either side of the vertical axis linking the center vortex pair is symmetric.
- 2) Moving the vortex further away from the flat wall will have an increased effect to the Δv .
- 3) By increasing the spacing between the vortices, the magnitude of Δv reduces in a linear or near-linear fashion.

The entire result of this research project is tabulated and included in Appendix A.

By removing the real, perturbed upper center vortex to compute the Δv , the velocity at its location is correct, as the vortex does not impose any induced velocity on itself. However, the velocity everywhere else is not accurate anymore, since the upper center perturbed vortex is removed. Therefore, all result plots shown in this paper has the correct value at the upper center vortex location, while the rest of the flow field is estimation without the upper center vortex's contribution.

Also, this is merely a static solution that can estimate the initial diverging speed. By solving the time-dependending solution, the exact trajectories can be found. Also, higher order solvers can be used to get a higher fidelity results that more closely resembles the actual physics of the parallel vortex sheet.

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APPENDIX A

Analysis Data Used For This Research

Index	Case ID	θ	Δx	r	h	λ	Δv	$\tau (\Delta x/\Delta v)$
1	1	0	0.40	1.00	0.50	2.00	-0.056	-7.168
2	2	45	0.40	1.00	0.50	2.00	-0.154	-2.594
3	3	90	0.40	1.00	0.50	2.00	-0.180	-2.226
4	4	135	0.40	1.00	0.50	2.00	-0.154	-2.594
5	5	180	0.40	1.00	0.50	2.00	-0.056	-7.168
6	6	225	0.40	1.00	0.50	2.00	0.117	3.432
7	7	270	0.40	1.00	0.50	2.00	0.245	1.630
8	8	315	0.40	1.00	0.50	2.00	0.117	3.432
9	1	0	0.30	1.00	0.50	2.00	-0.054	-5.546
10	2	45	0.30	1.00	0.50	2.00	-0.126	-2.377
11	3	90	0.30	1.00	0.50	2.00	-0.153	-1.957
12	4	135	0.30	1.00	0.50	2.00	-0.126	-2.377
13	5	180	0.30	1.00	0.50	2.00	-0.054	-5.546
14	6	225	0.30	1.00	0.50	2.00	0.052	5.779
15	7	270	0.30	1.00	0.50	2.00	0.124	2.413
16	8	315	0.30	1.00	0.50	2.00	0.052	5.779
17	1	0	0.20	1.00	0.50	2.00	-0.053	-3.780
18	2	45	0.20	1.00	0.50	2.00	-0.107	-1.867
19	3	90	0.20	1.00	0.50	2.00	-0.124	-1.616
20	4	135	0.20	1.00	0.50	2.00	-0.107	-1.867
21	5	180	0.20	1.00	0.50	2.00	-0.053	-3.780
22	6	225	0.20	1.00	0.50	2.00	0.017	11.566
23	7	270	0.20	1.00	0.50	2.00	0.049	4.056
24	8	315	0.20	1.00	0.50	2.00	0.017	11.566
25	1	0	0.10	1.00	0.50	2.00	-0.052	-1.915
26	2	45	0.10	1.00	0.50	2.00	-0.075	-1.334
27	3	90	0.10	1.00	0.50	2.00	-0.090	-1.107
28	4	135	0.10	1.00	0.50	2.00	-0.075	-1.334
29	5	180	0.10	1.00	0.50	2.00	-0.052	-1.915
30	6	225	0.10	1.00	0.50	2.00	-0.027	-3.736
31	7	270	0.10	1.00	0.50	2.00	-0.007	-14.990
32	8	315	0.10	1.00	0.50	2.00	-0.027	-3.736
33	1	0	0.05	1.00	0.50	2.00	-0.052	-0.961
34	2	45	0.05	1.00	0.50	2.00	-0.070	-0.716
35	3	90	0.05	1.00	0.50	2.00	-0.072	-0.695
36	4	135	0.05	1.00	0.50	2.00	-0.070	-0.716
37	5	180	0.05	1.00	0.50	2.00	-0.052	-0.961

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
38	6	225	0.05	1.00	0.50	2.00	-0.033	-1.514
39	7	270	0.05	1.00	0.50	2.00	-0.030	-1.646
40	8	315	0.05	1.00	0.50	2.00	-0.033	-1.514
41	1	0	0.00	1.00	0.50	2.00	-0.052	0.000
42	2	45	0.00	1.00	0.50	2.00	-0.052	0.000
43	3	90	0.00	1.00	0.50	2.00	-0.052	0.000
44	4	135	0.00	1.00	0.50	2.00	-0.052	0.000
45	5	180	0.00	1.00	0.50	2.00	-0.052	0.000
46	6	225	0.00	1.00	0.50	2.00	-0.052	0.000
47	7	270	0.00	1.00	0.50	2.00	-0.052	0.000
48	8	315	0.00	1.00	0.50	2.00	-0.052	0.000
49	1	0	0.40	0.50	0.50	2.00	-0.028	-14.335
50	2	45	0.40	0.50	0.50	2.00	-0.077	-5.187
51	3	90	0.40	0.50	0.50	2.00	-0.090	-4.451
52	4	135	0.40	0.50	0.50	2.00	-0.077	-5.187
53	5	180	0.40	0.50	0.50	2.00	-0.028	-14.335
54	6	225	0.40	0.50	0.50	2.00	0.058	6.864
55	7	270	0.40	0.50	0.50	2.00	0.123	3.261
56	8	315	0.40	0.50	0.50	2.00	0.058	6.864
57	1	0	0.30	0.50	0.50	2.00	-0.027	-11.091
58	2	45	0.30	0.50	0.50	2.00	-0.063	-4.753
59	3	90	0.30	0.50	0.50	2.00	-0.077	-3.915
60	4	135	0.30	0.50	0.50	2.00	-0.063	-4.753
61	5	180	0.30	0.50	0.50	2.00	-0.027	-11.091
62	6	225	0.30	0.50	0.50	2.00	0.026	11.558
63	7	270	0.30	0.50	0.50	2.00	0.062	4.826
64	8	315	0.30	0.50	0.50	2.00	0.026	11.558
65	1	0	0.20	0.50	0.50	2.00	-0.026	-7.559
66	2	45	0.20	0.50	0.50	2.00	-0.054	-3.733
67	3	90	0.20	0.50	0.50	2.00	-0.062	-3.233
68	4	135	0.20	0.50	0.50	2.00	-0.054	-3.733
69	5	180	0.20	0.50	0.50	2.00	-0.026	-7.559
70	6	225	0.20	0.50	0.50	2.00	0.009	23.132
71	7	270	0.20	0.50	0.50	2.00	0.025	8.113
72	8	315	0.20	0.50	0.50	2.00	0.009	23.132
73	1	0	0.10	0.50	0.50	2.00	-0.026	-3.830
74	2	45	0.10	0.50	0.50	2.00	-0.037	-2.668
75	3	90	0.10	0.50	0.50	2.00	-0.045	-2.213
76	4	135	0.10	0.50	0.50	2.00	-0.037	-2.668
77	5	180	0.10	0.50	0.50	2.00	-0.026	-3.830
78	6	225	0.10	0.50	0.50	2.00	-0.013	-7.473

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
79	7	270	0.10	0.50	0.50	2.00	-0.003	-29.980
80	8	315	0.10	0.50	0.50	2.00	-0.013	-7.473
81	1	0	0.05	0.50	0.50	2.00	-0.026	-1.921
82	2	45	0.05	0.50	0.50	2.00	-0.035	-1.432
83	3	90	0.05	0.50	0.50	2.00	-0.036	-1.391
84	4	135	0.05	0.50	0.50	2.00	-0.035	-1.432
85	5	180	0.05	0.50	0.50	2.00	-0.026	-1.921
86	6	225	0.05	0.50	0.50	2.00	-0.017	-3.029
87	7	270	0.05	0.50	0.50	2.00	-0.015	-3.292
88	8	315	0.05	0.50	0.50	2.00	-0.017	-3.029
89	1	0	0.00	0.50	0.50	2.00	-0.026	0.000
90	2	45	0.00	0.50	0.50	2.00	-0.026	0.000
91	3	90	0.00	0.50	0.50	2.00	-0.026	0.000
92	4	135	0.00	0.50	0.50	2.00	-0.026	0.000
93	5	180	0.00	0.50	0.50	2.00	-0.026	0.000
94	6	225	0.00	0.50	0.50	2.00	-0.026	0.000
95	7	270	0.00	0.50	0.50	2.00	-0.026	0.000
96	8	315	0.00	0.50	0.50	2.00	-0.026	0.000
97	1	0	0.40	0.25	0.50	2.00	-0.014	-28.671
98	2	45	0.40	0.25	0.50	2.00	-0.039	-10.374
99	3	90	0.40	0.25	0.50	2.00	-0.045	-8.903
100	4	135	0.40	0.25	0.50	2.00	-0.039	-10.374
101	5	180	0.40	0.25	0.50	2.00	-0.014	-28.671
102	6	225	0.40	0.25	0.50	2.00	0.029	13.728
103	7	270	0.40	0.25	0.50	2.00	0.061	6.521
104	8	315	0.40	0.25	0.50	2.00	0.029	13.728
105	1	0	0.30	0.25	0.50	2.00	-0.014	-22.182
106	2	45	0.30	0.25	0.50	2.00	-0.032	-9.506
107	3	90	0.30	0.25	0.50	2.00	-0.038	-7.829
108	4	135	0.30	0.25	0.50	2.00	-0.032	-9.506
109	5	180	0.30	0.25	0.50	2.00	-0.014	-22.182
110	6	225	0.30	0.25	0.50	2.00	0.013	23.116
111	7	270	0.30	0.25	0.50	2.00	0.031	9.652
112	8	315	0.30	0.25	0.50	2.00	0.013	23.116
113	1	0	0.20	0.25	0.50	2.00	-0.013	-15.119
114	2	45	0.20	0.25	0.50	2.00	-0.027	-7.467
115	3	90	0.20	0.25	0.50	2.00	-0.031	-6.466
116	4	135	0.20	0.25	0.50	2.00	-0.027	-7.467
117	5	180	0.20	0.25	0.50	2.00	-0.013	-15.119
118	6	225	0.20	0.25	0.50	2.00	0.004	46.265
119	7	270	0.20	0.25	0.50	2.00	0.012	16.225

