出國報告（出國類別：進修 線上訓練課程）

參加美國美國警察科技及管理研究所線上課程「交通事故重建(Traffic Crash Reconstruction) Online」線上課程報告

服務機關：國家運輸安全調查委員會
姓名職務：曾仁松/公路調查組首席調查官
派赴國家：臺灣，中華民國（線上訓練課程）
線上訓練期間：民國 111 年 01 月 10 日至 03 月 20 日
報告日期：民國 111 年 06 月 15 日

公務出國報告提要　　系統識別號

出國報告名稱：參加美國警察科技及管理研究所線上課程「交通事故重建(Traffic Crash Reconstruction) Online」線上課程報告

頁數：56 頁　　含附件：否

出國計畫主辦機關：國家運輸安全調查委員會
聯絡人：郭芷桉
電話：（02）7727-6228

出國人員姓名：曾仁松
服務機關：國家運輸安全調查委員會
單位：公路調查組
職稱：首席調查官
電話：（02）7727-6270

出國類別：□1 考察■2 進修□3 研究□4 實習□5 視察□6 訪問□7 開會□8 談判
□9 其他

出國期間：民國 111 年 01 月 10 日至 03 月 20 日
出國地區：臺灣，中華民國（線上訓練課程）
報告日期：民國 111 年 06 月 15 日
分類號/目

關鍵詞：肇事重建、交通事故調查員、摩擦係數、車輛動力學、行人/自行車/機車事故調查、商業車事故調查、牛頓三運動定律

內容摘要：

本課程由美國警察科技及管理研究所(IPTM)舉辦，參訓人員背景以執法人員和交通事故調查員、理賠員、工程師、律師、安全官員、軍事調查人員、動畫師和平

面設計師等，整體課程包含 80 小時的課程內容。

課程內容以 IPTM 的事故現場調查、進階交通事故調查等課程為基礎，加入車輛動力學、向量數學、進階事故現場繪製等內容。須利用事故車輛現場所收集之資料，計算撞擊前之時間及運行距離，採用二維向量、三角函數與使用牛頓運動力學方程式等數學公式，以計算事故車輛的撞擊速度等。課程內容涵蓋：常用速度公式的推導和由來、使用線性動量守恆的車輛撞擊速度、使用牛頓三運動定律的車輛在碰撞中的行為、商用車與摩托車碰撞動力學探討、確定車輛在道路上的行駛方向、初始接觸和位置等。且課程要求參訓學員以手繪方式求繪製和分析各種不同的碰撞案例，以及詳細計算多車輛撞擊每個場景的完整向量和分析。每週皆須完成指派之作業且達 80 分以上，方能進行下一單元之課程，於完成期末測驗，並通過期末測驗達到 80 分以上，方能取得結訓證書。完成訓練課程內容可作為本會未來在重大公路事故調查之基本技能及公路運輸安全相關研究參考。

目次

壹、 目的

我國於 107 年 10 月 21 日發生臺鐵第 6432 次車新馬站重大鐵道事故，造成 18 人死亡、291 人輕重傷，政府因而決定由飛航安全調查委員會改制成立國家運輸安全調查委員會（以下簡稱本會），調查業務從航空擴充至水路、鐵道及公路重大事故。本會公路調查組自 108 年 8 月 1 日起開始運作迄 110 年 12 月底，依「運輸事故調查法」第 3 及 6 條之調查權責共計接獲 89 件事故通報，其中 11 件立案調查(1 件鐵路、公路複合事故；2 件 2 級、8 件 1 級)，共計完成 7 件重大公路事故調查報告。

本會公路調查組成立調查之重大公路事故類型包含汽車運輸業九大營運類別之汽車貨運業、遊覽車客運業、公路汽車客運業、市區汽車客運業、計程車客運業、汽車貨櫃貨運業等六大項。事故類型包含酒駕、無照駕駛、疲勞駕駛、天候不良、載運危險物品、駕駛操作不當、駕駛健康因素、車輛機械故障等類型。事故道路樣態包括山區長下坡道路、高速公路及其匝道、港口道路、市區道路、橋樑斷裂等。

調查事故發生之根本原因之最基本作為，即是收集事故現場所遺留之各種證物、殘骸、刮痕等，參酌人員駕駛操作行為、天候、道路環境、機械狀況等因素，進行事故之重建與模擬，因此，事故調查重建之訓練對後續找到事故發生之根本原因是非常重要之一環。本會公路事故調查組人員為能完成所有各類型之事故調查，故有必要派員參加美國警察科技及管理研究所(IPTM) 提供予執法人員和交通事故調查員等之「交通事故重建(Traffic Crash Reconstruction) Online」線上專業課程，以累積本會在公路事故調查之調查能量。

本線上課程內容以 IPTM 的事故現場調查、進階交通事故調查等課程為基礎，涵蓋車輛動力學、向量數學、進階事故現場繪製等內容。課程內容涵蓋事故車輛現

場資料收集、牛頓三運動定律的車輛在碰撞中的行為模式、線性動量守恆的車輛撞擊行為模式、商用車與摩托車碰撞動力學探討等方向。且課程要求參訓學員以手繪方式繪製和分析各種不同的碰撞案例，以及詳細計算多車輛撞擊每個場景的完整向量、角度和分析。每週皆須完成指派之作業，並通過期末測驗達到 80 分以上，方能取得結訓證書。完成訓練課程內容可作為本會未來在重大公路事故調查之基本技能及公路運輸安全相關研究參考，強化公路調查之智能。

貳、 過程

1. 課程

本次線上課程由美國警察科技及管理研究所(IPTM)舉辦，日期為民國 111 年 01 月 10 日至 03 月 20 日，共計 10 週，每週 8 小時共計 80 小時授課時數，參訓學員須完成各個課程模組(modules)、完成作業和討論、參加在線測驗和期末考試，並使用從現場調查員收集的圖表和數據重建幾起事故。課程中設置可選的視頻會議來幫助學員解決有關每個模組的數學主題的問題，並根據需要安排視頻會議，以在整個課程中根據需要為學員提供幫助。須通過每週的小考及完成作業，要通過本課程，必須參與討論和活動，完成所有測驗和期末考試，並提交所需的任何項目。這些活動將計入最終成績，其中，各週之測驗題占比為 40%，動量繪圖項目占比 20%，各模組作業占比 10%，期末考試占比 30%，且期末考試成績達 80 分以上才能取得證書。

課程前首先介紹課程講師，課程大綱，由每一位學生自我介紹，提供參與學生協助之系統，並進行課程前之考試，了解每一位學生入學前程度，課前考試不計入取得證書之成績。

第一週之課程大綱為數學複習、摩擦和牛頓定律，第二週之課程大綱為質心、估計速度和動能，共有 7 個作業或考試；第三週之課程大綱為時間、距離，共有 4 個測驗及一個做圖題，作圖題是將事故現場以道路相對位置畫出車輛之位置、煞車距離、散落物、人員等相對位置座標；第四週之課程大綱為空降(airborne)和臨界速度，主要說明車輛墜落山谷或是側向翻覆時之特性及速度計算方法，共有 5 個測驗；第五週之課程大綱為向量講座，詳述車輛碰撞力學的能量轉換、三角函數運算等，共有 3 個測驗；第六週之課程大綱為線性動量和二維動量，共有 5 個測驗；第七週之課程大綱為功動量，共有 2 個測驗，並繪製車輛碰撞之向量圖；第八週之課程大綱為多次碰撞之離開方向與動量，講述車輛若有二次事故時，車輛之動能變化情形，需繪製車輛碰撞後之向量大小、角度、製作動量圖表及車輛之輪胎滑痕；第九週之課程大綱為摩托車、商用車和行人/自行車碰撞；第十週為期末考週，先進行所有課程之簡單複習，所有的公式概述講解，並進行複習測驗，之後即期末考試測驗，考試題目共計 60 題是非或選擇題，考試題目約 70%為計算題，測驗時間為 4 小時，考試成績計入期末整體成績，期末考試成績需要獲得 80% 或更高的分數才能通過，且不得重考，期末考試成績併計課週小考、作業成績達 80 分以上，才能取得證書。課程架構與大綱如表 1 所示。

表 1 課程架構與大綱

項目	課程內容	完成條件
Welcome	1. Instructor & Course Introduction 2. Student Expectations 3. Syllabus 4. Student Introductions 5. Ask the Facilitator 6. Pre-Test	1. Complete All Items 2. Passed the pre-test
Module One (M1)	Math Review, Friction & Newton's Laws 1. M1 Introduction 2. M1 Lesson One: Math Review 3. M1 Lesson Two: Friction	Complete All Items

項目	課程內容	完成條件
	4. M1 Lesson Three: Newton's Laws 5. M1 Lesson Four: Extracting Data From AutoStats Reports	
Module Two (M2)	Center of Mass, Estimating Speed & Kinetic Energy 1. M2 Introduction 2. M2 Lesson One: Center of Mass Lecture 3. M2 Lesson One: Center of Mass Project One (Instructor Led Whiteboard) 4. M2 Lesson One: Project Two (Quiz) 5. M2 Lesson One: Project Two Solution Guide 6. M2 Lesson One: Project Three (Quiz) 7. M2 Lesson One: Project Three Solution Guide 8. M2 Lesson One: Project Four (Quiz) 9. M2 Lesson One: Project Four Solution Guide 10. M2 Lesson Two: Estimating Speed Lecture 11. M2 Lesson Two: Project One (Quiz) 12. M2 Lesson Two: Project One Solution Guide 13. M2 Lesson Three: Kinetic Energy Lecture 14. M2 Lesson Three: Kinetic Energy Instructor Led Project 15. M2 Lesson Three: Project One (Quiz) 16. M2 Lesson Three: Project One Solution Guide 17. M2 Lesson Three: Project Two (Quiz) 18. M2 Lesson Three: Project Two Solution Guide 19. M2 Lesson Three: Project Three (Quiz) 20. M2 Lesson Three: Project Three Solution Guide	1. Complete All Items 2. Module item has been completed by scoring at least 80.0
Module Three (M3)	Time/Distance 1. M3 Introduction 2. M3 Resources 3. M3 Lesson One: Time/Distance Lecture 4. M3 Lesson One: Time/Distance Instructor Led Project 5. M3 Lesson One: Project One (Quiz) 6. M3 Lesson One: Project One Solution Guide 7. M3 Lesson One: Project Two (Quiz) 8. M3 Lesson One: Project Two Solution Guide 9. M3 Lesson One: Project Three (Quiz) 10. M3 Lesson One: Project Three Solution Guide 11. M3 Lesson One: Project Four (Quiz)	1. Complete All Items 2. Module item has been completed by scoring at least 80.0

