Fall and Slide

Fall and Slide

- James C. Collins developed a formula which neglects the pedestrian launch angle.
- Collins assumed that at impact the pedestrian trajectory is horizontal in the direction of the impacting vehicle and dependent on the height of the pedestrian's center of mass.

Fall and Slide

- When the body strikes the ground, it begins to lose energy by scraping and tumbling.
- Energy is lost in both abrasion from the surface and the work being done to stir up the contents.

Fall and Slide

US

$$d_f = \frac{S\sqrt{h}}{2.73}$$

d_f = distance of fall

S= forward projectile speed

h= distance of CM fall

2.73= constant

SI

$$d_f = \frac{S\sqrt{h}}{7.97}$$

d_f = distance of fall

S= forward projectile speed

h= distance of CM fall

7.97 = constant

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Fall and Slide

US

$$d_s = \frac{S^2}{30f}$$

SI

$$d_s = \frac{S^2}{254f}$$

d_s = distance traveled during the slide

S = speed of projectle

f = friction value of the pedestrian

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Fall and Slide

The total distance of travel is simply the summation of the equations.

US

$$d_t = \frac{S\sqrt{h}}{2.73} + \frac{S^2}{30f}$$

SI

$$d_t = \frac{S\sqrt{h}}{7.97} + \frac{S^2}{254f}$$

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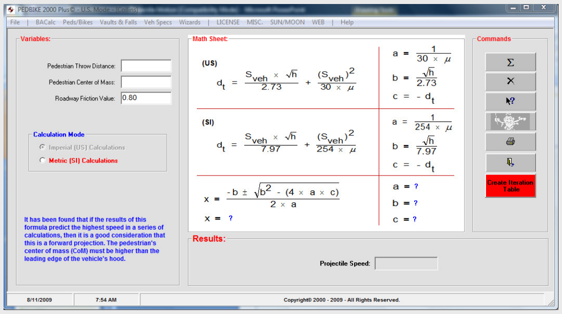
Fall and Slide



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NUTI Equation

The Traffic Institute provided a set of formulas that allow the investigator to isolate the fall and slide distance from the total throw distance. This analysis method is used to calculate the speed of the projectile (body) as it leaves the vehicle and makes first contact with the ground. This method will calculate the airborne speed and the sliding speed.

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NUTI Equation

In this vehicle-pedestrian collision, the full impact is centered on the body. The body will be accelerated to the vehicles speed in a very short distance. Once the vehicle and the body obtain the same velocity, the force between each will reach zero and the body will begin to fall to the ground. In this type of collision the vehicle does not impart any vertical component of velocity to the body. The body only has horizontal velocity when prior to separation.

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NUTI Equation

The fall equation:

$$v = d_f \sqrt{\frac{-g}{2(-h)}}$$

The slide equation:

$$v = \sqrt{2\, f\, g\, d}$$

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NUTI Equation

By setting the two equations for velocity equal to each other. The general equations to solve for the velocity in the area of impact is:

$$v = d_f \sqrt{\frac{-g}{2(-h)}}$$ fall equation

$$v = \sqrt{-2\, f\, (-g)\, d}$$ slide equation

where

$$d_f = 2\, f\, h - 2h\sqrt{f^2 - \frac{df}{h}}$$

$$d_s = d_t - d_f$$

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NUTI Equation

Example:

Total throw distance= 114 feet

Center of Mass of Ped= 3 feet

Frictional value of Ped= .50

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NUTI Equation

$$d_f = 2fh - 2h\sqrt{f^2 - \frac{df}{h}}$$

$$d_f = 2(.5) - 3 - 2(-3)\sqrt{.5^2 - \frac{.5(114)}{-3}}$$

$$d_f = -3 - (-6)\sqrt{.25 - \frac{57}{-3}}$$

$$d_f = -3 - (-6)\sqrt{.25 - (-19)}$$

$$d_f = -3 - (-6)\sqrt{19.25}$$

$$d_f = -3 - (-6)(4.38) \; {**}$$

$$d_f = -3 - (-26.28)$$

$$d_f = 23.28 \text{ feet}$$

$$d_s = 114 - 23.28 = 90.72 \, feet$$

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NUTI Equation

$$v = d_f \sqrt{\frac{-g}{2h}} \quad \text{fall equation}$$

$$v = 23.28\sqrt{\frac{-32.2}{2(-3)}}$$

$$v = 23.28\sqrt{\frac{-32.2}{-6}}$$

$$v = 23.28\sqrt{5.36}$$

$$v = 23.28(2.31)$$

$$v = 53.77 \, fps$$

$$S = 36.68 \, mph$$

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NUTI Equation

$$v = \sqrt{-2\,f\,g\,d} \quad \text{slide equation}$$

$$v = \sqrt{-2(.5) - 32.2(90.72)}$$

$$v = \sqrt{2921.18}$$

$$v = 54.04 \, fps$$

$$S = 36.86 \, mph$$

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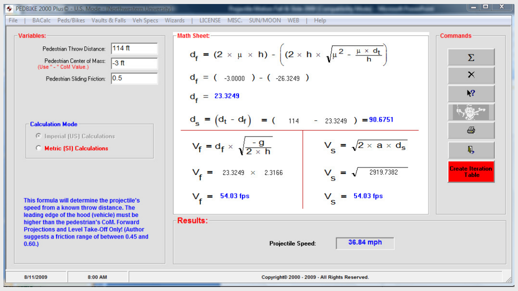
NUTI Equation



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Vault-Slide Integration

PEDESTRIAN VAULTS – HUMANS GOING BALLISTIC:
Pedestrian vaults from a *ballistic* perspective.

Published by IPTM
www.iptm.org

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Vault-Slide Integration

- **What distinguishes a pedestrian vault from a regular vault ?**
  - **The point of launch and the point of touchdown or landing define the regular vault.**

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Vault-Slide Integration

- **Pedestrian vaults use a "Throw" distance.**
  - **Throw distance should be measured from the point of release or separation of the pedestrian from the vehicle to the point of final rest of the pedestrian.**
  - **The actual release point is almost impossible to determine, as it must account for the carry distance of the pedestrian by the vehicle.**

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Vault-Slide Integration

- **The throw distance is usually measured from first contact or impact to the point of final rest of the pedestrian.**
- **Pedestrian Vaults involve both a vault over an undetermined distance and a slide over an undetermined distance.**
- **Undetermined, but not undeterminable.**

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Vault-Slide Integration

- **A *regular* vault involves three primary variables that enable us to determine the fourth variable, the vault speed:**
  - **horizontal distance**
  - **vertical distance**
  - **launch angle**

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Vault-Slide Integration

- A *regular* slide involves a beginning speed, a final speed, a distance and the friction factor between the surface and the object.
  - If three of the variables are known, the fourth variable or unknown is easily solved for using a relatively simple non-linear equation.

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Vault-Slide Integration

- The unique feature of the pedestrian vault is that two of the components, the vault and the slide, are shared in an initially undetermined ratio.
- To help complicate matters, as is all too often true with the regular vault, the launch angle of the pedestrian vault is probably unknown.

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Vault-Slide Integration

- Pedestrian vaults deal with the pedestrian from the release or separation from the vehicle to the point of final rest, the throw distance.
- This throw distance involves both a vault and a slide.

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Vault-Slide Integration

- Once separation occurs, the vehicle no longer has any influence on the pedestrian unless there is a secondary collision.
- The subsequent motion of the pedestrian as governed by the laws of physics should be the primary focus of our investigation.

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Vault-Slide Integration

- For any given launch angle and friction coefficient between the pedestrian and the surface over which the pedestrian is sliding, the vault and the slide components of the pedestrian vault are tied to each other.

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Vault-Slide Integration

- If the throw distance and height are kept constant, the only way the different currently published pedestrian formulae that use height, throw distance, friction and angle can arrive at their different solutions is by varying either the launch angle or the friction factor of the pedestrian.

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Vault-Slide Integration

- **Almost all of the pedestrian formulae are designed to handle one of two different types of problems:**
  - **Wrap**
  - **Frontal Projection**

The foregoing statement is technically correct, but when examined closely, all that is usually at issue is the launch angle.