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
120	8	315	0.20	0.25	0.50	2.00	0.004	46.265
121	1	0	0.10	0.25	0.50	2.00	-0.013	-7.660
122	2	45	0.10	0.25	0.50	2.00	-0.019	-5.337
123	3	90	0.10	0.25	0.50	2.00	-0.023	-4.427
124	4	135	0.10	0.25	0.50	2.00	-0.019	-5.337
125	5	180	0.10	0.25	0.50	2.00	-0.013	-7.660
126	6	225	0.10	0.25	0.50	2.00	-0.007	-14.945
127	7	270	0.10	0.25	0.50	2.00	-0.002	-59.960
128	8	315	0.10	0.25	0.50	2.00	-0.007	-14.945
129	1	0	0.05	0.25	0.50	2.00	-0.013	-3.843
130	2	45	0.05	0.25	0.50	2.00	-0.017	-2.864
131	3	90	0.05	0.25	0.50	2.00	-0.018	-2.782
132	4	135	0.05	0.25	0.50	2.00	-0.017	-2.864
133	5	180	0.05	0.25	0.50	2.00	-0.013	-3.843
134	6	225	0.05	0.25	0.50	2.00	-0.008	-6.058
135	7	270	0.05	0.25	0.50	2.00	-0.008	-6.585
136	8	315	0.05	0.25	0.50	2.00	-0.008	-6.058
137	1	0	0.00	0.25	0.50	2.00	-0.013	0.000
138	2	45	0.00	0.25	0.50	2.00	-0.013	0.000
139	3	90	0.00	0.25	0.50	2.00	-0.013	0.000
140	4	135	0.00	0.25	0.50	2.00	-0.013	0.000
141	5	180	0.00	0.25	0.50	2.00	-0.013	0.000
142	6	225	0.00	0.25	0.50	2.00	-0.013	0.000
143	7	270	0.00	0.25	0.50	2.00	-0.013	0.000
144	8	315	0.00	0.25	0.50	2.00	-0.013	0.000
145	1	0	0.40	0.10	0.50	2.00	-0.006	-71.677
146	2	45	0.40	0.10	0.50	2.00	-0.015	-25.936
147	3	90	0.40	0.10	0.50	2.00	-0.018	-22.257
148	4	135	0.40	0.10	0.50	2.00	-0.015	-25.936
149	5	180	0.40	0.10	0.50	2.00	-0.006	-71.677
150	6	225	0.40	0.10	0.50	2.00	0.012	34.320
151	7	270	0.40	0.10	0.50	2.00	0.025	16.304
152	8	315	0.40	0.10	0.50	2.00	0.012	34.320
153	1	0	0.30	0.10	0.50	2.00	-0.005	-55.456
154	2	45	0.30	0.10	0.50	2.00	-0.013	-23.766
155	3	90	0.30	0.10	0.50	2.00	-0.015	-19.574
156	4	135	0.30	0.10	0.50	2.00	-0.013	-23.766
157	5	180	0.30	0.10	0.50	2.00	-0.005	-55.456
158	6	225	0.30	0.10	0.50	2.00	0.005	57.791
159	7	270	0.30	0.10	0.50	2.00	0.012	24.130
160	8	315	0.30	0.10	0.50	2.00	0.005	57.791

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
161	1	0	0.20	0.10	0.50	2.00	-0.005	-37.797
162	2	45	0.20	0.10	0.50	2.00	-0.011	-18.667
163	3	90	0.20	0.10	0.50	2.00	-0.012	-16.164
164	4	135	0.20	0.10	0.50	2.00	-0.011	-18.667
165	5	180	0.20	0.10	0.50	2.00	-0.005	-37.797
166	6	225	0.20	0.10	0.50	2.00	0.002	115.662
167	7	270	0.20	0.10	0.50	2.00	0.005	40.563
168	8	315	0.20	0.10	0.50	2.00	0.002	115.662
169	1	0	0.10	0.10	0.50	2.00	-0.005	-19.150
170	2	45	0.10	0.10	0.50	2.00	-0.007	-13.342
171	3	90	0.10	0.10	0.50	2.00	-0.009	-11.067
172	4	135	0.10	0.10	0.50	2.00	-0.007	-13.342
173	5	180	0.10	0.10	0.50	2.00	-0.005	-19.150
174	6	225	0.10	0.10	0.50	2.00	-0.003	-37.363
175	7	270	0.10	0.10	0.50	2.00	-0.001	-149.899
176	8	315	0.10	0.10	0.50	2.00	-0.003	-37.363
177	1	0	0.05	0.10	0.50	2.00	-0.005	-9.606
178	2	45	0.05	0.10	0.50	2.00	-0.007	-7.159
179	3	90	0.05	0.10	0.50	2.00	-0.007	-6.954
180	4	135	0.05	0.10	0.50	2.00	-0.007	-7.159
181	5	180	0.05	0.10	0.50	2.00	-0.005	-9.606
182	6	225	0.05	0.10	0.50	2.00	-0.003	-15.145
183	7	270	0.05	0.10	0.50	2.00	-0.003	-16.462
184	8	315	0.05	0.10	0.50	2.00	-0.003	-15.145
185	1	0	0.00	0.10	0.50	2.00	-0.005	0.000
186	2	45	0.00	0.10	0.50	2.00	-0.005	0.000
187	3	90	0.00	0.10	0.50	2.00	-0.005	0.000
188	4	135	0.00	0.10	0.50	2.00	-0.005	0.000
189	5	180	0.00	0.10	0.50	2.00	-0.005	0.000
190	6	225	0.00	0.10	0.50	2.00	-0.005	0.000
191	7	270	0.00	0.10	0.50	2.00	-0.005	0.000
192	8	315	0.00	0.10	0.50	2.00	-0.005	0.000
193	1	0	0.40	1.00	0.50	1.00	-0.205	-1.951
194	2	45	0.40	1.00	0.50	1.00	-0.326	-1.226
195	3	90	0.40	1.00	0.50	1.00	-0.345	-1.159
196	4	135	0.40	1.00	0.50	1.00	-0.326	-1.226
197	5	180	0.40	1.00	0.50	1.00	-0.205	-1.951
198	6	225	0.40	1.00	0.50	1.00	0.054	7.354
199	7	270	0.40	1.00	0.50	1.00	0.218	1.835
200	8	315	0.40	1.00	0.50	1.00	0.054	7.354
201	1	0	0.30	1.00	0.50	1.00	-0.190	-1.579

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
202	2	45	0.30	1.00	0.50	1.00	-0.282	-1.065
203	3	90	0.30	1.00	0.50	1.00	-0.312	-0.961
204	4	135	0.30	1.00	0.50	1.00	-0.282	-1.065
205	5	180	0.30	1.00	0.50	1.00	-0.190	-1.579
206	6	225	0.30	1.00	0.50	1.00	-0.032	-9.453
207	7	270	0.30	1.00	0.50	1.00	0.070	4.257
208	8	315	0.30	1.00	0.50	1.00	-0.032	-9.453
209	1	0	0.20	1.00	0.50	1.00	-0.180	-1.112
210	2	45	0.20	1.00	0.50	1.00	-0.254	-0.787
211	3	90	0.20	1.00	0.50	1.00	-0.273	-0.733
212	4	135	0.20	1.00	0.50	1.00	-0.254	-0.787
213	5	180	0.20	1.00	0.50	1.00	-0.180	-1.112
214	6	225	0.20	1.00	0.50	1.00	-0.076	-2.634
215	7	270	0.20	1.00	0.50	1.00	-0.029	-6.826
216	8	315	0.20	1.00	0.50	1.00	-0.076	-2.634
217	1	0	0.10	1.00	0.50	1.00	-0.174	-0.574
218	2	45	0.10	1.00	0.50	1.00	-0.204	-0.490
219	3	90	0.10	1.00	0.50	1.00	-0.227	-0.441
220	4	135	0.10	1.00	0.50	1.00	-0.204	-0.490
221	5	180	0.10	1.00	0.50	1.00	-0.174	-0.574
222	6	225	0.10	1.00	0.50	1.00	-0.138	-0.724
223	7	270	0.10	1.00	0.50	1.00	-0.108	-0.930
224	8	315	0.10	1.00	0.50	1.00	-0.138	-0.724
225	1	0	0.05	1.00	0.50	1.00	-0.173	-0.289
226	2	45	0.05	1.00	0.50	1.00	-0.199	-0.251
227	3	90	0.05	1.00	0.50	1.00	-0.201	-0.249
228	4	135	0.05	1.00	0.50	1.00	-0.199	-0.251
229	5	180	0.05	1.00	0.50	1.00	-0.173	-0.289
230	6	225	0.05	1.00	0.50	1.00	-0.144	-0.346
231	7	270	0.05	1.00	0.50	1.00	-0.141	-0.354
232	8	315	0.05	1.00	0.50	1.00	-0.144	-0.346
233	1	0	0.00	1.00	0.50	1.00	-0.172	0.000
234	2	45	0.00	1.00	0.50	1.00	-0.172	0.000
235	3	90	0.00	1.00	0.50	1.00	-0.172	0.000
236	4	135	0.00	1.00	0.50	1.00	-0.172	0.000
237	5	180	0.00	1.00	0.50	1.00	-0.172	0.000
238	6	225	0.00	1.00	0.50	1.00	-0.172	0.000
239	7	270	0.00	1.00	0.50	1.00	-0.172	0.000
240	8	315	0.00	1.00	0.50	1.00	-0.172	0.000
241	1	0	0.40	0.50	0.50	1.00	-0.103	-3.901
242	2	45	0.40	0.50	0.50	1.00	-0.163	-2.453

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
243	3	90	0.40	0.50	0.50	1.00	-0.173	-2.317
244	4	135	0.40	0.50	0.50	1.00	-0.163	-2.453
245	5	180	0.40	0.50	0.50	1.00	-0.103	-3.901
246	6	225	0.40	0.50	0.50	1.00	0.027	14.708
247	7	270	0.40	0.50	0.50	1.00	0.109	3.670
248	8	315	0.40	0.50	0.50	1.00	0.027	14.708
249	1	0	0.30	0.50	0.50	1.00	-0.095	-3.159
250	2	45	0.30	0.50	0.50	1.00	-0.141	-2.129
251	3	90	0.30	0.50	0.50	1.00	-0.156	-1.923
252	4	135	0.30	0.50	0.50	1.00	-0.141	-2.129
253	5	180	0.30	0.50	0.50	1.00	-0.095	-3.159
254	6	225	0.30	0.50	0.50	1.00	-0.016	-18.906
255	7	270	0.30	0.50	0.50	1.00	0.035	8.514
256	8	315	0.30	0.50	0.50	1.00	-0.016	-18.906
257	1	0	0.20	0.50	0.50	1.00	-0.090	-2.224
258	2	45	0.20	0.50	0.50	1.00	-0.127	-1.575
259	3	90	0.20	0.50	0.50	1.00	-0.136	-1.466
260	4	135	0.20	0.50	0.50	1.00	-0.127	-1.575
261	5	180	0.20	0.50	0.50	1.00	-0.090	-2.224
262	6	225	0.20	0.50	0.50	1.00	-0.038	-5.267
263	7	270	0.20	0.50	0.50	1.00	-0.015	-13.651
264	8	315	0.20	0.50	0.50	1.00	-0.038	-5.267
265	1	0	0.10	0.50	0.50	1.00	-0.087	-1.149
266	2	45	0.10	0.50	0.50	1.00	-0.102	-0.980
267	3	90	0.10	0.50	0.50	1.00	-0.113	-0.882
268	4	135	0.10	0.50	0.50	1.00	-0.102	-0.980
269	5	180	0.10	0.50	0.50	1.00	-0.087	-1.149
270	6	225	0.10	0.50	0.50	1.00	-0.069	-1.448
271	7	270	0.10	0.50	0.50	1.00	-0.054	-1.859
272	8	315	0.10	0.50	0.50	1.00	-0.069	-1.448
273	1	0	0.05	0.50	0.50	1.00	-0.086	-0.579
274	2	45	0.05	0.50	0.50	1.00	-0.099	-0.503
275	3	90	0.05	0.50	0.50	1.00	-0.100	-0.498
276	4	135	0.05	0.50	0.50	1.00	-0.099	-0.503
277	5	180	0.05	0.50	0.50	1.00	-0.086	-0.579
278	6	225	0.05	0.50	0.50	1.00	-0.072	-0.693
279	7	270	0.05	0.50	0.50	1.00	-0.071	-0.707
280	8	315	0.05	0.50	0.50	1.00	-0.072	-0.693
281	1	0	0.00	0.50	0.50	2.00	-0.026	0.000
282	2	45	0.00	0.50	0.50	2.00	-0.026	0.000
283	3	90	0.00	0.50	0.50	2.00	-0.026	0.000