項目	課程內容	完成條件
	12. M3 Lesson One: Project Four Solution Guide 13. M3 Lesson One: Project Five (Drawing Project) (Quiz) 14. M3 Lesson One: Project Five (Drawing Project) Solution Guide	
Module Four (M4)	Airborne & Critical Speed 1. M4 Introduction 2. M4 Lesson One: Airborne Lecture 3. M4 Lesson One: Airborne Instructor Led Project 4. M4 Lesson One: Project One (Quiz) 5. M4 Lesson One: Project One Solution Guide 6. M4 Lesson One: Project Two (Quiz) 7. M4 Lesson One: Project Two Solution Guide 8. M4 Lesson Two: Critical Speed Lecture 9. M4 Lesson Two: Critical Speed Instructor Led Project 10. M4 Lesson Two: Project One (Quiz) 11. M4 Lesson Two: Project One Solution Guide 12. M4 Lesson Two: Project Two (Quiz) 13. M4 Lesson Two: Project Two Solution Guide 14. M4 Lesson Two: Critical Speed & Airborne Combo Project (Quiz) 15. M4 Lesson Two: Critical Speed & Airborne Combo Project Solution Guide	1. Complete All Items 2. Module item has been completed by scoring at least 80.0
Module Five (M5)	Vectors 1. M5 Introduction 2. M5 Lesson One: Vectors Lecture 3. M5 Lesson One: General Vector Demonstration 4. M5 Lesson One: Vectors Instructor Led Mathematical Project 5. M5 Lesson One: Vectors Instructor Led Graphical Project 6. M5 Lesson One: Project One (Quiz) 7. M5 Lesson One: Project One Solution Guide 8. M5 Lesson One: Project Two (Quiz) 9. M5 Lesson One: Project Two Solution Guide 10. M5 Lesson One: Project Three (Quiz) 11. M5 Lesson One: Project Three Solution Guide	1. Complete All Items 2. Module item has been completed by scoring at least 80.0
Module Six (M6)	Inline Momentum & Two Dimensional Momentum 1. M6 Introduction	1. Complete All Items

項目	課程內容	完成條件
	2. M6 Resources 3. M6 Lesson One: Inline Momentum Lecture 4. M6 Lesson One: Inline Momentum Instructor Led Project 5. M6 Lesson One: Project One (Quiz) 6. M6 Lesson One: Project One Solution Guide 7. M6 Lesson One: Project Two (Quiz) 8. M6 Lesson One: Project Two Solution Guide 9. M6 Lesson One: Project Three (Quiz) 10. M6 Lesson One: Project Three Solution Guide 11. M6 Lesson Two: Two Dimensional Momentum Lecture 12. M6 Lesson Two: Two Dimensional Momentum Instructor Led Project 13. M6 Lesson Two: Project One (Quiz) 14. M6 Lesson Two: Project One Solution Guide 15. M6 Lesson Two: Project Two (Quiz) 16. M6 Lesson Two: Project Two Solution Guide	2. Module item has been completed by scoring at least 80.0
Module Seven (M7)	Working Momentum 1. M7 Introduction 2. M7 Resources 3. M7 Lesson One: Working Momentum - Center of Mass & Drawing Cars 4. M7 Lesson One: Working Momentum - Measuring Angles & Skid Marks 5. M7 Lesson One: Working Momentum - Vector Math 6. M7 Lesson One: Working Momentum - Vector Diagrams 7. M7 Lesson One: Project One (Quiz) 8. M7 Lesson One: Project One Solution Guide 9. M7 Lesson One: Project Two (Quiz) 10. M7 Lesson One: Project Two Solution Guide	1. Complete All Items 2. Module item has been completed by scoring at least 80.0
Module Eight (M8)	Multiple Departures 1. M8 Introduction 2. M8 Lesson One: Multiple Departures - Center of Mass & Drawing Cars 3. M8 Lesson One: Multiple Departures - Measuring Angles & Skid Marks 4. M8 Lesson One: Multiple Departures - Vector Math &	1. Complete All Items 2. Module item has been completed by scoring

項目	課程內容	完成條件
	Diagrams	at least 80.0
Module Nine (M9)	Motorcycles, Commercial Vehicles & Pedestrian/Bicycle Crashes 1. M9 Introduction 2. M9 Resources 3. M9: Multiple Crash Project (Assignment) 4. M9: Multiple Crash Project Solution Guide 5. M9: Multiple Crash Project Solution Guide 6. M9 Lesson One: Introduction to Motorcycle Crashes 7. M9 Lesson Two: Introduction to Commercial Vehicle Crashes 8. M9 Lesson Three: Introduction to Pedestrian/Bicycle Crashes	1. Complete All Items 2. Module item has been completed by scoring at least 80.0
Module Ten (M10)	Course Review, Optional Project, Final Exam 1. M10 Introduction 2. M10 Course Review (Knowledge) 3. M10 Course Review (Math) (Quiz) 4. M10 Course Review (Math) Solution Guide 5. Final Exam (Quiz)	1. Complete All Items 2. Module item has been completed by scoring at least 80.0

2. 參與人員及講師

本次線上課程參與學員共計 27 名，其中大多數為美國各州地方之公路警察，因為美國公路事故與本國之各地方政府警察局編製之交通隊類似，交通事故皆須由交通隊人員處理。而美國國家公路交通安全管理局 (NHTSA) 在 1985 年，提供預算用於製定交通事故重建領域培訓標準化的國家指南。由事故重建人員、工程師、警察、教育工作者和律師組成的工作群組，製定了一份題為「警察交通事故重建人員最低培訓標準」的報告。在該報告中，工作組處理了現場人員的認證問題，並建議「成立認證委員會」來認證事故調查員和重建人員，1990 年具有全球代表性的

11 個專業事故重建協會開會，探討形成一個對公共和私人事故重建者開放的國際公認認證計畫，遂成立「交通事故重建認證委員會（ACTAR, The Accreditation Commission for Traffic Accident Reconstruction）」，本課程即為 ACTAR 委託各學院、大學和其他培訓機構之事故調查員和重建人員之訓練課程。

講師為羅曼塞拉諾(Roman Serrano)，是美國公路警察退休人員，1998 年 9 月開始在李郡警長辦公室的道路巡邏部門工作，2001 年 11 月，塞拉諾從道路巡邏部門調到特別行動部門，擔任酒駕執法官，2009 年開始在位於佛羅里達州傑克遜維爾的警察技術與管理學院擔任兼職講師，有十多年講師教學經驗，其主要專長在事故調查、交通/酒駕等，人員培訓則教授碰撞報告寫作和計算機輔助圖表，並使用計算機軟件創建佛羅里達州公警巡邏人員碰撞報告中使用的圖紙和圖表。塞拉諾偵探還在佛羅里達州邁爾斯堡的西南佛羅里達公共安全學院教授新進人員，包括酒駕和車禍調查等領域。

3. 授課方式

由於新冠肺炎（covid-19）疫情，無法到美國佛羅里達州當地學校上課，本次課程採線上錄影視訊方式進行，使用 IPTM 提供之網頁課程，於登入帳號授權後，即可開始上課，課程平台如圖 1 所示；課程講師透過平台建立之會議機制可與學員互動問答。

課程內容每週皆有一個主題，在每週的星期一 00:00 開放學員登入上課，於每週日 23:59 結束課程網頁，每週課程安排的章節內容需依序完成，並完成測驗或習題後，才能進入下一個章節，且學員需於時間內完成該週之所有課程安排作業及測驗，若未能及時完成，則該週課程內容於時限內即關閉課程，未完成部分則無法取得成績。圖 1 為本次課程上課即時畫面一覽。羅曼塞拉諾(Roman Serrano)講師上課