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Vault-Slide Integration

- **How do we determine the percentage of the throw distance allotted to the vault portion of the combined maneuver?**
  - **Quit**
  - **Quadratic**
  - **Guess**

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Vault-Slide Integration

- **The Guess - One of the options is to assume a horizontal distance for the vault. With this assumption, a speed can be computed using the vault formula with an assumed launch angle.**

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Vault-Slide Integration

- With the vault velocity from an assumed launch angle, trigonometry provides a horizontal velocity for the pedestrian.
- The horizontal velocity of the vault is the initial speed in the slide.
- The final speed of the slide is obviously zero.

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Vault-Slide Integration

- With a known initial and final speed and a deceleration factor, a simple computation solves for the distance required for the change of speed.

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Vault-Slide Integration

- When the distance computed for the skid combined with the initial *assumed* vault distance is equal to the throw distance, we will have arrived at the solution for a given launch angle.

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Vault-Slide Integration

- **Most of the published pedestrian formulae do not require a launch angle. This angle will have to be a supposition supplied by the individual investigator. While it requires an assumption, it is the investigator who is in the best position to determine the angle or range of angles most suitable for use in connection with the specific incident under investigation.**

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Vault-Slide Integration

- **If the throw distance is kept as a constant, then the only way the eighty plus different currently published pedestrian formulae can arrive at different solutions is by varying either the launch angle or the friction factor of the pedestrian.**

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Vault-Slide Integration

- **As every pedestrian vault formula requires an input of the friction factor, the only remaining variable is the launch angle.**
- **Because of this fundamental relationship based on physics principles, the only real difference between all of the existing pedestrian formulae is the *assumed* launch angle.**

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Vault-Slide Integration

- **Basic Vault Formula**
  - V_v = Sqr(g / 2 * X^2 / cos^2(A) * (X * tan(A) –Y))
- **Horizontal speed of the pedestrian**
  - $V_h = V_v$ * cos(A)
- **Slide**
  - T = $(V_i – V_f)$ / (f * g)
  - D = V_i * T – f * g * T^2 / 2

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Vault-Slide Integration

- It is now time to methodically plow through the step-by-step process of arriving at a solution for a pedestrian vault. Manually calculating a solution will give us a better understanding of how the system works.
  - Throw distance = 125 feet
  - Vertical distance = –2.5 feet
  - Coefficient of friction = .9
  - Takeoff Angle = 5 degrees

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Vault-Slide Integration

- **Initial Vault distance approx. 65 feet**
- **Vault**
  - V_v = Sqr(32.2 / 2 * 65^2 / cos^2(5) * (65 * tan(5) – (-2.5)))
  - V_v = 91.501 feet per second
- **Horizontal Speed**
  - V_h = 91.501 * cos(5)
  - V_h = 91.1528 feet per second

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Vault-Slide Integration

- **Time**
  - **T = (91.1528 – 0) / (.9 * 32.2)**
  - **T = 3.1453 seconds**
- **Distance**
  - **D = 91.1528 * 3.1453 – .9 * 32.2 * 3.1453^2 / 2**
  - **D = 143.3546 feet**

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Vault-Slide Integration

- **Throw Distance**

  TD = 143.3546 + 65 = 208.3546 feet

- **It looks like 65 feet gets a pass on this one, as it obviously does not provide a solution (125 feet) to the problem. However, all is not lost, as now we know that the suspect vault distance must be less than 65 feet.**

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Vault-Slide Integration

- **The next approx. value is 45 feet. The same procedure is used for 45 feet as was used for 65 feet. While this suspect is a closer match generating a horizontal speed of 71.1679 f/s and a combined distance of 132.3856 feet, it is still too long to be correct.**

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Vault-Slide Integration

- **The third value is 40 feet. Again the same procedure is used, but this time the suspect is too short with a horizontal speed of 65.5260 f/s and a combined distance of 114.0796 feet. This process continues until we arrive at a "perfect" result of 125 feet when the vault distance is added to the slide distance.**

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Questions?

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