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
284	4	135	0.00	0.50	0.50	2.00	-0.026	0.000
285	5	180	0.00	0.50	0.50	2.00	-0.026	0.000
286	6	225	0.00	0.50	0.50	2.00	-0.026	0.000
287	7	270	0.00	0.50	0.50	2.00	-0.026	0.000
288	8	315	0.00	0.50	0.50	2.00	-0.026	0.000
289	1	0	0.40	0.25	0.50	1.00	-0.051	-7.803
290	2	45	0.40	0.25	0.50	1.00	-0.082	-4.905
291	3	90	0.40	0.25	0.50	1.00	-0.086	-4.635
292	4	135	0.40	0.25	0.50	1.00	-0.082	-4.905
293	5	180	0.40	0.25	0.50	1.00	-0.051	-7.803
294	6	225	0.40	0.25	0.50	1.00	0.014	29.416
295	7	270	0.40	0.25	0.50	1.00	0.054	7.341
296	8	315	0.40	0.25	0.50	1.00	0.014	29.416
297	1	0	0.30	0.25	0.50	1.00	-0.047	-6.318
298	2	45	0.30	0.25	0.50	1.00	-0.070	-4.258
299	3	90	0.30	0.25	0.50	1.00	-0.078	-3.846
300	4	135	0.30	0.25	0.50	1.00	-0.070	-4.258
301	5	180	0.30	0.25	0.50	1.00	-0.047	-6.318
302	6	225	0.30	0.25	0.50	1.00	-0.008	-37.812
303	7	270	0.30	0.25	0.50	1.00	0.018	17.029
304	8	315	0.30	0.25	0.50	1.00	-0.008	-37.812
305	1	0	0.20	0.25	0.50	1.00	-0.045	-4.447
306	2	45	0.20	0.25	0.50	1.00	-0.064	-3.149
307	3	90	0.20	0.25	0.50	1.00	-0.068	-2.932
308	4	135	0.20	0.25	0.50	1.00	-0.064	-3.149
309	5	180	0.20	0.25	0.50	1.00	-0.045	-4.447
310	6	225	0.20	0.25	0.50	1.00	-0.019	-10.534
311	7	270	0.20	0.25	0.50	1.00	-0.007	-27.303
312	8	315	0.20	0.25	0.50	1.00	-0.019	-10.534
313	1	0	0.10	0.25	0.50	1.00	-0.044	-2.297
314	2	45	0.10	0.25	0.50	1.00	-0.051	-1.960
315	3	90	0.10	0.25	0.50	1.00	-0.057	-1.764
316	4	135	0.10	0.25	0.50	1.00	-0.051	-1.960
317	5	180	0.10	0.25	0.50	1.00	-0.044	-2.297
318	6	225	0.10	0.25	0.50	1.00	-0.035	-2.896
319	7	270	0.10	0.25	0.50	1.00	-0.027	-3.718
320	8	315	0.10	0.25	0.50	1.00	-0.035	-2.896
321	1	0	0.05	0.25	0.50	1.00	-0.043	-1.158
322	2	45	0.05	0.25	0.50	1.00	-0.050	-1.005
323	3	90	0.05	0.25	0.50	1.00	-0.050	-0.997
324	4	135	0.05	0.25	0.50	1.00	-0.050	-1.005

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
325	5	180	0.05	0.25	0.50	1.00	-0.043	-1.158
326	6	225	0.05	0.25	0.50	1.00	-0.036	-1.385
327	7	270	0.05	0.25	0.50	1.00	-0.035	-1.415
328	8	315	0.05	0.25	0.50	1.00	-0.036	-1.385
329	1	0	0.00	0.25	0.50	1.00	-0.043	0.000
330	2	45	0.00	0.25	0.50	1.00	-0.043	0.000
331	3	90	0.00	0.25	0.50	1.00	-0.043	0.000
332	4	135	0.00	0.25	0.50	1.00	-0.043	0.000
333	5	180	0.00	0.25	0.50	1.00	-0.043	0.000
334	6	225	0.00	0.25	0.50	1.00	-0.043	0.000
335	7	270	0.00	0.25	0.50	1.00	-0.043	0.000
336	8	315	0.00	0.25	0.50	1.00	-0.043	0.000
337	1	0	0.40	0.10	0.50	1.00	-0.021	-19.507
338	2	45	0.40	0.10	0.50	1.00	-0.033	-12.264
339	3	90	0.40	0.10	0.50	1.00	-0.035	-11.587
340	4	135	0.40	0.10	0.50	1.00	-0.033	-12.264
341	5	180	0.40	0.10	0.50	1.00	-0.021	-19.507
342	6	225	0.40	0.10	0.50	1.00	0.005	73.540
343	7	270	0.40	0.10	0.50	1.00	0.022	18.352
344	8	315	0.40	0.10	0.50	1.00	0.005	73.540
345	1	0	0.30	0.10	0.50	1.00	-0.019	-15.795
346	2	45	0.30	0.10	0.50	1.00	-0.028	-10.645
347	3	90	0.30	0.10	0.50	1.00	-0.031	-9.615
348	4	135	0.30	0.10	0.50	1.00	-0.028	-10.645
349	5	180	0.30	0.10	0.50	1.00	-0.019	-15.795
350	6	225	0.30	0.10	0.50	1.00	-0.003	-94.531
351	7	270	0.30	0.10	0.50	1.00	0.007	42.572
352	8	315	0.30	0.10	0.50	1.00	-0.003	-94.531
353	1	0	0.20	0.10	0.50	1.00	-0.018	-11.118
354	2	45	0.20	0.10	0.50	1.00	-0.025	-7.874
355	3	90	0.20	0.10	0.50	1.00	-0.027	-7.330
356	4	135	0.20	0.10	0.50	1.00	-0.025	-7.874
357	5	180	0.20	0.10	0.50	1.00	-0.018	-11.118
358	6	225	0.20	0.10	0.50	1.00	-0.008	-26.336
359	7	270	0.20	0.10	0.50	1.00	-0.003	-68.256
360	8	315	0.20	0.10	0.50	1.00	-0.008	-26.336
361	1	0	0.10	0.10	0.50	1.00	-0.017	-5.743
362	2	45	0.10	0.10	0.50	1.00	-0.020	-4.900
363	3	90	0.10	0.10	0.50	1.00	-0.023	-4.411
364	4	135	0.10	0.10	0.50	1.00	-0.020	-4.900
365	5	180	0.10	0.10	0.50	1.00	-0.017	-5.743

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
366	6	225	0.10	0.10	0.50	1.00	-0.014	-7.239
367	7	270	0.10	0.10	0.50	1.00	-0.011	-9.295
368	8	315	0.10	0.10	0.50	1.00	-0.014	-7.239
369	1	0	0.05	0.10	0.50	1.00	-0.017	-2.895
370	2	45	0.05	0.10	0.50	1.00	-0.020	-2.513
371	3	90	0.05	0.10	0.50	1.00	-0.020	-2.492
372	4	135	0.05	0.10	0.50	1.00	-0.020	-2.513
373	5	180	0.05	0.10	0.50	1.00	-0.017	-2.895
374	6	225	0.05	0.10	0.50	1.00	-0.014	-3.463
375	7	270	0.05	0.10	0.50	1.00	-0.014	-3.537
376	8	315	0.05	0.10	0.50	1.00	-0.014	-3.463
377	1	0	0.00	0.10	0.50	1.00	-0.017	0.000
378	2	45	0.00	0.10	0.50	1.00	-0.017	0.000
379	3	90	0.00	0.10	0.50	1.00	-0.017	0.000
380	4	135	0.00	0.10	0.50	1.00	-0.017	0.000
381	5	180	0.00	0.10	0.50	1.00	-0.017	0.000
382	6	225	0.00	0.10	0.50	1.00	-0.017	0.000
383	7	270	0.00	0.10	0.50	1.00	-0.017	0.000
384	8	315	0.00	0.10	0.50	1.00	-0.017	0.000
385	1	0	0.40	1.00	0.50	0.50	-0.676	-0.592
386	2	45	0.40	1.00	0.50	0.50	-0.671	-0.596
387	3	90	0.40	1.00	0.50	0.50	-0.657	-0.609
388	4	135	0.40	1.00	0.50	0.50	-0.671	-0.596
389	5	180	0.40	1.00	0.50	0.50	-0.676	-0.592
390	6	225	0.40	1.00	0.50	0.50	-0.109	-3.680
391	7	270	0.40	1.00	0.50	0.50	0.147	2.713
392	8	315	0.40	1.00	0.50	0.50	-0.109	-3.680
393	1	0	0.30	1.00	0.50	0.50	-0.560	-0.535
394	2	45	0.30	1.00	0.50	0.50	-0.623	-0.482
395	3	90	0.30	1.00	0.50	0.50	-0.631	-0.475
396	4	135	0.30	1.00	0.50	0.50	-0.623	-0.482
397	5	180	0.30	1.00	0.50	0.50	-0.560	-0.535
398	6	225	0.30	1.00	0.50	0.50	-0.252	-1.192
399	7	270	0.30	1.00	0.50	0.50	-0.068	-4.434
400	8	315	0.30	1.00	0.50	0.50	-0.252	-1.192
401	1	0	0.20	1.00	0.50	0.50	-0.501	-0.399
402	2	45	0.20	1.00	0.50	0.50	-0.585	-0.342
403	3	90	0.20	1.00	0.50	0.50	-0.593	-0.337
404	4	135	0.20	1.00	0.50	0.50	-0.585	-0.342
405	5	180	0.20	1.00	0.50	0.50	-0.501	-0.399
406	6	225	0.20	1.00	0.50	0.50	-0.316	-0.632

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
407	7	270	0.20	1.00	0.50	0.50	-0.229	-0.874
408	8	315	0.20	1.00	0.50	0.50	-0.316	-0.632
409	1	0	0.10	1.00	0.50	0.50	-0.470	-0.213
410	2	45	0.10	1.00	0.50	0.50	-0.507	-0.197
411	3	90	0.10	1.00	0.50	0.50	-0.538	-0.186
412	4	135	0.10	1.00	0.50	0.50	-0.507	-0.197
413	5	180	0.10	1.00	0.50	0.50	-0.470	-0.213
414	6	225	0.10	1.00	0.50	0.50	-0.411	-0.243
415	7	270	0.10	1.00	0.50	0.50	-0.358	-0.279
416	8	315	0.10	1.00	0.50	0.50	-0.411	-0.243
417	1	0	0.05	1.00	0.50	0.50	-0.463	-0.108
418	2	45	0.05	1.00	0.50	0.50	-0.502	-0.100
419	3	90	0.05	1.00	0.50	0.50	-0.502	-0.100
420	4	135	0.05	1.00	0.50	0.50	-0.502	-0.100
421	5	180	0.05	1.00	0.50	0.50	-0.463	-0.108
422	6	225	0.05	1.00	0.50	0.50	-0.418	-0.120
423	7	270	0.05	1.00	0.50	0.50	-0.413	-0.121
424	8	315	0.05	1.00	0.50	0.50	-0.418	-0.120
425	1	0	0.00	1.00	0.50	0.50	-0.461	0.000
426	2	45	0.00	1.00	0.50	0.50	-0.461	0.000
427	3	90	0.00	1.00	0.50	0.50	-0.461	0.000
428	4	135	0.00	1.00	0.50	0.50	-0.461	0.000
429	5	180	0.00	1.00	0.50	0.50	-0.461	0.000
430	6	225	0.00	1.00	0.50	0.50	-0.461	0.000
431	7	270	0.00	1.00	0.50	0.50	-0.461	0.000
432	8	315	0.00	1.00	0.50	0.50	-0.461	0.000
433	1	0	0.40	0.50	0.50	0.50	-0.338	-1.183
434	2	45	0.40	0.50	0.50	0.50	-0.335	-1.192
435	3	90	0.40	0.50	0.50	0.50	-0.328	-1.218
436	4	135	0.40	0.50	0.50	0.50	-0.335	-1.192
437	5	180	0.40	0.50	0.50	0.50	-0.338	-1.183
438	6	225	0.40	0.50	0.50	0.50	-0.054	-7.360
439	7	270	0.40	0.50	0.50	0.50	0.074	5.426
440	8	315	0.40	0.50	0.50	0.50	-0.054	-7.360
441	1	0	0.30	0.50	0.50	0.50	-0.280	-1.071
442	2	45	0.30	0.50	0.50	0.50	-0.311	-0.964
443	3	90	0.30	0.50	0.50	0.50	-0.316	-0.951
444	4	135	0.30	0.50	0.50	0.50	-0.311	-0.964
445	5	180	0.30	0.50	0.50	0.50	-0.280	-1.071
446	6	225	0.30	0.50	0.50	0.50	-0.126	-2.385
447	7	270	0.30	0.50	0.50	0.50	-0.034	-8.868