之畫面如圖 2 所示。

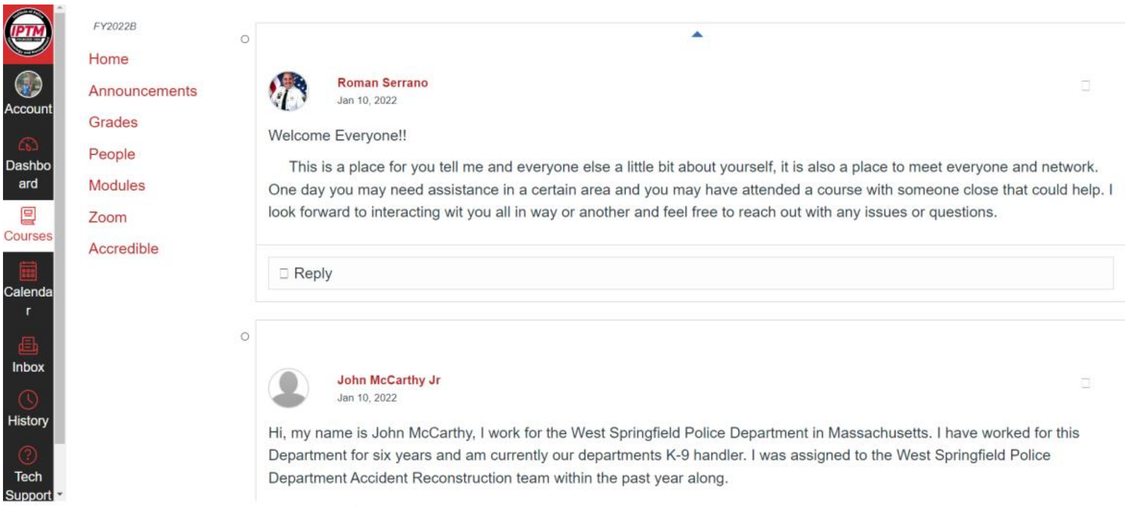


圖 1 課程平台

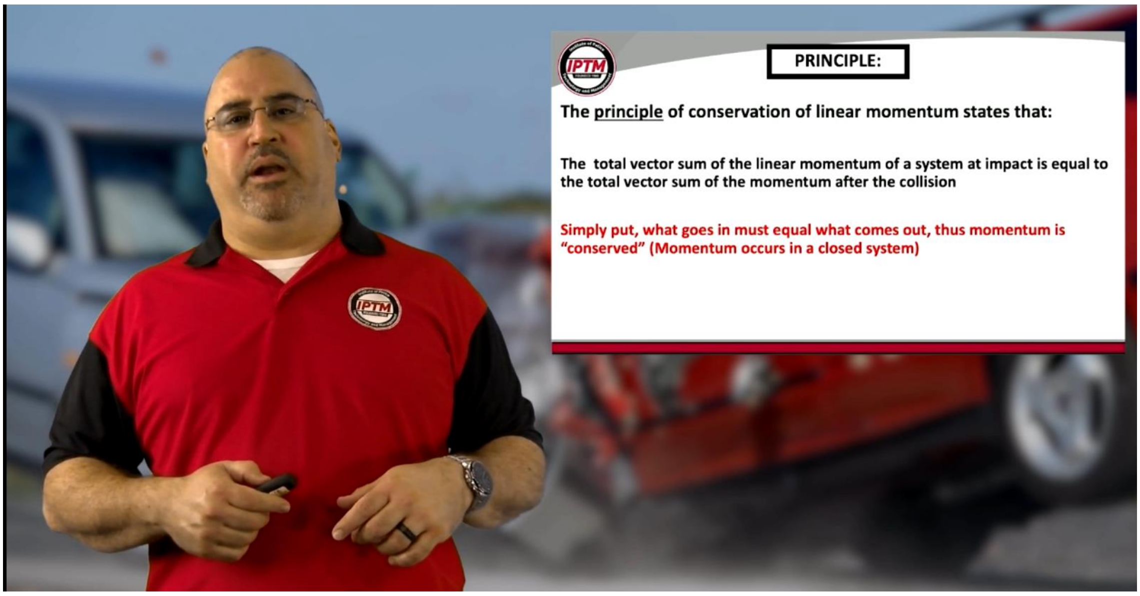


圖 2 課程講師

參、 課程摘要與心得

一、 前言

本課程開始前，參照一般實體課程模式，講師先自我介紹，並規定所有參訓人員須完成自我介紹，讓彼此大致了解參訓人員的基本背景與參訓目的，增加參訓人員之互動，其中有香港地區參加人員是與台灣同一個時區，互相討論更加熱絡。另外，也有美國地區之公路巡警提供一些事故調查經驗，可以做為未來事故調查之參考。

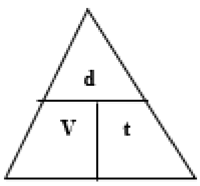
為理解參訓人員對於事故調查之基本能力，於正式授課前先進行課前測試，這個測驗分數不計入學習的總成績，但可以幫助講師了解學員欠缺的基本智識，用以調整授課內容，增進學習成效。

二、 數學複習、摩擦和牛頓定律(Math Review, Friction & Newton's Laws)

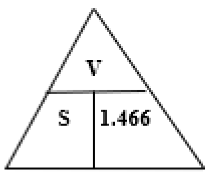
<u>數學公式</u>

因事故重建需要用到非常多的數學計算、物理學的摩擦力計算及牛頓運動定律的應用，是以，第一週之課程內容為數學複習、摩擦和牛頓定律，所使用的數學公式與定律對於台灣學生而言相對簡單，但對於美國地區之公路巡邏警員(PD)，是有些難度的課程。美國的課程內容相較台灣的學習環境，比較友善，課程講師會從最基本的數學加減乘除，括弧應用開始講解，由淺入深，有一套很完整、有系統的教學內容；其教學的精神是教會學員如何利用數學公式、物理定律作為事故重建之基本技能，而非考倒學員，很值得國人學習。其所使用之數學公式概分為時間、距離、速度、摩擦係數、能量、向量、功等幾大類，如圖 3 所示。

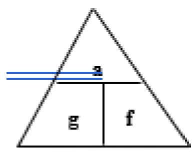
Question	*Anytime Motion* Need "a" or "f"	*To/From a Stop* Need "a" or "f"	*Constant* **P/R/Pedestrian** No "a or "f"
t **Time** **(Long)**	$t = \frac{V_1 - V_2}{a}$ **OR** $t = \frac{\Delta V}{a}$	$t = 0.45\sqrt{\frac{d}{f}}$ $t = \frac{V}{a}$ **OR** $t = \frac{V}{f(g)}$	$t = \frac{d}{V}$
d **Distance** **(Far)**	$d = V_0(t) \pm .5(a)(t^2)$ **OR** $d = V_0(t) \pm 16.1(f)(t^2)$	$d = \frac{S^2}{254(f)}$ **OR** $d = \frac{V^2}{19.62(f)}$ $d = .5(a)(t^2)$ (# 36) **OR** $d = 4.90(f)(t^2)$ (#36)	$d = V(t)$
Speed **Velocity** **(Fast)**	$S = \sqrt{So^2 \pm 254(d)(f)}$ $V = \sqrt{Vo^2 \pm 2(a)(d)}$ **OR** $V = \sqrt{Vo^2 \pm 19.62(f)(d)}$ $V = V_0 \pm a(t)$	$S = \sqrt{254(d)(f)}$ $V = \sqrt{2(a)(d)}$ **OR** $V = \sqrt{19.62(f)(d)}$ **(when Vo = 0)** $V = a(t)$	$V = \frac{d}{t}$
Factor (f) **Deceleration** **OR** **Acceleration**	$f = \frac{V_1 - V_2}{g(t)}$	$f = \frac{S^2}{254(d)}$ $f = \frac{V}{g(t)}$ $f = \frac{d}{4.9(t^2)}$	$f_{adj.} = \mu(n) \pm m$ $f_{adj.} = \mu \pm e$ $f_{adj.} = \mu \pm m$



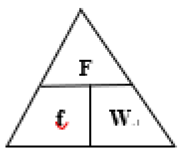
Constants



Conversions



Acceleration



Drag Sled

Kinetic Energy

$$K_e = 1/2(m)(V^2)$$

$$K_e = \frac{W(S^2)}{25.92}$$

$$K_e = \frac{m(V^2)}{2}$$

(Work)

$$Wk = W(f)(g)(d)$$

(Speed/Velocity)

$$S = \sqrt{\frac{25.92(Ke)}{W}}$$

$$V = \sqrt{\frac{2(Ke)}{W}}$$

Critical Speed

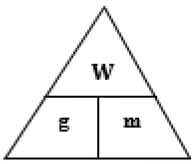
(Radius)

$$r = \frac{C^2}{8(mo)} + \frac{mo}{2}$$

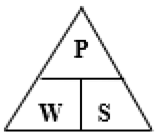
(Speed)

$$S = 11.27\sqrt{r(f)}$$

Mass



Momentum



Airborne

(Any airborne)

$$S = \frac{7.97(d)}{\mathrm{Cos}\,\theta\sqrt{\pm h + [d(\mathrm{Tan}\,\theta)]}}$$

$$V = \frac{2.21(d)}{\mathrm{Cos}\,\theta\sqrt{\pm h + [d(\mathrm{Tan}\,\theta)]}}$$

Level take-off

$$S = \frac{7.97(d)}{\sqrt{h}}$$

$$V = \frac{4.01(d)}{\sqrt{h}}$$

Convert grade to angle

$$\theta = m^{\mathrm{Tan}^{-1}}$$

Convert angle to grade

$$m = \mathrm{Tan}\,\theta$$

Center of Mass

(Behind front axle)

$$X_f = \frac{W_r(Wb)}{W}$$

(In front of rear axle)

$$X_r = \frac{W_f(Wb)}{W}$$

In - Line Momentum

Rear-end (Unit 2 stopped)

$$W_1S_1 = W_1S_3 + W_2S_4$$

or

$$S_1 = S_3 + \frac{W_2S_4}{W_1}$$

Rear-end (Unit 2 moving)

$$W_1S_1 + W_2S_2 = W_1S_3 + W_2S_4$$

or

$$S_1 = S_3 + \frac{W_2S_4}{W_1} - \frac{W_2S_2}{W_1}$$

Head-on (Unit 2 departs to 0°)

$$W_1S_1 - W_2S_2 = W_1S_3 + W_2S_4$$ or

$$S_1 = S_3 + \frac{W_2S_4}{W_1} + \frac{W_2S_2}{W_1}$$

Head-on (Unit 2 departs to 180°)

$$W_1S_1 - W_2S_2 = W_1S_3 - W_2S_4$$ or

$$S_1 = S_3 - \frac{W_2S_4}{W_1} + \frac{W_2S_2}{W_1}$$

Two-Dimensional Momentum

(Impact speed unit 2)

$$W_2S_2\mathrm{Sin}\psi = W_1S_3\mathrm{Sin}\theta + W_2S_4\mathrm{Sin}\phi$$

or

$$S_2 = \frac{W_1S_3\mathrm{Sin}\theta}{W_2\mathrm{Sin}\psi} + \frac{S_4\mathrm{Sin}\phi}{\mathrm{Sin}\psi}$$

(Impact speed unit 1)

$$W_1S_1\mathrm{Cos}\alpha + W_2S_2\mathrm{Cos}\psi = W_1S_3\mathrm{Cos}\theta + W_2S_4\mathrm{Cos}\phi$$

or

$$S_1 = S_3\mathrm{Cos}\theta + \frac{W_2S_4\mathrm{Cos}\phi}{W_1} - \frac{W_2S_2\mathrm{Cos}\psi}{W_1}$$

Two - Dimensional Momentum Symbols

W_1 = Unit #1 total weight	W_2 = Unit # 2 total weight
S_1 = Impact speed Unit # 1	S_2 = Impact speed Unit # 2
S_3 = Post impact speed Unit # 1	S_4 = Post impact speed Unit # 2
α = Approach angle Unit # 1	ψ = Approach angle Unit # 2
θ = Departure angle Unit # 1	ϕ = Departure angle Unit # 2

圖 3 數學公式

事故重建所需的資料除道路環境、天候、駕駛人員外，還需包括事故車輛之基本資料，在美國地區，調查人員可以很容易地取得事故車輛之基本資料，如車輛廠牌、車輛型式、出廠日期、車輛總重、前後軸重量及重量分配比率、輪胎數、前後輪傳動型態、車輛長度、前保險桿到前橋、前保險桿到引擎蓋前

部、前保險桿到擋風玻璃底部、擋風玻璃頂部的前保險桿、後保險桿到後橋、後保險桿到行李箱後部、後保險桿到後窗底座、車輛寬度、前後軸寬度、車輛高度、前後保險桿高度以及各結構之分項高度、車輛重心、車輛翻覆穩定比值、NHTSA 碰撞等級、無負載慣性等動量資料、各零部件角度、最大轉向輪胎角度、撞擊最先損壞因子、車輛內裝各部件尺寸、安全帶、安全氣囊、轉向數據、轉彎直徑、轉向比、車輪半徑、輪胎尺寸、加速和制動信息、煞車類型、ABS 系統、制動能力、動力傳輸類型、車輛額定保險桿強度等，各種資訊相當齊全，如圖 4 所示。事故重建需從車輛之基本資料計算各車種之質心，作為車輛碰撞動能移轉之數值來源，作為事故重建之基本資料。

Expert AutoStats®

RUSSELL STRICKLAND
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1200 ALUMNI DRIVE
JACKSONVILLE FL 32224-2678

10/31/2019

2010 FORD CROWN VICTORIA COMMERCIAL LWB 4 DOOR SEDAN

Curb Weight:	4137 lbs.		1877 kg.	
Curb Weight Distribution - Front:	56 %	Rear:	44 %	
Gross Vehicle Weight Rating:	5500 lbs.		2495 kg.	
Number of Tires on Vehicle:	4			
Drive Wheels:	REAR			

Horizontal Dimensions	Inches	Feet	Meters
Total Length	218	18.17	5.54
Wheelbase:	121	10.08	3.07
Front Bumper to Front Axle:	43	3.58	1.09
Front Bumper to Front of Front Well:	26	2.17	0.66
Front Bumper to Front of Hood:	8	0.67	0.20
Front Bumper to Base of Windshield:	65	5.42	1.65
Front Bumper to Top of Windshield:	91	7.58	2.31
Rear Bumper to Rear Axle:	54	4.50	1.37
Rear Bumper to Rear of Rear Well:	38	3.17	0.97
Rear Bumper to Rear of Trunk:	8	0.67	0.20
Rear Bumper to Base of Rear Window:	38	3.17	0.97
Width Dimensions			
Maximum Width:	78	6.50	1.98
Front Track:	63	5.25	1.60
Rear Track:	66	5.50	1.68
Vertical Dimensions			
Height:	59	4.92	1.50
Ground to -			
Front Bumper (Top)	23	1.92	0.58
Headlight - center	27	2.25	0.69
Hood - top front:	31	2.58	0.79
Base of Windshield	39	3.25	0.99
Rear Bumper - top:	25	2.08	0.64
Trunk - top rear:	39	3.25	0.99
Base of Rear Window:	40	3.33	1.02

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2010 FORD CROWN VICTORIA COMMERCIAL LWB 4 DOOR SEDAN

Interior Dimensions

	Inches	Feet	Meters
Front Seat Shoulder Width	61	5.08	1.55
Front Seat to Headliner	39	3.25	0.99
Front Leg Room - seatback to floor (max)	43	3.58	1.09
Rear Seat Shoulder Width	60	5.00	1.52
Rear Seat to Headliner	38	3.17	0.97
Front Leg Room - seatback to floor (min)	46	3.83	1.17

Seatbelts: **3pt - front and rear**
Airbags: **FRONT SEAT AIRBAGS**

Steering Data

	Inches	Feet	Meters
Turning Circle (Diameter)			
Steering Ratio: :1			
Wheel Radius:	12	1.00	0.30
Tire Size (OEM): P225/60R16			

Acceleration & Braking Information

Brake Type: **ALL DISC**
ABS System: **ALL WHEEL ABS**

Braking, 60 mph to 0 (Hard pedal, no skid, dry pavement):
d = **140.0** ft t = **3.2** sec a = **-27.6** ft/sec² G-force = **-0.86**

Acceleration:

	t		a		G-force
0 to 30mph	2.8	sec	15.7	ft/sec²	0.49
0 to 60mph	8.0	sec	11.0	ft/sec²	0.34
45 to 65mph	5.1	sec	5.8	ft/sec²	0.18

Transmission Type: **4spd AUTOMATIC**

Notes:
Federal Bumper Standard Requirements: **2.5** mph
This vehicles Rated Bumper Strength: **2.5** mph

N.S.D.C = **2010 - 2012**

Expert AutoStats®

2010 FORD CROWN VICTORIA COMMERCIAL LWB 4 DOOR SEDAN

Other Information

Tip-Over Stability Ratio =	1.39	Stable
NHTSA Star Rating (calculated)		****

Center of Gravity (No Load):

		Inches	Feet	Meters
behind front axle	=	53.24	4.44	1.35
in front of rear axle	=	67.76	5.65	1.72
from side of vehicle	=	39.00	3.25	0.99
from ground	=	23.16	1.93	0.59
from front corner	=	103.84	8.65	2.64
from rear corner	=	127.85	10.65	3.25
from front bumper	=	96.24	8.02	2.44
from rear bumper	=	121.76	10.15	3.09

Moments of Inertia Approximations (No Load):

Yaw Moment of Inertia	=	3055.11	lb*ft*sec²
Pitch Moment of Inertia	=	2946.63	lb*ft*sec²
Roll Moment of Inertia	=	594.66	lb*ft*sec²

Front Profile Information

Angle Front Bumper to Hood Front	=	45.0	deg
Angle Front of Hood to Windshield Base	=	8.0	deg
Angle Front of Hood to Windshield Top	=	17.4	deg
Angle of Windshield	=	34.7	deg
Angle of Steering Tires at Max Turn	=		deg

First Approximation Crush Factors:

Speed Equivalent (mph) of Kinetic Energy (KE) used in causing crush of indentation may be evaluated using the following formula, the appropriated Crush Factor (CF), and Maximum Indentation Depth (MID), in feet:

$$V(mph) = \sqrt{(30 * CF * MID)}$$

KE Equivalent Speed (Front/Rear/Side) = 21 CF

Bullet vehicle IMPACT SPEED estimation
based on TARGET VEHICLE damage ONLY = 27 CF
(Tested for Rear/Side Impact only)

These CF values are based upon analysis of NHTSA Barrier Crash data, and from over 1000 vehicle accidents where independent evaluation of speed was possible. (These are NOT 'A', 'B', 'C', or 'G' values)

The rear Impact data with more then 2-3 inches of crush damage should be looked at carefully, since some vehicles have very weak trunk & fender strength. Therefore, on some cars, especially GM, you estimate from the rear crush data may be high by as much as 4-5 mph (on a crush of 18 inches).

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圖 4 車輛基本資料

牛頓運動定律

牛頓運動定律共有三運動定律，牛頓第一運動定律為『慣性定律』，是指

除非物體有受到外力，要不然保持靜止的物體，會一直保持靜止；沿一直線作等速度運動的物體，也會一直保持等速度運動。牛頓第二運動定律也稱『運動定律』，當物體受外力作用時，會在力的方向產生加速度，其大小與外力成正比，與質量成反比。牛頓第三運動定律也稱『作用與反作用定律』，當施加力於物體時，會同時產生一個大小相等而且方向相反的反作用力。作用力與反作用力大小相等、方向相反，且作用在同一直線上，因為受力對象不同，所以不能互相抵銷，兩者同時發生，同時消失。

在事故重建之應用上，當車輛第一次碰撞接觸時，它們擁有其撞擊前動量向量的大小，因能量不變定律，會以反作用力移轉至碰撞之物體，車輛從第一次碰撞到最大接合(分離)移動到對面車輛(物體)施加全部向量動量(簡稱 PDOF)的點，所有的量能會依質心的動量變動而移轉，如圖 5 所示。

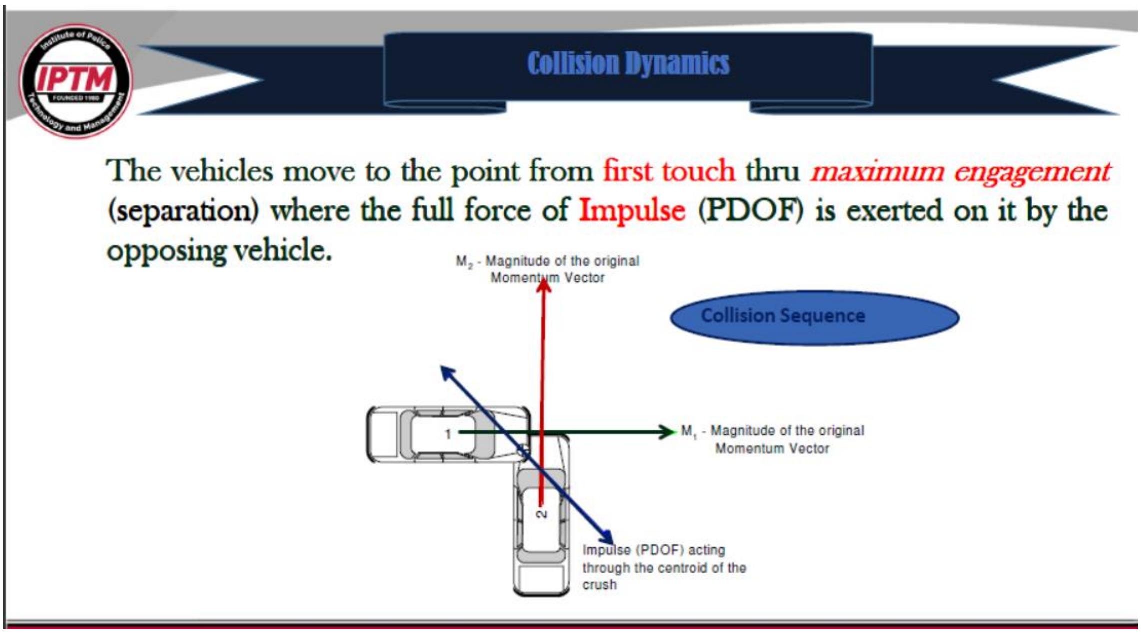


圖 5 車輛撞擊的動態模式

三、 質心、估計速度和動能(Center of Mass, Estimating Speed & Kinetic Energy)