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
448	8	315	0.30	0.50	0.50	0.50	-0.126	-2.385
449	1	0	0.20	0.50	0.50	0.50	-0.250	-0.799
450	2	45	0.20	0.50	0.50	0.50	-0.292	-0.684
451	3	90	0.20	0.50	0.50	0.50	-0.297	-0.674
452	4	135	0.20	0.50	0.50	0.50	-0.292	-0.684
453	5	180	0.20	0.50	0.50	0.50	-0.250	-0.799
454	6	225	0.20	0.50	0.50	0.50	-0.158	-1.265
455	7	270	0.20	0.50	0.50	0.50	-0.114	-1.749
456	8	315	0.20	0.50	0.50	0.50	-0.158	-1.265
457	1	0	0.10	0.50	0.50	0.50	-0.235	-0.425
458	2	45	0.10	0.50	0.50	0.50	-0.254	-0.394
459	3	90	0.10	0.50	0.50	0.50	-0.269	-0.372
460	4	135	0.10	0.50	0.50	0.50	-0.254	-0.394
461	5	180	0.10	0.50	0.50	0.50	-0.235	-0.425
462	6	225	0.10	0.50	0.50	0.50	-0.206	-0.486
463	7	270	0.10	0.50	0.50	0.50	-0.179	-0.558
464	8	315	0.10	0.50	0.50	0.50	-0.206	-0.486
465	1	0	0.05	0.50	0.50	0.50	-0.231	-0.216
466	2	45	0.05	0.50	0.50	0.50	-0.251	-0.199
467	3	90	0.05	0.50	0.50	0.50	-0.251	-0.199
468	4	135	0.05	0.50	0.50	0.50	-0.251	-0.199
469	5	180	0.05	0.50	0.50	0.50	-0.231	-0.216
470	6	225	0.05	0.50	0.50	0.50	-0.209	-0.240
471	7	270	0.05	0.50	0.50	0.50	-0.206	-0.242
472	8	315	0.05	0.50	0.50	0.50	-0.209	-0.240
473	1	0	0.00	0.50	0.50	0.50	-0.230	0.000
474	2	45	0.00	0.50	0.50	0.50	-0.230	0.000
475	3	90	0.00	0.50	0.50	0.50	-0.230	0.000
476	4	135	0.00	0.50	0.50	0.50	-0.230	0.000
477	5	180	0.00	0.50	0.50	0.50	-0.230	0.000
478	6	225	0.00	0.50	0.50	0.50	-0.230	0.000
479	7	270	0.00	0.50	0.50	0.50	-0.230	0.000
480	8	315	0.00	0.50	0.50	0.50	-0.230	0.000
481	1	0	0.40	0.25	0.50	0.50	-0.169	-2.366
482	2	45	0.40	0.25	0.50	0.50	-0.168	-2.385
483	3	90	0.40	0.25	0.50	0.50	-0.164	-2.436
484	4	135	0.40	0.25	0.50	0.50	-0.168	-2.385
485	5	180	0.40	0.25	0.50	0.50	-0.169	-2.366
486	6	225	0.40	0.25	0.50	0.50	-0.027	-14.719
487	7	270	0.40	0.25	0.50	0.50	0.037	10.852
488	8	315	0.40	0.25	0.50	0.50	-0.027	-14.719

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
489	1	0	0.30	0.25	0.50	0.50	-0.140	-2.141
490	2	45	0.30	0.25	0.50	0.50	-0.156	-1.928
491	3	90	0.30	0.25	0.50	0.50	-0.158	-1.901
492	4	135	0.30	0.25	0.50	0.50	-0.156	-1.928
493	5	180	0.30	0.25	0.50	0.50	-0.140	-2.141
494	6	225	0.30	0.25	0.50	0.50	-0.063	-4.770
495	7	270	0.30	0.25	0.50	0.50	-0.017	-17.735
496	8	315	0.30	0.25	0.50	0.50	-0.063	-4.770
497	1	0	0.20	0.25	0.50	0.50	-0.125	-1.597
498	2	45	0.20	0.25	0.50	0.50	-0.146	-1.368
499	3	90	0.20	0.25	0.50	0.50	-0.148	-1.349
500	4	135	0.20	0.25	0.50	0.50	-0.146	-1.368
501	5	180	0.20	0.25	0.50	0.50	-0.125	-1.597
502	6	225	0.20	0.25	0.50	0.50	-0.079	-2.529
503	7	270	0.20	0.25	0.50	0.50	-0.057	-3.498
504	8	315	0.20	0.25	0.50	0.50	-0.079	-2.529
505	1	0	0.10	0.25	0.50	0.50	-0.118	-0.851
506	2	45	0.10	0.25	0.50	0.50	-0.127	-0.788
507	3	90	0.10	0.25	0.50	0.50	-0.134	-0.744
508	4	135	0.10	0.25	0.50	0.50	-0.127	-0.788
509	5	180	0.10	0.25	0.50	0.50	-0.118	-0.851
510	6	225	0.10	0.25	0.50	0.50	-0.103	-0.973
511	7	270	0.10	0.25	0.50	0.50	-0.090	-1.117
512	8	315	0.10	0.25	0.50	0.50	-0.103	-0.973
513	1	0	0.05	0.25	0.50	0.50	-0.116	-0.432
514	2	45	0.05	0.25	0.50	0.50	-0.126	-0.398
515	3	90	0.05	0.25	0.50	0.50	-0.126	-0.398
516	4	135	0.05	0.25	0.50	0.50	-0.126	-0.398
517	5	180	0.05	0.25	0.50	0.50	-0.116	-0.432
518	6	225	0.05	0.25	0.50	0.50	-0.104	-0.479
519	7	270	0.05	0.25	0.50	0.50	-0.103	-0.485
520	8	315	0.05	0.25	0.50	0.50	-0.104	-0.479
521	1	0	0.00	0.25	0.50	0.50	-0.115	0.000
522	2	45	0.00	0.25	0.50	0.50	-0.115	0.000
523	3	90	0.00	0.25	0.50	0.50	-0.115	0.000
524	4	135	0.00	0.25	0.50	0.50	-0.115	0.000
525	5	180	0.00	0.25	0.50	0.50	-0.115	0.000
526	6	225	0.00	0.25	0.50	0.50	-0.115	0.000
527	7	270	0.00	0.25	0.50	0.50	-0.115	0.000
528	8	315	0.00	0.25	0.50	0.50	-0.115	0.000
529	1	0	0.40	0.10	0.50	0.50	-0.068	-5.915

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
530	2	45	0.40	0.10	0.50	0.50	-0.067	-5.962
531	3	90	0.40	0.10	0.50	0.50	-0.066	-6.091
532	4	135	0.40	0.10	0.50	0.50	-0.067	-5.962
533	5	180	0.40	0.10	0.50	0.50	-0.068	-5.915
534	6	225	0.40	0.10	0.50	0.50	-0.011	-36.798
535	7	270	0.40	0.10	0.50	0.50	0.015	27.130
536	8	315	0.40	0.10	0.50	0.50	-0.011	-36.798
537	1	0	0.30	0.10	0.50	0.50	-0.056	-5.353
538	2	45	0.30	0.10	0.50	0.50	-0.062	-4.819
539	3	90	0.30	0.10	0.50	0.50	-0.063	-4.753
540	4	135	0.30	0.10	0.50	0.50	-0.062	-4.819
541	5	180	0.30	0.10	0.50	0.50	-0.056	-5.353
542	6	225	0.30	0.10	0.50	0.50	-0.025	-11.925
543	7	270	0.30	0.10	0.50	0.50	-0.007	-44.339
544	8	315	0.30	0.10	0.50	0.50	-0.025	-11.925
545	1	0	0.20	0.10	0.50	0.50	-0.050	-3.994
546	2	45	0.20	0.10	0.50	0.50	-0.058	-3.419
547	3	90	0.20	0.10	0.50	0.50	-0.059	-3.372
548	4	135	0.20	0.10	0.50	0.50	-0.058	-3.419
549	5	180	0.20	0.10	0.50	0.50	-0.050	-3.994
550	6	225	0.20	0.10	0.50	0.50	-0.032	-6.324
551	7	270	0.20	0.10	0.50	0.50	-0.023	-8.744
552	8	315	0.20	0.10	0.50	0.50	-0.032	-6.324
553	1	0	0.10	0.10	0.50	0.50	-0.047	-2.127
554	2	45	0.10	0.10	0.50	0.50	-0.051	-1.971
555	3	90	0.10	0.10	0.50	0.50	-0.054	-1.860
556	4	135	0.10	0.10	0.50	0.50	-0.051	-1.971
557	5	180	0.10	0.10	0.50	0.50	-0.047	-2.127
558	6	225	0.10	0.10	0.50	0.50	-0.041	-2.432
559	7	270	0.10	0.10	0.50	0.50	-0.036	-2.792
560	8	315	0.10	0.10	0.50	0.50	-0.041	-2.432
561	1	0	0.05	0.10	0.50	0.50	-0.046	-1.080
562	2	45	0.05	0.10	0.50	0.50	-0.050	-0.995
563	3	90	0.05	0.10	0.50	0.50	-0.050	-0.996
564	4	135	0.05	0.10	0.50	0.50	-0.050	-0.995
565	5	180	0.05	0.10	0.50	0.50	-0.046	-1.080
566	6	225	0.05	0.10	0.50	0.50	-0.042	-1.198
567	7	270	0.05	0.10	0.50	0.50	-0.041	-1.212
568	8	315	0.05	0.10	0.50	0.50	-0.042	-1.198
569	1	0	0.00	0.10	0.50	0.50	-0.046	0.000
570	2	45	0.00	0.10	0.50	0.50	-0.046	0.000