質心

課程內容是教導學員如何利用車輛之基本資料，計算各車種之車輛質心，以提供牛頓運動定律所需之資料，主要利用公式計算出質心位置，再由繪圖方式繪製車輛質心，如圖 6 所示，並需動手練習計算與繪製四個案例作業。

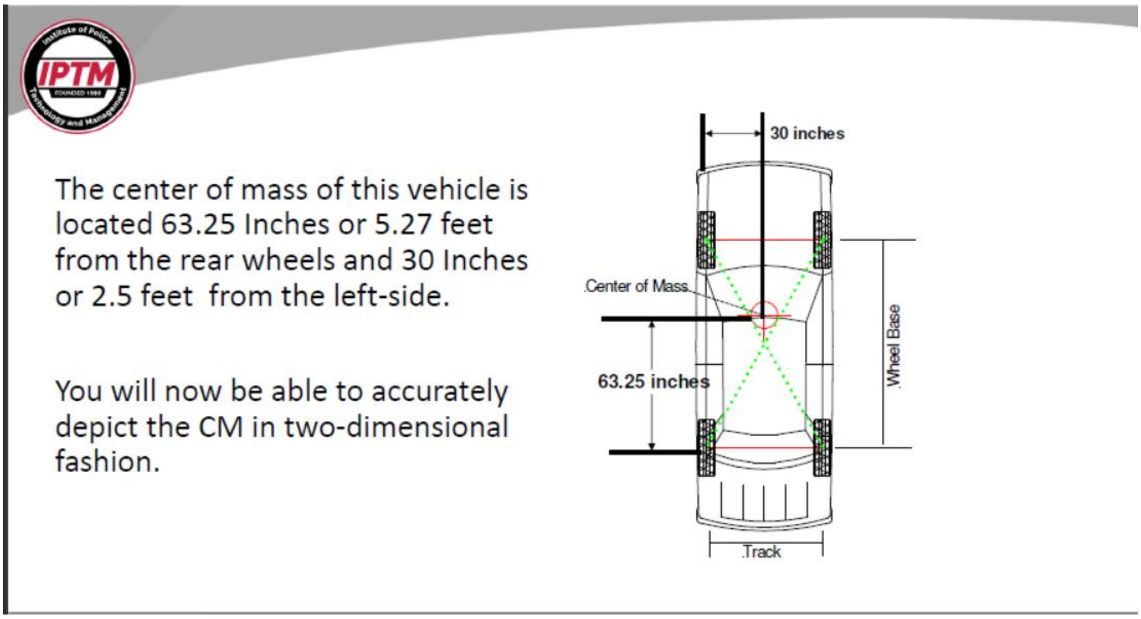


圖 6 車輛質心之計算與繪製案例

估計速度

事故重建中最主要的參數之一是車輛碰撞前之速度，速度估計可以利用輪胎擦痕(Skid Marks)、輪胎側向滑痕(Yaw Marks)、車輛跌落(airborne)、翻轉或彈跳、車輛損壞分析、證人的陳述(最不可靠)等之一種或組合進行估算，調查員所估算之速度，可以用在民事訴訟或刑事法庭中均可被接受。是以輪胎擦痕為計算速度之主要參數，其量測結果是一項重要的現場資料收集要項，測量輪胎擦痕需包括 Smear 及 Shadow 兩段之長度如圖 7 所示。

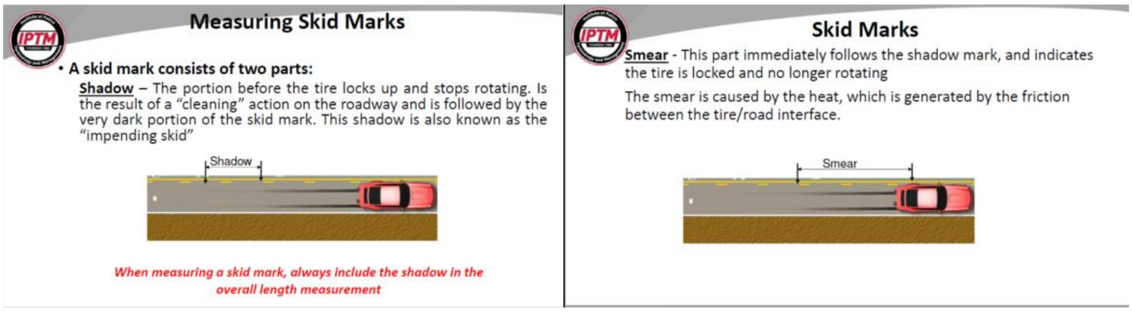


圖 7 輪胎擦痕量測

四、 時間、距離(Time/Distance)

時間、距離是計算車輛碰撞前速度的主要變數，本週課程詳細敘述如何利用時間、距離的公式，計算車輛的速度，且因為事故現場所能收集的資料如煞車痕跡距離、車輛行駛時間、車輛速度等因子，並非每一個事故皆能完整收集，時間、摩擦係數、距離、加減速度、速度變化等皆有轉換公式，是以必須對其相對應之公式熟悉應用，才能完整構建出事故之原貌。車輛行進距離與時間、速度間之因果關係示意圖，如圖 8。為讓學員可以熟悉公式之應用，本週課程安排 5 個測驗，以過去實際案例為範例，供學員練習，測驗題目如圖 9 所示。

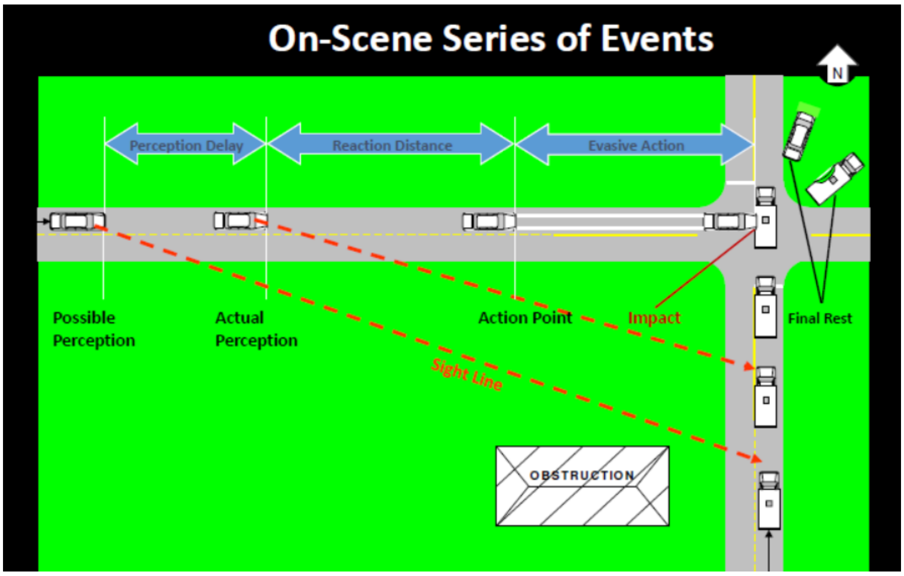
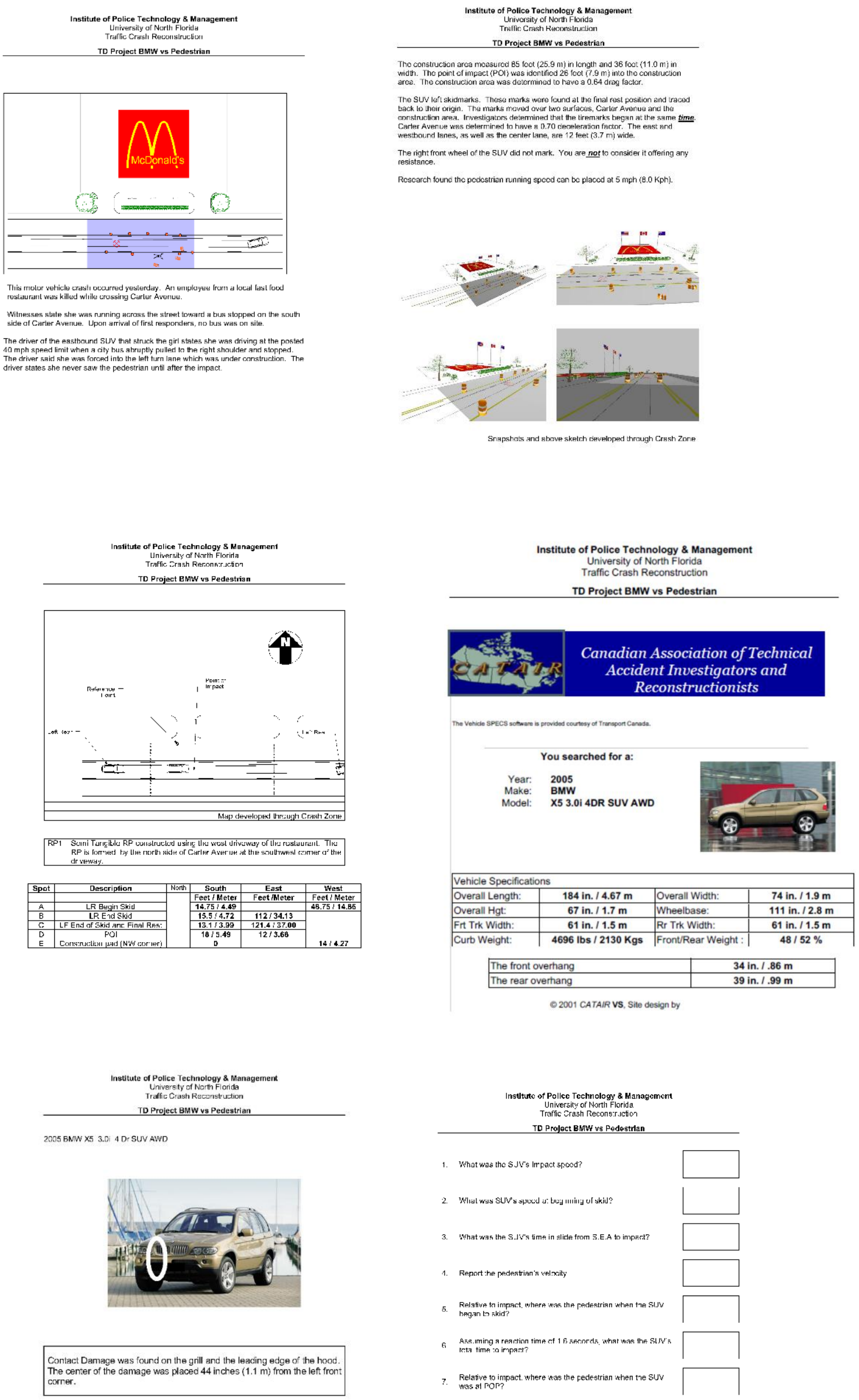


圖 8 事故現場車輛動態變化情形



Institute of Police Technology & Management
University of North Florida
Traffic Crash Reconstruction

TD Project BMW vs Pedestrian

This motor vehicle crash occurred yesterday. An employee from a local fast food restaurant was killed while crossing Carter Avenue.

Witnesses state she was running across the street toward a bus stopped on the south side of Carter Avenue. Upon arrival of first responders, no bus was on site.

The driver of the eastbound SUV that struck the girl states she was driving at the posted 40 mph speed limit when a city bus abruptly pulled to the right shoulder and stopped. The driver said she was forced into the left turn lane which was under construction. The driver states she never saw the pedestrian until after the impact.

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Traffic Crash Reconstruction

TD Project BMW vs Pedestrian

The construction area measured 85 feet (25.9 m) in length and 36 feet (11.0 m) in width. The point of impact (POI) was identified 26 feet (7.9 m) into the construction area. The construction area was determined to have a 0.64 drag factor.

The SUV left skidmarks. These marks were found at the final rest position and traced back to their origin. The marks moved over two surfaces, Carter Avenue and the construction area. Investigators determined that the tiremarks began at the same ***time***. Carter Avenue was determined to have a 0.70 deceleration factor. The east and westbound lanes, as well as the center lane, are 12 feet (3.7 m) wide.

The right front wheel of the SUV did not mark. You are ***not*** to consider it offering any resistance.

Research found the pedestrian running speed can be placed at 5 mph (8.0 Kph).

Snapshots and above sketch developed through Crash Zone

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Traffic Crash Reconstruction

TD Project BMW vs Pedestrian

Reference Point
Point of Impact
Map developed through Crash Zone

RP1 Semi Tangible RP constructed using the west driveway of the restaurant. The RP is formed by the north side of Carter Avenue at the southwest corner of the driveway.

Spot	Description	North	South	East	West
			Feet / Meter	Feet /Meter	Feet / Meter
A	LR Begin Skid		14.75 / 4.49		48.75 / 14.86
B	LR End Skid		15.5 / 4.72	112 / 34.13	
C	LF End of Skid and Final Rest		13.1 / 3.99	121.4 / 37.00	
D	POI		18 / 5.49	12 / 3.66	
E	Construction pad (NW corner)		0		14 / 4.27

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TD Project BMW vs Pedestrian

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The Vehicle SPECS software is provided courtesy of Transport Canada.

You searched for a:

Year: **2005**
Make: **BMW**
Model: **X5 3.0i 4DR SUV AWD**

Vehicle Specifications			
Overall Length:	**184 in. / 4.67 m**	Overall Width:	**74 in. / 1.9 m**
Overall Hgt:	**67 in. / 1.7 m**	Wheelbase:	**111 in. / 2.8 m**
Frt Trk Width:	**61 in. / 1.5 m**	Rr Trk Width:	**61 in. / 1.5 m**
Curb Weight:	**4696 lbs / 2130 Kgs**	Front/Rear Weight :	**48 / 52 %**

The front overhang	**34 in. / .86 m**
The rear overhang	**39 in. / .99 m**

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TD Project BMW vs Pedestrian

2005 BMW X5 3.0i 4 Dr SUV AWD

Contact Damage was found on the grill and the leading edge of the hood. The center of the damage was placed 44 inches (1.1 m) from the left front corner.

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TD Project BMW vs Pedestrian

1. What was the SUV's Impact speed?
2. What was SUV's speed at beginning of skid?
3. What was the SUV's time in slide from S.E.A to impact?
4. Report the pedestrian's velocity
5. Relative to impact, where was the pedestrian when the SUV began to skid?
6. Assuming a reaction time of 1.6 seconds, what was the SUV's total time to impact?
7. Relative to impact, where was the pedestrian when the SUV was at POP?

圖 9 作業案例

五、 空降(airborne)和臨界速度(Critical Speed)

<u>空降(airborne)</u>

交通事故經常發生在山區路段，車輛撞擊後會有墜落路外邊坡或山谷之情形如圖 10 所示，該如何計算車輛跌落山谷前之速度，用以判斷車輛事故發生前是否有不當駕駛之行為，則可以利用 airborne 之計算公式取得事故前之速度，其計算公式如下：

$$S = \frac{2.73d}{\cos\theta\sqrt{\pm h + [d(\tan\theta)]}} \qquad S = \frac{2.73d}{\cos\theta\sqrt{\pm h + [d(m)]}}$$

其中：

d = Horizontal distance traveled in the air

h = Vertical height change (-h if the object lands higher) (+h if the object lands lower)

θ "Theta" = "Takeoff angle" (in degrees) enter calculator as a negative number.

Cos θ = will become a positive number (4 decimal places)

tan θ (m) = enter as a negative number (4 decimal places)

m (tan θ) = "Takeoff grade" (2 decimal places) is a negative number

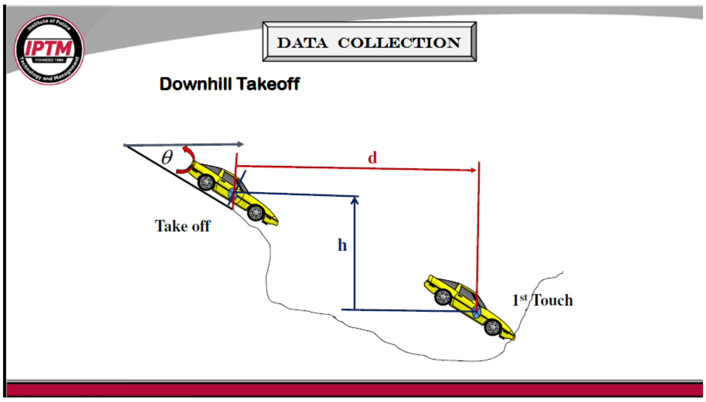

圖 10 車輛跌落山谷之示意圖

本章節有許多案例供學員熟悉公式之應用與計算，其中之案例如圖 11 所示。車輛在剛性路面、柏油路面、草地等路面行駛，再跌落邊坡，須將三種不同鋪面之速度及 airborne 之速度分別計算後，再行累加為最終速度。

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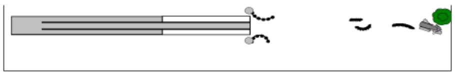
Airborne Equation Project 2



An ATV skidded across two surfaces of an abandoned road before going airborne.

The vehicle slid 120 feet (36.6 m) on a concrete surface with a 0.65 deceleration factor.

It continued skidding an additional 60 feet (18.3 m) on an asphalt surfaced bridge with a 0.45 deceleration factor.

The vehicle then went airborne from a level takeoff, traveled 37 feet (11.3 m) horizontally and fell 3.8 feet (1.2 m).

Distance	Height ↑↓	(Tan θ) m	(Tan^{-1} m) θ	Cos θ

1. What was the airborne speed of the vehicle?
2. What was the speed of the vehicle when it started on the asphalt bridge surface?
3. What was the speed of the vehicle when it started on the concrete surface?

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Airborne Equation Project 2

Time Distance Study

4. How long was the vehicle sliding on the asphalt bridge surface?
5. How long was the vehicle sliding on the concrete surface?
6. What was the speed of the vehicle after skidding for 83 feet (25.3 m) on the concrete surface?
7. How long did it take to slide 83 feet (25.3 m) on the concrete surface?

圖 11 airborne 之作業習題案例

臨界速度(Airborne & Critical Speed)

車輛在轉向時可以執行的最大轉向角度取決於速度(Speed)、摩擦係數(Coefficient of friction)與道路超高度(Super-elevation of the roadway)，當車輛速度超過臨界速率(critical speed)，側滑車輛向外推時，輪胎會隨著輪胎側滑而出現超過臨界速度的滑痕(critical speed yaw mark，CSY)，可以利用 CSY 分析來估計實際速度。車輛的運動分為三種類型分別為沿著 X 軸方向的”PITCH”，沿著 Y 方向的”ROLL”，以及沿著 Z 方向的”YAW”，如圖 12 所示。

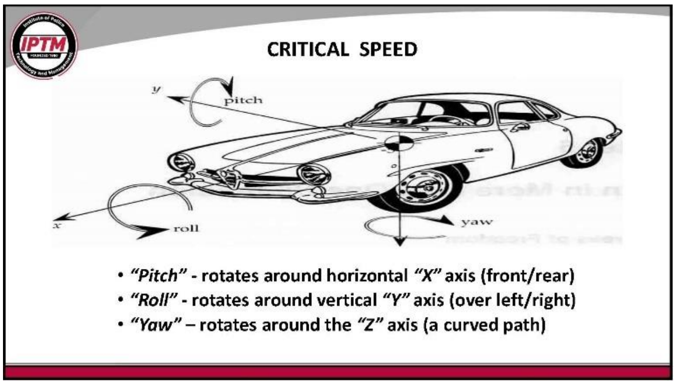


圖 12 車輛運動的三種類型

車輛打滑時行進的"航向"與"方位"所成的角度就是車輛的側偏角。通常以"∝"(Alpha)表示，當車輛開始偏航時，"側偏角"很小，隨著偏航的進行，這個角度會增加，側偏角的增加導致輪胎打滑更多而滾動更少，從而使車輛減速，對於處於臨界速度偏航的車輛，側偏角的正弦值是後輪胎跟隨到相應前輪胎外側的距離與車輛軸距的比值。其所產生的"CSY"角度應約為 20°或更小。如圖 13 所示。