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
571	3	90	0.00	0.10	0.50	0.50	-0.046	0.000
572	4	135	0.00	0.10	0.50	0.50	-0.046	0.000
573	5	180	0.00	0.10	0.50	0.50	-0.046	0.000
574	6	225	0.00	0.10	0.50	0.50	-0.046	0.000
575	7	270	0.00	0.10	0.50	0.50	-0.046	0.000
576	8	315	0.00	0.10	0.50	0.50	-0.046	0.000
577	1	0	0.40	1.00	1.00	2.00	-0.290	-1.378
578	2	45	0.40	1.00	1.00	2.00	-0.364	-1.098
579	3	90	0.40	1.00	1.00	2.00	-0.383	-1.044
580	4	135	0.40	1.00	1.00	2.00	-0.364	-1.098
581	5	180	0.40	1.00	1.00	2.00	-0.290	-1.378
582	6	225	0.40	1.00	1.00	2.00	-0.186	-2.148
583	7	270	0.40	1.00	1.00	2.00	-0.140	-2.865
584	8	315	0.40	1.00	1.00	2.00	-0.186	-2.148
585	1	0	0.30	1.00	1.00	2.00	-0.287	-1.046
586	2	45	0.30	1.00	1.00	2.00	-0.340	-0.883
587	3	90	0.30	1.00	1.00	2.00	-0.361	-0.831
588	4	135	0.30	1.00	1.00	2.00	-0.340	-0.883
589	5	180	0.30	1.00	1.00	2.00	-0.287	-1.046
590	6	225	0.30	1.00	1.00	2.00	-0.218	-1.374
591	7	270	0.30	1.00	1.00	2.00	-0.181	-1.659
592	8	315	0.30	1.00	1.00	2.00	-0.218	-1.374
593	1	0	0.20	1.00	1.00	2.00	-0.284	-0.703
594	2	45	0.20	1.00	1.00	2.00	-0.325	-0.616
595	3	90	0.20	1.00	1.00	2.00	-0.337	-0.593
596	4	135	0.20	1.00	1.00	2.00	-0.325	-0.616
597	5	180	0.20	1.00	1.00	2.00	-0.284	-0.703
598	6	225	0.20	1.00	1.00	2.00	-0.237	-0.844
599	7	270	0.20	1.00	1.00	2.00	-0.218	-0.918
600	8	315	0.20	1.00	1.00	2.00	-0.237	-0.844
601	1	0	0.10	1.00	1.00	2.00	-0.283	-0.353
602	2	45	0.10	1.00	1.00	2.00	-0.299	-0.335
603	3	90	0.10	1.00	1.00	2.00	-0.311	-0.322
604	4	135	0.10	1.00	1.00	2.00	-0.299	-0.335
605	5	180	0.10	1.00	1.00	2.00	-0.283	-0.353
606	6	225	0.10	1.00	1.00	2.00	-0.266	-0.376
607	7	270	0.10	1.00	1.00	2.00	-0.252	-0.397
608	8	315	0.10	1.00	1.00	2.00	-0.266	-0.376
609	1	0	0.05	1.00	1.00	2.00	-0.283	-0.177
610	2	45	0.05	1.00	1.00	2.00	-0.296	-0.169
611	3	90	0.05	1.00	1.00	2.00	-0.297	-0.168

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
612	4	135	0.05	1.00	1.00	2.00	-0.296	-0.169
613	5	180	0.05	1.00	1.00	2.00	-0.283	-0.177
614	6	225	0.05	1.00	1.00	2.00	-0.269	-0.186
615	7	270	0.05	1.00	1.00	2.00	-0.267	-0.187
616	8	315	0.05	1.00	1.00	2.00	-0.269	-0.186
617	1	0	0.00	1.00	1.00	2.00	-0.283	0.000
618	2	45	0.00	1.00	1.00	2.00	-0.283	0.000
619	3	90	0.00	1.00	1.00	2.00	-0.283	0.000
620	4	135	0.00	1.00	1.00	2.00	-0.283	0.000
621	5	180	0.00	1.00	1.00	2.00	-0.283	0.000
622	6	225	0.00	1.00	1.00	2.00	-0.283	0.000
623	7	270	0.00	1.00	1.00	2.00	-0.283	0.000
624	8	315	0.00	1.00	1.00	2.00	-0.283	0.000
625	1	0	0.40	0.50	1.00	2.00	-0.145	-2.757
626	2	45	0.40	0.50	1.00	2.00	-0.182	-2.196
627	3	90	0.40	0.50	1.00	2.00	-0.192	-2.088
628	4	135	0.40	0.50	1.00	2.00	-0.182	-2.196
629	5	180	0.40	0.50	1.00	2.00	-0.145	-2.757
630	6	225	0.40	0.50	1.00	2.00	-0.093	-4.295
631	7	270	0.40	0.50	1.00	2.00	-0.070	-5.730
632	8	315	0.40	0.50	1.00	2.00	-0.093	-4.295
633	1	0	0.30	0.50	1.00	2.00	-0.143	-2.092
634	2	45	0.30	0.50	1.00	2.00	-0.170	-1.766
635	3	90	0.30	0.50	1.00	2.00	-0.181	-1.662
636	4	135	0.30	0.50	1.00	2.00	-0.170	-1.766
637	5	180	0.30	0.50	1.00	2.00	-0.143	-2.092
638	6	225	0.30	0.50	1.00	2.00	-0.109	-2.747
639	7	270	0.30	0.50	1.00	2.00	-0.090	-3.319
640	8	315	0.30	0.50	1.00	2.00	-0.109	-2.747
641	1	0	0.20	0.50	1.00	2.00	-0.142	-1.406
642	2	45	0.20	0.50	1.00	2.00	-0.162	-1.232
643	3	90	0.20	0.50	1.00	2.00	-0.169	-1.187
644	4	135	0.20	0.50	1.00	2.00	-0.162	-1.232
645	5	180	0.20	0.50	1.00	2.00	-0.142	-1.406
646	6	225	0.20	0.50	1.00	2.00	-0.118	-1.688
647	7	270	0.20	0.50	1.00	2.00	-0.109	-1.836
648	8	315	0.20	0.50	1.00	2.00	-0.118	-1.688
649	1	0	0.10	0.50	1.00	2.00	-0.142	-0.707
650	2	45	0.10	0.50	1.00	2.00	-0.149	-0.669
651	3	90	0.10	0.50	1.00	2.00	-0.155	-0.643
652	4	135	0.10	0.50	1.00	2.00	-0.149	-0.669

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
653	5	180	0.10	0.50	1.00	2.00	-0.142	-0.707
654	6	225	0.10	0.50	1.00	2.00	-0.133	-0.752
655	7	270	0.10	0.50	1.00	2.00	-0.126	-0.795
656	8	315	0.10	0.50	1.00	2.00	-0.133	-0.752
657	1	0	0.05	0.50	1.00	2.00	-0.141	-0.354
658	2	45	0.05	0.50	1.00	2.00	-0.148	-0.338
659	3	90	0.05	0.50	1.00	2.00	-0.149	-0.337
660	4	135	0.05	0.50	1.00	2.00	-0.148	-0.338
661	5	180	0.05	0.50	1.00	2.00	-0.141	-0.354
662	6	225	0.05	0.50	1.00	2.00	-0.134	-0.372
663	7	270	0.05	0.50	1.00	2.00	-0.134	-0.374
664	8	315	0.05	0.50	1.00	2.00	-0.134	-0.372
665	1	0	0.00	0.50	1.00	2.00	-0.141	0.000
666	2	45	0.00	0.50	1.00	2.00	-0.141	0.000
667	3	90	0.00	0.50	1.00	2.00	-0.141	0.000
668	4	135	0.00	0.50	1.00	2.00	-0.141	0.000
669	5	180	0.00	0.50	1.00	2.00	-0.141	0.000
670	6	225	0.00	0.50	1.00	2.00	-0.141	0.000
671	7	270	0.00	0.50	1.00	2.00	-0.141	0.000
672	8	315	0.00	0.50	1.00	2.00	-0.141	0.000
673	1	0	0.40	0.25	1.00	2.00	-0.073	-5.513
674	2	45	0.40	0.25	1.00	2.00	-0.091	-4.392
675	3	90	0.40	0.25	1.00	2.00	-0.096	-4.176
676	4	135	0.40	0.25	1.00	2.00	-0.091	-4.392
677	5	180	0.40	0.25	1.00	2.00	-0.073	-5.513
678	6	225	0.40	0.25	1.00	2.00	-0.047	-8.590
679	7	270	0.40	0.25	1.00	2.00	-0.035	-11.460
680	8	315	0.40	0.25	1.00	2.00	-0.047	-8.590
681	1	0	0.30	0.25	1.00	2.00	-0.072	-4.184
682	2	45	0.30	0.25	1.00	2.00	-0.085	-3.532
683	3	90	0.30	0.25	1.00	2.00	-0.090	-3.324
684	4	135	0.30	0.25	1.00	2.00	-0.085	-3.532
685	5	180	0.30	0.25	1.00	2.00	-0.072	-4.184
686	6	225	0.30	0.25	1.00	2.00	-0.055	-5.495
687	7	270	0.30	0.25	1.00	2.00	-0.045	-6.638
688	8	315	0.30	0.25	1.00	2.00	-0.055	-5.495
689	1	0	0.20	0.25	1.00	2.00	-0.071	-2.813
690	2	45	0.20	0.25	1.00	2.00	-0.081	-2.464
691	3	90	0.20	0.25	1.00	2.00	-0.084	-2.374
692	4	135	0.20	0.25	1.00	2.00	-0.081	-2.464
693	5	180	0.20	0.25	1.00	2.00	-0.071	-2.813

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
694	6	225	0.20	0.25	1.00	2.00	-0.059	-3.376
695	7	270	0.20	0.25	1.00	2.00	-0.054	-3.671
696	8	315	0.20	0.25	1.00	2.00	-0.059	-3.376
697	1	0	0.10	0.25	1.00	2.00	-0.071	-1.413
698	2	45	0.10	0.25	1.00	2.00	-0.075	-1.339
699	3	90	0.10	0.25	1.00	2.00	-0.078	-1.286
700	4	135	0.10	0.25	1.00	2.00	-0.075	-1.339
701	5	180	0.10	0.25	1.00	2.00	-0.071	-1.413
702	6	225	0.10	0.25	1.00	2.00	-0.066	-1.505
703	7	270	0.10	0.25	1.00	2.00	-0.063	-1.589
704	8	315	0.10	0.25	1.00	2.00	-0.066	-1.505
705	1	0	0.05	0.25	1.00	2.00	-0.071	-0.708
706	2	45	0.05	0.25	1.00	2.00	-0.074	-0.676
707	3	90	0.05	0.25	1.00	2.00	-0.074	-0.673
708	4	135	0.05	0.25	1.00	2.00	-0.074	-0.676
709	5	180	0.05	0.25	1.00	2.00	-0.071	-0.708
710	6	225	0.05	0.25	1.00	2.00	-0.067	-0.744
711	7	270	0.05	0.25	1.00	2.00	-0.067	-0.748
712	8	315	0.05	0.25	1.00	2.00	-0.067	-0.744
713	1	0	0.00	0.25	1.00	2.00	-0.071	0.000
714	2	45	0.00	0.25	1.00	2.00	-0.071	0.000
715	3	90	0.00	0.25	1.00	2.00	-0.071	0.000
716	4	135	0.00	0.25	1.00	2.00	-0.071	0.000
717	5	180	0.00	0.25	1.00	2.00	-0.071	0.000
718	6	225	0.00	0.25	1.00	2.00	-0.071	0.000
719	7	270	0.00	0.25	1.00	2.00	-0.071	0.000
720	8	315	0.00	0.25	1.00	2.00	-0.071	0.000
721	1	0	0.40	0.10	1.00	2.00	-0.029	-13.784
722	2	45	0.40	0.10	1.00	2.00	-0.036	-10.979
723	3	90	0.40	0.10	1.00	2.00	-0.038	-10.439
724	4	135	0.40	0.10	1.00	2.00	-0.036	-10.979
725	5	180	0.40	0.10	1.00	2.00	-0.029	-13.784
726	6	225	0.40	0.10	1.00	2.00	-0.019	-21.475
727	7	270	0.40	0.10	1.00	2.00	-0.014	-28.649
728	8	315	0.40	0.10	1.00	2.00	-0.019	-21.475
729	1	0	0.30	0.10	1.00	2.00	-0.029	-10.460
730	2	45	0.30	0.10	1.00	2.00	-0.034	-8.830
731	3	90	0.30	0.10	1.00	2.00	-0.036	-8.309
732	4	135	0.30	0.10	1.00	2.00	-0.034	-8.830
733	5	180	0.30	0.10	1.00	2.00	-0.029	-10.460
734	6	225	0.30	0.10	1.00	2.00	-0.022	-13.737