正常的車輛轉向其後輪的痕跡會在前輪的內側，惟當車輛出現 CSY 時，後輪的胎痕會在前輪的外側。如果不存在縱向力，則滑動的方向是橫向的，輪胎是自由滾動的，輪胎痕條紋將平行於車軸；若輪胎是處於煞車狀態，煞車制動力會產生一個向前的分量，輪胎條紋變得與輪胎標記的邊緣緊密平行，如果輪胎因煞車鎖死，在速度足夠大時，其條紋會過渡到幾乎完全平行；若車輛是處於加速度的狀態，將導致輪胎條紋在軸後面傾斜。可以檢視驅動軸上的輪胎產生的輪胎痕跡，來確認是否有加速度產生；如圖 14 所示。

量測 CSY 的弦的長度(chord)及中垂距(MO)用以計算車輛的臨界速度之半徑，其量測方式如圖 15 所示。再利用速度、半徑與摩擦係數之公式，可計算出車輛之速度，其計算公式如下：

$$\mathbf{r} = \frac{\mathbf{C}^2}{\mathbf{8(m_O)}} + \frac{\mathbf{m_O}}{\mathbf{2}}$$

r = 半徑

C = 弦長

mo = 中垂距長度

8 = 推導的數值常數

2 = 推導的數值常數

$$S = 3.86\sqrt{rf}$$

S = 以 mph 為單位的速度

r = 調整後的圓弧半徑

f = 調整後的道路摩擦係數

3.86 = 推導的數值常數

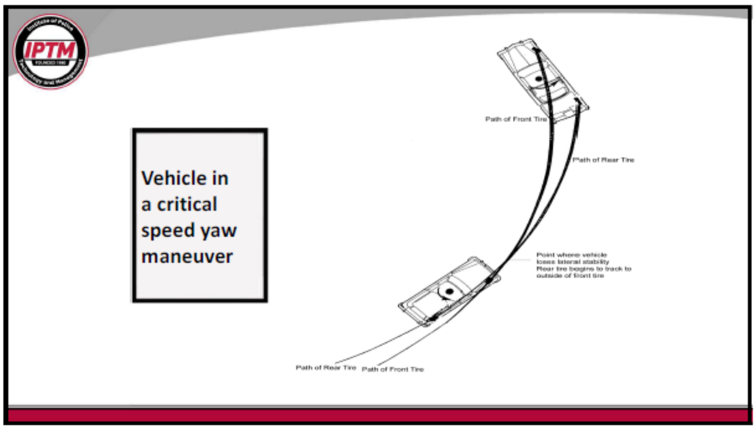


圖 13 車輛出現 CSY 之胎痕軌跡

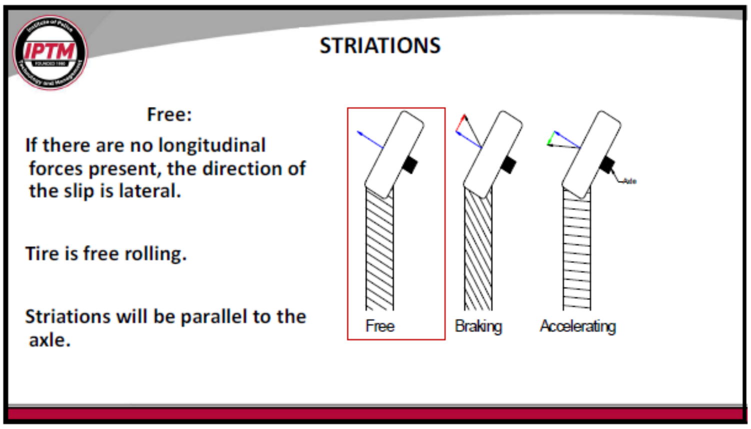


圖 14 胎紋痕跡因車輛輪胎的滾動狀態之差異情形

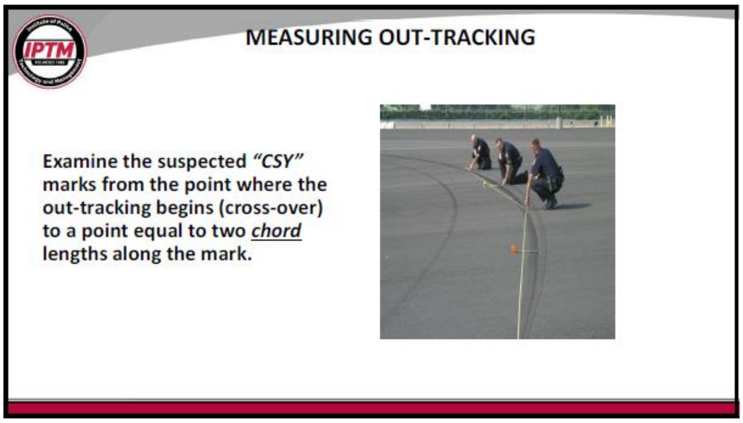
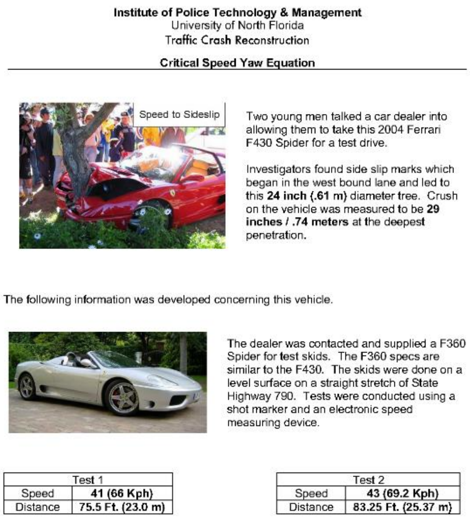


圖 15 量測 CSY 的弦的長度(chord)及中垂線(MO)用以計算速度

本章節有 3 個案例供學員熟悉 CSY 公式之應用與計算，其中之案例如圖 16 所示。



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Critical Speed Yaw Equation

Speed to Sideslip

Two young men talked a car dealer into allowing them to take this 2004 Ferrari F430 Spider for a test drive.

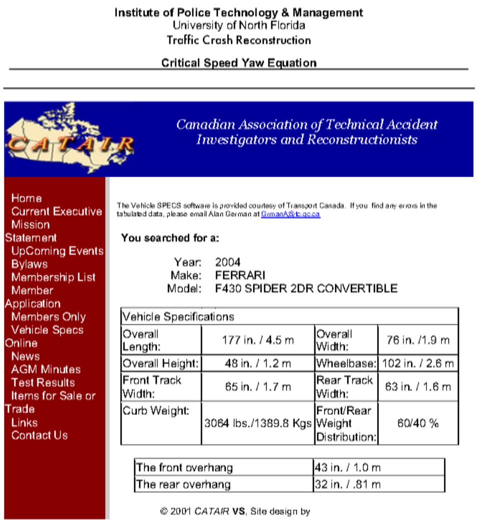
Investigators found side slip marks which began in the west bound lane and led to this **24 inch (.61 m)** diameter tree. Crush on the vehicle was measured to be **29 inches / .74 meters** at the deepest penetration.

The following information was developed concerning this vehicle.

The dealer was contacted and supplied a F360 Spider for test skids. The F360 specs are similar to the F430. The skids were done on a level surface on a straight stretch of State Highway 790. Tests were conducted using a shot marker and an electronic speed measuring device.

Test 1	
Speed	**41 (66 Kph)**
Distance	**75.5 Ft. (23.0 m)**

Test 2	
Speed	**43 (69.2 Kph)**
Distance	**83.25 Ft. (25.37 m)**



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Critical Speed Yaw Equation

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The Vehicle SPECS software is provided courtesy of Transport Canada. If you find any errors in the tabulated data, please email Alan German at GrmanA@tc.gc.ca

You searched for a:

Year: 2004
Make: FERRARI
Model: F430 SPIDER 2DR CONVERTIBLE

Vehicle Specifications			
Overall Length:	177 in. / 4.5 m	Overall Width:	76 in. /1.9 m
Overall Height:	48 in. / 1.2 m	Wheelbase:	102 in. / 2.6 m
Front Track Width:	65 in. / 1.7 m	Rear Track Width:	63 in. / 1.6 m
Curb Weight:	3064 lbs./1389.8 Kgs	Front/Rear Weight Distribution:	60/40 %

The front overhang	43 in. / 1.0 m
The rear overhang	32 in. / .81 m

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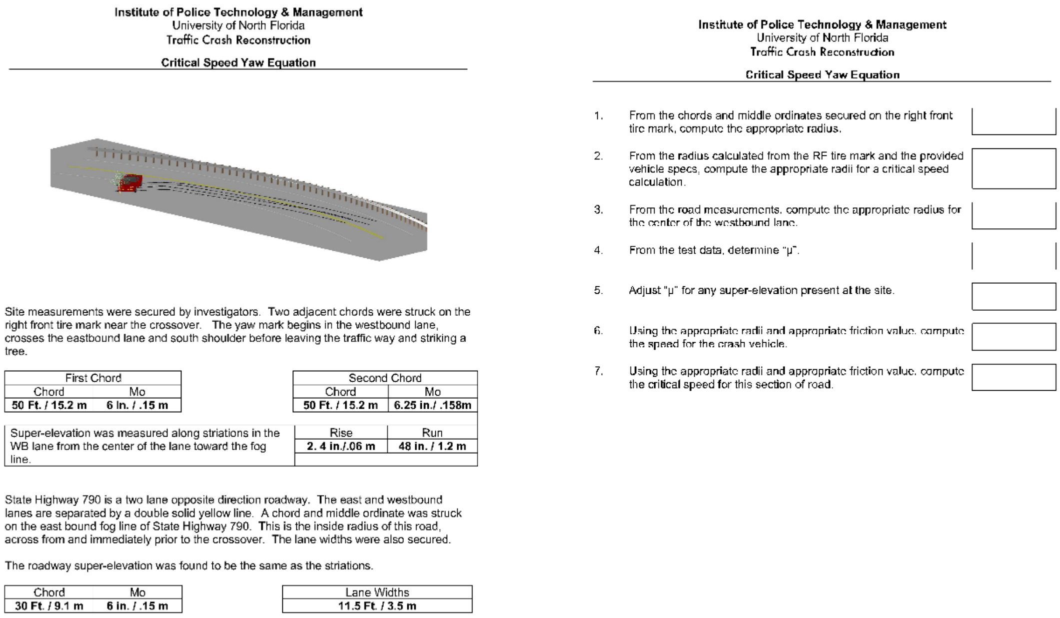

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Critical Speed Yaw Equation

Site measurements were secured by investigators. Two adjacent chords were struck on the right front tire mark near the crossover. The yaw mark begins in the westbound lane, crosses the eastbound lane and south shoulder before leaving the traffic way and striking a tree.