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
735	7	270	0.30	0.10	1.00	2.00	-0.018	-16.594
736	8	315	0.30	0.10	1.00	2.00	-0.022	-13.737
737	1	0	0.20	0.10	1.00	2.00	-0.028	-7.031
738	2	45	0.20	0.10	1.00	2.00	-0.032	-6.159
739	3	90	0.20	0.10	1.00	2.00	-0.034	-5.934
740	4	135	0.20	0.10	1.00	2.00	-0.032	-6.159
741	5	180	0.20	0.10	1.00	2.00	-0.028	-7.031
742	6	225	0.20	0.10	1.00	2.00	-0.024	-8.440
743	7	270	0.20	0.10	1.00	2.00	-0.022	-9.178
744	8	315	0.20	0.10	1.00	2.00	-0.024	-8.440
745	1	0	0.10	0.10	1.00	2.00	-0.028	-3.533
746	2	45	0.10	0.10	1.00	2.00	-0.030	-3.347
747	3	90	0.10	0.10	1.00	2.00	-0.031	-3.216
748	4	135	0.10	0.10	1.00	2.00	-0.030	-3.347
749	5	180	0.10	0.10	1.00	2.00	-0.028	-3.533
750	6	225	0.10	0.10	1.00	2.00	-0.027	-3.762
751	7	270	0.10	0.10	1.00	2.00	-0.025	-3.973
752	8	315	0.10	0.10	1.00	2.00	-0.027	-3.762
753	1	0	0.05	0.10	1.00	2.00	-0.028	-1.769
754	2	45	0.05	0.10	1.00	2.00	-0.030	-1.689
755	3	90	0.05	0.10	1.00	2.00	-0.030	-1.683
756	4	135	0.05	0.10	1.00	2.00	-0.030	-1.689
757	5	180	0.05	0.10	1.00	2.00	-0.028	-1.769
758	6	225	0.05	0.10	1.00	2.00	-0.027	-1.860
759	7	270	0.05	0.10	1.00	2.00	-0.027	-1.869
760	8	315	0.05	0.10	1.00	2.00	-0.027	-1.860
761	1	0	0.00	0.10	1.00	2.00	-0.028	0.000
762	2	45	0.00	0.10	1.00	2.00	-0.028	0.000
763	3	90	0.00	0.10	1.00	2.00	-0.028	0.000
764	4	135	0.00	0.10	1.00	2.00	-0.028	0.000
765	5	180	0.00	0.10	1.00	2.00	-0.028	0.000
766	6	225	0.00	0.10	1.00	2.00	-0.028	0.000
767	7	270	0.00	0.10	1.00	2.00	-0.028	0.000
768	8	315	0.00	0.10	1.00	2.00	-0.028	0.000
769	1	0	0.40	1.00	1.00	1.00	-0.611	-0.655
770	2	45	0.40	1.00	1.00	1.00	-0.695	-0.575
771	3	90	0.40	1.00	1.00	1.00	-0.703	-0.569
772	4	135	0.40	1.00	1.00	1.00	-0.695	-0.575
773	5	180	0.40	1.00	1.00	1.00	-0.611	-0.655
774	6	225	0.40	1.00	1.00	1.00	-0.427	-0.938
775	7	270	0.40	1.00	1.00	1.00	-0.339	-1.180

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
776	8	315	0.40	1.00	1.00	1.00	-0.427	-0.938
777	1	0	0.30	1.00	1.00	1.00	-0.593	-0.506
778	2	45	0.30	1.00	1.00	1.00	-0.658	-0.456
779	3	90	0.30	1.00	1.00	1.00	-0.678	-0.442
780	4	135	0.30	1.00	1.00	1.00	-0.658	-0.456
781	5	180	0.30	1.00	1.00	1.00	-0.593	-0.506
782	6	225	0.30	1.00	1.00	1.00	-0.476	-0.630
783	7	270	0.30	1.00	1.00	1.00	-0.407	-0.737
784	8	315	0.30	1.00	1.00	1.00	-0.476	-0.630
785	1	0	0.20	1.00	1.00	1.00	-0.580	-0.345
786	2	45	0.20	1.00	1.00	1.00	-0.635	-0.315
787	3	90	0.20	1.00	1.00	1.00	-0.648	-0.309
788	4	135	0.20	1.00	1.00	1.00	-0.635	-0.315
789	5	180	0.20	1.00	1.00	1.00	-0.580	-0.345
790	6	225	0.20	1.00	1.00	1.00	-0.502	-0.398
791	7	270	0.20	1.00	1.00	1.00	-0.469	-0.427
792	8	315	0.20	1.00	1.00	1.00	-0.502	-0.398
793	1	0	0.10	1.00	1.00	1.00	-0.573	-0.174
794	2	45	0.10	1.00	1.00	1.00	-0.595	-0.168
795	3	90	0.10	1.00	1.00	1.00	-0.612	-0.163
796	4	135	0.10	1.00	1.00	1.00	-0.595	-0.168
797	5	180	0.10	1.00	1.00	1.00	-0.573	-0.174
798	6	225	0.10	1.00	1.00	1.00	-0.547	-0.183
799	7	270	0.10	1.00	1.00	1.00	-0.523	-0.191
800	8	315	0.10	1.00	1.00	1.00	-0.547	-0.183
801	1	0	0.05	1.00	1.00	1.00	-0.571	-0.088
802	2	45	0.05	1.00	1.00	1.00	-0.592	-0.084
803	3	90	0.05	1.00	1.00	1.00	-0.592	-0.084
804	4	135	0.05	1.00	1.00	1.00	-0.592	-0.084
805	5	180	0.05	1.00	1.00	1.00	-0.571	-0.088
806	6	225	0.05	1.00	1.00	1.00	-0.549	-0.091
807	7	270	0.05	1.00	1.00	1.00	-0.548	-0.091
808	8	315	0.05	1.00	1.00	1.00	-0.549	-0.091
809	1	0	0.00	1.00	1.00	1.00	-0.571	0.000
810	2	45	0.00	1.00	1.00	1.00	-0.571	0.000
811	3	90	0.00	1.00	1.00	1.00	-0.571	0.000
812	4	135	0.00	1.00	1.00	1.00	-0.571	0.000
813	5	180	0.00	1.00	1.00	1.00	-0.571	0.000
814	6	225	0.00	1.00	1.00	1.00	-0.571	0.000
815	7	270	0.00	1.00	1.00	1.00	-0.571	0.000
816	8	315	0.00	1.00	1.00	1.00	-0.571	0.000

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
817	1	0	0.40	0.50	1.00	1.00	-0.306	-1.309
818	2	45	0.40	0.50	1.00	1.00	-0.348	-1.151
819	3	90	0.40	0.50	1.00	1.00	-0.352	-1.137
820	4	135	0.40	0.50	1.00	1.00	-0.348	-1.151
821	5	180	0.40	0.50	1.00	1.00	-0.306	-1.309
822	6	225	0.40	0.50	1.00	1.00	-0.213	-1.875
823	7	270	0.40	0.50	1.00	1.00	-0.170	-2.360
824	8	315	0.40	0.50	1.00	1.00	-0.213	-1.875
825	1	0	0.30	0.50	1.00	1.00	-0.296	-1.012
826	2	45	0.30	0.50	1.00	1.00	-0.329	-0.912
827	3	90	0.30	0.50	1.00	1.00	-0.339	-0.885
828	4	135	0.30	0.50	1.00	1.00	-0.329	-0.912
829	5	180	0.30	0.50	1.00	1.00	-0.296	-1.012
830	6	225	0.30	0.50	1.00	1.00	-0.238	-1.261
831	7	270	0.30	0.50	1.00	1.00	-0.204	-1.473
832	8	315	0.30	0.50	1.00	1.00	-0.238	-1.261
833	1	0	0.20	0.50	1.00	1.00	-0.290	-0.689
834	2	45	0.20	0.50	1.00	1.00	-0.318	-0.629
835	3	90	0.20	0.50	1.00	1.00	-0.324	-0.617
836	4	135	0.20	0.50	1.00	1.00	-0.318	-0.629
837	5	180	0.20	0.50	1.00	1.00	-0.290	-0.689
838	6	225	0.20	0.50	1.00	1.00	-0.251	-0.796
839	7	270	0.20	0.50	1.00	1.00	-0.234	-0.854
840	8	315	0.20	0.50	1.00	1.00	-0.251	-0.796
841	1	0	0.10	0.50	1.00	1.00	-0.287	-0.349
842	2	45	0.10	0.50	1.00	1.00	-0.297	-0.336
843	3	90	0.10	0.50	1.00	1.00	-0.306	-0.327
844	4	135	0.10	0.50	1.00	1.00	-0.297	-0.336
845	5	180	0.10	0.50	1.00	1.00	-0.287	-0.349
846	6	225	0.10	0.50	1.00	1.00	-0.273	-0.366
847	7	270	0.10	0.50	1.00	1.00	-0.261	-0.382
848	8	315	0.10	0.50	1.00	1.00	-0.273	-0.366
849	1	0	0.05	0.50	1.00	1.00	-0.286	-0.175
850	2	45	0.05	0.50	1.00	1.00	-0.296	-0.169
851	3	90	0.05	0.50	1.00	1.00	-0.296	-0.169
852	4	135	0.05	0.50	1.00	1.00	-0.296	-0.169
853	5	180	0.05	0.50	1.00	1.00	-0.286	-0.175
854	6	225	0.05	0.50	1.00	1.00	-0.275	-0.182
855	7	270	0.05	0.50	1.00	1.00	-0.274	-0.183
856	8	315	0.05	0.50	1.00	1.00	-0.275	-0.182
857	1	0	0.00	0.50	1.00	1.00	-0.285	0.000

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
858	2	45	0.00	0.50	1.00	1.00	-0.285	0.000
859	3	90	0.00	0.50	1.00	1.00	-0.285	0.000
860	4	135	0.00	0.50	1.00	1.00	-0.285	0.000
861	5	180	0.00	0.50	1.00	1.00	-0.285	0.000
862	6	225	0.00	0.50	1.00	1.00	-0.285	0.000
863	7	270	0.00	0.50	1.00	1.00	-0.285	0.000
864	8	315	0.00	0.50	1.00	1.00	-0.285	0.000
865	1	0	0.40	0.25	1.00	1.00	-0.153	-2.618
866	2	45	0.40	0.25	1.00	1.00	-0.174	-2.301
867	3	90	0.40	0.25	1.00	1.00	-0.176	-2.275
868	4	135	0.40	0.25	1.00	1.00	-0.174	-2.301
869	5	180	0.40	0.25	1.00	1.00	-0.153	-2.618
870	6	225	0.40	0.25	1.00	1.00	-0.107	-3.751
871	7	270	0.40	0.25	1.00	1.00	-0.085	-4.719
872	8	315	0.40	0.25	1.00	1.00	-0.107	-3.751
873	1	0	0.30	0.25	1.00	1.00	-0.148	-2.024
874	2	45	0.30	0.25	1.00	1.00	-0.164	-1.825
875	3	90	0.30	0.25	1.00	1.00	-0.170	-1.769
876	4	135	0.30	0.25	1.00	1.00	-0.164	-1.825
877	5	180	0.30	0.25	1.00	1.00	-0.148	-2.024
878	6	225	0.30	0.25	1.00	1.00	-0.119	-2.521
879	7	270	0.30	0.25	1.00	1.00	-0.102	-2.946
880	8	315	0.30	0.25	1.00	1.00	-0.119	-2.521
881	1	0	0.20	0.25	1.00	1.00	-0.145	-1.378
882	2	45	0.20	0.25	1.00	1.00	-0.159	-1.259
883	3	90	0.20	0.25	1.00	1.00	-0.162	-1.235
884	4	135	0.20	0.25	1.00	1.00	-0.159	-1.259
885	5	180	0.20	0.25	1.00	1.00	-0.145	-1.378
886	6	225	0.20	0.25	1.00	1.00	-0.126	-1.592
887	7	270	0.20	0.25	1.00	1.00	-0.117	-1.708
888	8	315	0.20	0.25	1.00	1.00	-0.126	-1.592
889	1	0	0.10	0.25	1.00	1.00	-0.143	-0.698
890	2	45	0.10	0.25	1.00	1.00	-0.149	-0.673
891	3	90	0.10	0.25	1.00	1.00	-0.153	-0.653
892	4	135	0.10	0.25	1.00	1.00	-0.149	-0.673
893	5	180	0.10	0.25	1.00	1.00	-0.143	-0.698
894	6	225	0.10	0.25	1.00	1.00	-0.137	-0.732
895	7	270	0.10	0.25	1.00	1.00	-0.131	-0.765
896	8	315	0.10	0.25	1.00	1.00	-0.137	-0.732
897	1	0	0.05	0.25	1.00	1.00	-0.143	-0.350
898	2	45	0.05	0.25	1.00	1.00	-0.148	-0.338

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
899	3	90	0.05	0.25	1.00	1.00	-0.148	-0.338
900	4	135	0.05	0.25	1.00	1.00	-0.148	-0.338
901	5	180	0.05	0.25	1.00	1.00	-0.143	-0.350
902	6	225	0.05	0.25	1.00	1.00	-0.137	-0.364
903	7	270	0.05	0.25	1.00	1.00	-0.137	-0.365
904	8	315	0.05	0.25	1.00	1.00	-0.137	-0.364
905	1	0	0.00	0.25	1.00	1.00	-0.143	0.000
906	2	45	0.00	0.25	1.00	1.00	-0.143	0.000
907	3	90	0.00	0.25	1.00	1.00	-0.143	0.000
908	4	135	0.00	0.25	1.00	1.00	-0.143	0.000
909	5	180	0.00	0.25	1.00	1.00	-0.143	0.000
910	6	225	0.00	0.25	1.00	1.00	-0.143	0.000
911	7	270	0.00	0.25	1.00	1.00	-0.143	0.000
912	8	315	0.00	0.25	1.00	1.00	-0.143	0.000
913	1	0	0.40	0.10	1.00	1.00	-0.061	-6.545
914	2	45	0.40	0.10	1.00	1.00	-0.070	-5.753
915	3	90	0.40	0.10	1.00	1.00	-0.070	-5.687
916	4	135	0.40	0.10	1.00	1.00	-0.070	-5.753
917	5	180	0.40	0.10	1.00	1.00	-0.061	-6.545
918	6	225	0.40	0.10	1.00	1.00	-0.043	-9.377
919	7	270	0.40	0.10	1.00	1.00	-0.034	-11.798
920	8	315	0.40	0.10	1.00	1.00	-0.043	-9.377
921	1	0	0.30	0.10	1.00	1.00	-0.059	-5.060
922	2	45	0.30	0.10	1.00	1.00	-0.066	-4.561
923	3	90	0.30	0.10	1.00	1.00	-0.068	-4.424
924	4	135	0.30	0.10	1.00	1.00	-0.066	-4.561
925	5	180	0.30	0.10	1.00	1.00	-0.059	-5.060
926	6	225	0.30	0.10	1.00	1.00	-0.048	-6.304
927	7	270	0.30	0.10	1.00	1.00	-0.041	-7.365
928	8	315	0.30	0.10	1.00	1.00	-0.048	-6.304
929	1	0	0.20	0.10	1.00	1.00	-0.058	-3.446
930	2	45	0.20	0.10	1.00	1.00	-0.064	-3.147
931	3	90	0.20	0.10	1.00	1.00	-0.065	-3.086
932	4	135	0.20	0.10	1.00	1.00	-0.064	-3.147
933	5	180	0.20	0.10	1.00	1.00	-0.058	-3.446
934	6	225	0.20	0.10	1.00	1.00	-0.050	-3.981
935	7	270	0.20	0.10	1.00	1.00	-0.047	-4.269
936	8	315	0.20	0.10	1.00	1.00	-0.050	-3.981
937	1	0	0.10	0.10	1.00	1.00	-0.057	-1.745
938	2	45	0.10	0.10	1.00	1.00	-0.059	-1.682
939	3	90	0.10	0.10	1.00	1.00	-0.061	-1.633

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
940	4	135	0.10	0.10	1.00	1.00	-0.059	-1.682
941	5	180	0.10	0.10	1.00	1.00	-0.057	-1.745
942	6	225	0.10	0.10	1.00	1.00	-0.055	-1.830
943	7	270	0.10	0.10	1.00	1.00	-0.052	-1.912
944	8	315	0.10	0.10	1.00	1.00	-0.055	-1.830
945	1	0	0.05	0.10	1.00	1.00	-0.057	-0.875
946	2	45	0.05	0.10	1.00	1.00	-0.059	-0.845
947	3	90	0.05	0.10	1.00	1.00	-0.059	-0.844
948	4	135	0.05	0.10	1.00	1.00	-0.059	-0.845
949	5	180	0.05	0.10	1.00	1.00	-0.057	-0.875
950	6	225	0.05	0.10	1.00	1.00	-0.055	-0.910
951	7	270	0.05	0.10	1.00	1.00	-0.055	-0.913
952	8	315	0.05	0.10	1.00	1.00	-0.055	-0.910
953	1	0	0.00	0.10	1.00	1.00	-0.057	0.000
954	2	45	0.00	0.10	1.00	1.00	-0.057	0.000
955	3	90	0.00	0.10	1.00	1.00	-0.057	0.000
956	4	135	0.00	0.10	1.00	1.00	-0.057	0.000
957	5	180	0.00	0.10	1.00	1.00	-0.057	0.000
958	6	225	0.00	0.10	1.00	1.00	-0.057	0.000
959	7	270	0.00	0.10	1.00	1.00	-0.057	0.000
960	8	315	0.00	0.10	1.00	1.00	-0.057	0.000
961	1	0	0.40	1.00	1.00	0.50	-1.308	-0.306
962	2	45	0.40	1.00	1.00	0.50	-1.232	-0.325
963	3	90	0.40	1.00	1.00	0.50	-1.199	-0.334
964	4	135	0.40	1.00	1.00	0.50	-1.232	-0.325
965	5	180	0.40	1.00	1.00	0.50	-1.308	-0.306
966	6	225	0.40	1.00	1.00	0.50	-0.862	-0.464
967	7	270	0.40	1.00	1.00	0.50	-0.696	-0.574
968	8	315	0.40	1.00	1.00	0.50	-0.862	-0.464
969	1	0	0.30	1.00	1.00	0.50	-1.192	-0.252
970	2	45	0.30	1.00	1.00	0.50	-1.203	-0.249
971	3	90	0.30	1.00	1.00	0.50	-1.192	-0.252
972	4	135	0.30	1.00	1.00	0.50	-1.203	-0.249
973	5	180	0.30	1.00	1.00	0.50	-1.192	-0.252
974	6	225	0.30	1.00	1.00	0.50	-0.954	-0.315
975	7	270	0.30	1.00	1.00	0.50	-0.818	-0.367
976	8	315	0.30	1.00	1.00	0.50	-0.954	-0.315
977	1	0	0.20	1.00	1.00	0.50	-1.131	-0.177
978	2	45	0.20	1.00	1.00	0.50	-1.178	-0.170
979	3	90	0.20	1.00	1.00	0.50	-1.174	-0.170
980	4	135	0.20	1.00	1.00	0.50	-1.178	-0.170

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
981	5	180	0.20	1.00	1.00	0.50	-1.131	-0.177
982	6	225	0.20	1.00	1.00	0.50	-0.994	-0.201
983	7	270	0.20	1.00	1.00	0.50	-0.926	-0.216
984	8	315	0.20	1.00	1.00	0.50	-0.994	-0.201
985	1	0	0.10	1.00	1.00	0.50	-1.100	-0.091
986	2	45	0.10	1.00	1.00	0.50	-1.123	-0.089
987	3	90	0.10	1.00	1.00	0.50	-1.142	-0.088
988	4	135	0.10	1.00	1.00	0.50	-1.123	-0.089
989	5	180	0.10	1.00	1.00	0.50	-1.100	-0.091
990	6	225	0.10	1.00	1.00	0.50	-1.057	-0.095
991	7	270	0.10	1.00	1.00	0.50	-1.018	-0.098
992	8	315	0.10	1.00	1.00	0.50	-1.057	-0.095
993	1	0	0.05	1.00	1.00	0.50	-1.093	-0.046
994	2	45	0.05	1.00	1.00	0.50	-1.120	-0.045
995	3	90	0.05	1.00	1.00	0.50	-1.119	-0.045
996	4	135	0.05	1.00	1.00	0.50	-1.120	-0.045
997	5	180	0.05	1.00	1.00	0.50	-1.093	-0.046
998	6	225	0.05	1.00	1.00	0.50	-1.060	-0.047
999	7	270	0.05	1.00	1.00	0.50	-1.057	-0.047
1000	8	315	0.05	1.00	1.00	0.50	-1.060	-0.047
1001	1	0	0.00	1.00	1.00	0.50	-1.090	0.000
1002	2	45	0.00	1.00	1.00	0.50	-1.090	0.000
1003	3	90	0.00	1.00	1.00	0.50	-1.090	0.000
1004	4	135	0.00	1.00	1.00	0.50	-1.090	0.000
1005	5	180	0.00	1.00	1.00	0.50	-1.090	0.000
1006	6	225	0.00	1.00	1.00	0.50	-1.090	0.000
1007	7	270	0.00	1.00	1.00	0.50	-1.090	0.000
1008	8	315	0.00	1.00	1.00	0.50	-1.090	0.000
1009	1	0	0.40	0.50	1.00	0.50	-0.654	-0.611
1010	2	45	0.40	0.50	1.00	0.50	-0.616	-0.649
1011	3	90	0.40	0.50	1.00	0.50	-0.599	-0.667
1012	4	135	0.40	0.50	1.00	0.50	-0.616	-0.649
1013	5	180	0.40	0.50	1.00	0.50	-0.654	-0.611
1014	6	225	0.40	0.50	1.00	0.50	-0.431	-0.928
1015	7	270	0.40	0.50	1.00	0.50	-0.348	-1.149
1016	8	315	0.40	0.50	1.00	0.50	-0.431	-0.928
1017	1	0	0.30	0.50	1.00	0.50	-0.596	-0.503
1018	2	45	0.30	0.50	1.00	0.50	-0.602	-0.499
1019	3	90	0.30	0.50	1.00	0.50	-0.596	-0.503
1020	4	135	0.30	0.50	1.00	0.50	-0.602	-0.499
1021	5	180	0.30	0.50	1.00	0.50	-0.596	-0.503

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
1022	6	225	0.30	0.50	1.00	0.50	-0.477	-0.629
1023	7	270	0.30	0.50	1.00	0.50	-0.409	-0.733
1024	8	315	0.30	0.50	1.00	0.50	-0.477	-0.629
1025	1	0	0.20	0.50	1.00	0.50	-0.566	-0.354
1026	2	45	0.20	0.50	1.00	0.50	-0.589	-0.340
1027	3	90	0.20	0.50	1.00	0.50	-0.587	-0.341
1028	4	135	0.20	0.50	1.00	0.50	-0.589	-0.340
1029	5	180	0.20	0.50	1.00	0.50	-0.566	-0.354
1030	6	225	0.20	0.50	1.00	0.50	-0.497	-0.403
1031	7	270	0.20	0.50	1.00	0.50	-0.463	-0.432
1032	8	315	0.20	0.50	1.00	0.50	-0.497	-0.403
1033	1	0	0.10	0.50	1.00	0.50	-0.550	-0.182
1034	2	45	0.10	0.50	1.00	0.50	-0.561	-0.178
1035	3	90	0.10	0.50	1.00	0.50	-0.571	-0.175
1036	4	135	0.10	0.50	1.00	0.50	-0.561	-0.178
1037	5	180	0.10	0.50	1.00	0.50	-0.550	-0.182
1038	6	225	0.10	0.50	1.00	0.50	-0.529	-0.189
1039	7	270	0.10	0.50	1.00	0.50	-0.509	-0.196
1040	8	315	0.10	0.50	1.00	0.50	-0.529	-0.189
1041	1	0	0.05	0.50	1.00	0.50	-0.546	-0.092
1042	2	45	0.05	0.50	1.00	0.50	-0.560	-0.089
1043	3	90	0.05	0.50	1.00	0.50	-0.559	-0.089
1044	4	135	0.05	0.50	1.00	0.50	-0.560	-0.089
1045	5	180	0.05	0.50	1.00	0.50	-0.546	-0.092
1046	6	225	0.05	0.50	1.00	0.50	-0.530	-0.094
1047	7	270	0.05	0.50	1.00	0.50	-0.528	-0.095
1048	8	315	0.05	0.50	1.00	0.50	-0.530	-0.094
1049	1	0	0.00	0.50	1.00	0.50	-0.545	0.000
1050	2	45	0.00	0.50	1.00	0.50	-0.545	0.000
1051	3	90	0.00	0.50	1.00	0.50	-0.545	0.000
1052	4	135	0.00	0.50	1.00	0.50	-0.545	0.000
1053	5	180	0.00	0.50	1.00	0.50	-0.545	0.000
1054	6	225	0.00	0.50	1.00	0.50	-0.545	0.000
1055	7	270	0.00	0.50	1.00	0.50	-0.545	0.000
1056	8	315	0.00	0.50	1.00	0.50	-0.545	0.000
1057	1	0	0.40	0.25	1.00	0.50	-0.327	-1.223
1058	2	45	0.40	0.25	1.00	0.50	-0.308	-1.299
1059	3	90	0.40	0.25	1.00	0.50	-0.300	-1.335
1060	4	135	0.40	0.25	1.00	0.50	-0.308	-1.299
1061	5	180	0.40	0.25	1.00	0.50	-0.327	-1.223
1062	6	225	0.40	0.25	1.00	0.50	-0.215	-1.857

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
1063	7	270	0.40	0.25	1.00	0.50	-0.174	-2.298
1064	8	315	0.40	0.25	1.00	0.50	-0.215	-1.857
1065	1	0	0.30	0.25	1.00	0.50	-0.298	-1.007
1066	2	45	0.30	0.25	1.00	0.50	-0.301	-0.997
1067	3	90	0.30	0.25	1.00	0.50	-0.298	-1.007
1068	4	135	0.30	0.25	1.00	0.50	-0.301	-0.997
1069	5	180	0.30	0.25	1.00	0.50	-0.298	-1.007
1070	6	225	0.30	0.25	1.00	0.50	-0.238	-1.258
1071	7	270	0.30	0.25	1.00	0.50	-0.205	-1.467
1072	8	315	0.30	0.25	1.00	0.50	-0.238	-1.258
1073	1	0	0.20	0.25	1.00	0.50	-0.283	-0.707
1074	2	45	0.20	0.25	1.00	0.50	-0.294	-0.679
1075	3	90	0.20	0.25	1.00	0.50	-0.294	-0.681
1076	4	135	0.20	0.25	1.00	0.50	-0.294	-0.679
1077	5	180	0.20	0.25	1.00	0.50	-0.283	-0.707
1078	6	225	0.20	0.25	1.00	0.50	-0.248	-0.805
1079	7	270	0.20	0.25	1.00	0.50	-0.232	-0.864
1080	8	315	0.20	0.25	1.00	0.50	-0.248	-0.805
1081	1	0	0.10	0.25	1.00	0.50	-0.275	-0.364
1082	2	45	0.10	0.25	1.00	0.50	-0.281	-0.356
1083	3	90	0.10	0.25	1.00	0.50	-0.285	-0.350
1084	4	135	0.10	0.25	1.00	0.50	-0.281	-0.356
1085	5	180	0.10	0.25	1.00	0.50	-0.275	-0.364
1086	6	225	0.10	0.25	1.00	0.50	-0.264	-0.378
1087	7	270	0.10	0.25	1.00	0.50	-0.255	-0.393
1088	8	315	0.10	0.25	1.00	0.50	-0.264	-0.378
1089	1	0	0.05	0.25	1.00	0.50	-0.273	-0.183
1090	2	45	0.05	0.25	1.00	0.50	-0.280	-0.179
1091	3	90	0.05	0.25	1.00	0.50	-0.280	-0.179
1092	4	135	0.05	0.25	1.00	0.50	-0.280	-0.179
1093	5	180	0.05	0.25	1.00	0.50	-0.273	-0.183
1094	6	225	0.05	0.25	1.00	0.50	-0.265	-0.189
1095	7	270	0.05	0.25	1.00	0.50	-0.264	-0.189
1096	8	315	0.05	0.25	1.00	0.50	-0.265	-0.189
1097	1	0	0.00	0.25	1.00	0.50	-0.273	0.000
1098	2	45	0.00	0.25	1.00	0.50	-0.273	0.000
1099	3	90	0.00	0.25	1.00	0.50	-0.273	0.000
1100	4	135	0.00	0.25	1.00	0.50	-0.273	0.000
1101	5	180	0.00	0.25	1.00	0.50	-0.273	0.000
1102	6	225	0.00	0.25	1.00	0.50	-0.273	0.000
1103	7	270	0.00	0.25	1.00	0.50	-0.273	0.000

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
1104	8	315	0.00	0.25	1.00	0.50	-0.273	0.000
1105	1	0	0.40	0.10	1.00	0.50	-0.131	-3.057
1106	2	45	0.40	0.10	1.00	0.50	-0.123	-3.247
1107	3	90	0.40	0.10	1.00	0.50	-0.120	-3.337
1108	4	135	0.40	0.10	1.00	0.50	-0.123	-3.247
1109	5	180	0.40	0.10	1.00	0.50	-0.131	-3.057
1110	6	225	0.40	0.10	1.00	0.50	-0.086	-4.642
1111	7	270	0.40	0.10	1.00	0.50	-0.070	-5.745
1112	8	315	0.40	0.10	1.00	0.50	-0.086	-4.642
1113	1	0	0.30	0.10	1.00	0.50	-0.119	-2.517
1114	2	45	0.30	0.10	1.00	0.50	-0.120	-2.493
1115	3	90	0.30	0.10	1.00	0.50	-0.119	-2.517
1116	4	135	0.30	0.10	1.00	0.50	-0.120	-2.493
1117	5	180	0.30	0.10	1.00	0.50	-0.119	-2.517
1118	6	225	0.30	0.10	1.00	0.50	-0.095	-3.146
1119	7	270	0.30	0.10	1.00	0.50	-0.082	-3.667
1120	8	315	0.30	0.10	1.00	0.50	-0.095	-3.146
1121	1	0	0.20	0.10	1.00	0.50	-0.113	-1.768
1122	2	45	0.20	0.10	1.00	0.50	-0.118	-1.698
1123	3	90	0.20	0.10	1.00	0.50	-0.117	-1.703
1124	4	135	0.20	0.10	1.00	0.50	-0.118	-1.698
1125	5	180	0.20	0.10	1.00	0.50	-0.113	-1.768
1126	6	225	0.20	0.10	1.00	0.50	-0.099	-2.013
1127	7	270	0.20	0.10	1.00	0.50	-0.093	-2.159
1128	8	315	0.20	0.10	1.00	0.50	-0.099	-2.013
1129	1	0	0.10	0.10	1.00	0.50	-0.110	-0.909
1130	2	45	0.10	0.10	1.00	0.50	-0.112	-0.891
1131	3	90	0.10	0.10	1.00	0.50	-0.114	-0.876
1132	4	135	0.10	0.10	1.00	0.50	-0.112	-0.891
1133	5	180	0.10	0.10	1.00	0.50	-0.110	-0.909
1134	6	225	0.10	0.10	1.00	0.50	-0.106	-0.946
1135	7	270	0.10	0.10	1.00	0.50	-0.102	-0.982
1136	8	315	0.10	0.10	1.00	0.50	-0.106	-0.946
1137	1	0	0.05	0.10	1.00	0.50	-0.109	-0.458
1138	2	45	0.05	0.10	1.00	0.50	-0.112	-0.446
1139	3	90	0.05	0.10	1.00	0.50	-0.112	-0.447
1140	4	135	0.05	0.10	1.00	0.50	-0.112	-0.446
1141	5	180	0.05	0.10	1.00	0.50	-0.109	-0.458
1142	6	225	0.05	0.10	1.00	0.50	-0.106	-0.472
1143	7	270	0.05	0.10	1.00	0.50	-0.106	-0.473
1144	8	315	0.05	0.10	1.00	0.50	-0.106	-0.472

Index	Case ID	θ	Δx	Γ	h	λ	Δv	$\tau (\Delta x/\Delta v)$
1145	1	0	0.00	0.10	1.00	0.50	-0.109	0.000
1146	2	45	0.00	0.10	1.00	0.50	-0.109	0.000
1147	3	90	0.00	0.10	1.00	0.50	-0.109	0.000
1148	4	135	0.00	0.10	1.00	0.50	-0.109	0.000
1149	5	180	0.00	0.10	1.00	0.50	-0.109	0.000
1150	6	225	0.00	0.10	1.00	0.50	-0.109	0.000
1151	7	270	0.00	0.10	1.00	0.50	-0.109	0.000
1152	8	315	0.00	0.10	1.00	0.50	-0.109	0.000