First Chord	
Chord	Mo
50 Ft. / 15.2 m	6 in. / .15 m

Second Chord	
Chord	Mo
50 Ft. / 15.2 m	6.25 in./ .158m

Super-elevation was measured along striations in the WB lane from the center of the lane toward the fog line.	Rise	Run
	2. 4 in./.06 m	48 in. / 1.2 m

State Highway 790 is a two lane opposite direction roadway. The east and westbound lanes are separated by a double solid yellow line. A chord and middle ordinate was struck on the east bound fog line of State Highway 790. This is the inside radius of this road, across from and immediately prior to the crossover. The lane widths were also secured.

The roadway super-elevation was found to be the same as the striations.

Chord	Mo
30 Ft. / 9.1 m	6 in. / .15 m

Lane Widths
11.5 Ft. / 3.5 m

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Critical Speed Yaw Equation

1. From the chords and middle ordinates secured on the right front tire mark, compute the appropriate radius.
2. From the radius calculated from the RF tire mark and the provided vehicle specs, compute the appropriate radii for a critical speed calculation.
3. From the road measurements, compute the appropriate radius for the center of the westbound lane.
4. From the test data, determine "μ".
5. Adjust "μ" for any super-elevation present at the site.
6. Using the appropriate radii and appropriate friction value, compute the speed for the crash vehicle.
7. Using the appropriate radii and appropriate friction value, compute the critical speed for this section of road.

圖 16 CSY 之作業習題案例

六、 向量講座(Vectors)

向量是指質心運動的方向、角度與動能，例如一個向量的標示 Vector R = 3.7 @ 302°，則其包含以下幾項：1. 選擇起點。2. 畫一條水平線。3. 畫第二條線與第一條線間有 302°的角度。4.測量向量之長度：3.7。5. 完成向量。其向量如圖 17 所示。

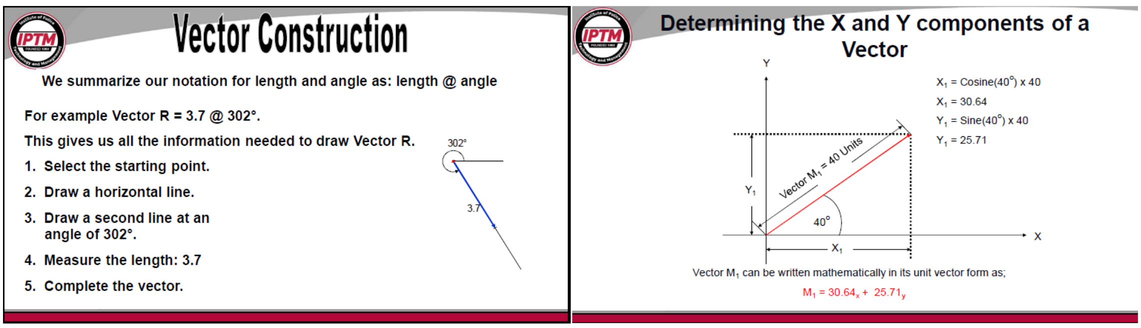
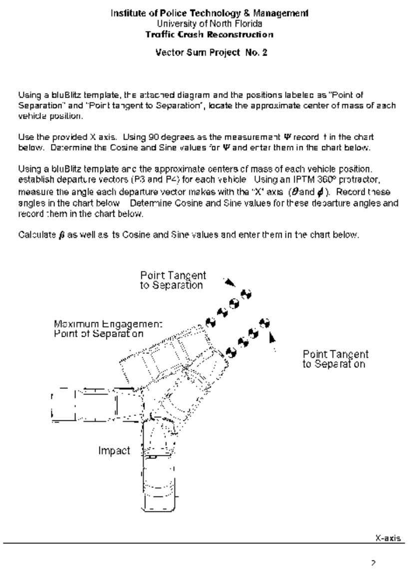


圖 17 一個簡單的向量

為讓學員可以熟悉公式之應用，本週課程安排 3 個測驗與實作，以過去實際案例為範例，供學員練習如何計算車輛碰撞產生之向量與動量之變化，其中每一個測驗包括 28 個以上之小題，並需實際繪製車輛碰撞後之移動方向與角度之變化，學員需由提供之車輛基本資料找到車輛之質心，以及車輛撞擊後之速度變化、車輛重量、不同舖面之摩擦係數、碰撞角度等，計算碰撞前後之動量變化，以計算出車輛撞擊前之速度，用以判斷車輛是否有超速之行為，測驗題目案例如圖 18 所示。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Vector Sum Project No. 2

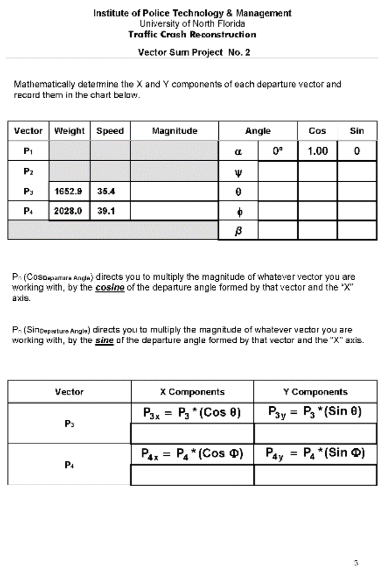
Using a bluBlitz template, the attached diagram and the positions labeled as "Point of Separation" and "Point tangent to Separation", locate the approximate center of mass of each vehicle position.

Use the provided X axis. Using 90 degrees as the measurement Ψ record it in the chart below. Determine the Cosine and Sine values for Ψ and enter them in the chart below.

Using a bluBlitz template and the approximate centers of mass of each vehicle position, establish departure vectors (P3 and P4) for each vehicle. Using an IPTM 360° protractor, measure the angle each departure vector makes with the "X" axis (θ and ϕ). Record these angles in the chart below. Determine Cosine and Sine values for these departure angles and record them in the chart below.

Calculate β as well as its Cosine and Sine values and enter them in the chart below.

2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Vector Sum Project No. 2

Mathematically determine the X and Y components of each departure vector and record them in the chart below.

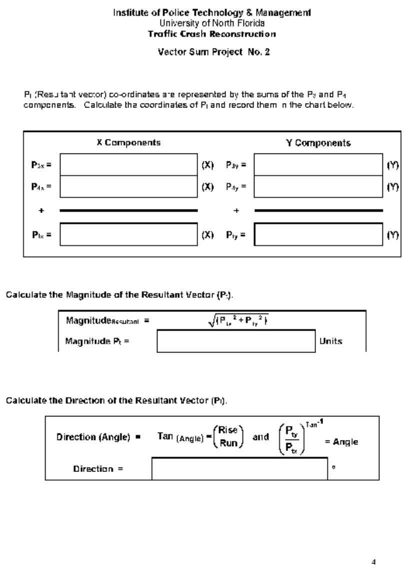
Vector	Weight	Speed	Magnitude	Angle		Cos	Sin
P_1				α	0°	1.00	0
P_2				ψ			
P_3	1652.9	35.4		θ			
P_4	2028.0	39.1		ϕ			
				β			

P_n (Cos$_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***cosine*** of the departure angle formed by that vector and the "X" axis.

P_n (Sin$_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***sine*** of the departure angle formed by that vector and the "X" axis.

Vector	X Components	Y Components
P_3	$P_{3x} = P_3 * (\text{Cos } \theta)$	$P_{3y} = P_3 * (\text{Sin } \theta)$
P_4	$P_{4x} = P_4 * (\text{Cos } \Phi)$	$P_{4y} = P_4 * (\text{Sin } \Phi)$

3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Vector Sum Project No. 2

P_t (Resultant vector) co-ordinates are represented by the sums of the P_3 and P_4 components. Calculate the coordinates of P_t and record them in the chart below.

X Components			Y Components		
P_{3x} =		(X)	P_{3y} =		(Y)
P_{4x} =		(X)	P_{4y} =		(Y)
+			+		
P_{tx} =		(X)	P_{ty} =		(Y)

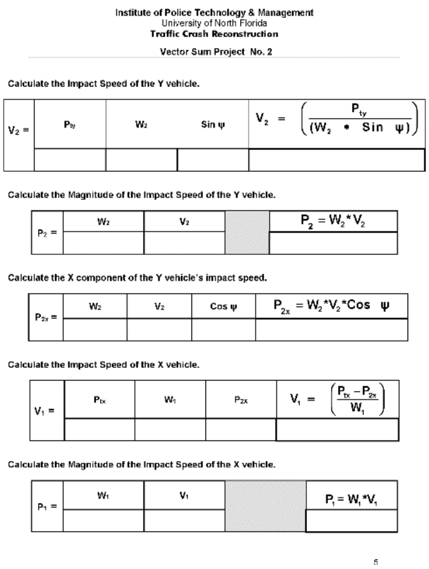
Calculate the Magnitude of the Resultant Vector (P_t).

Magnitude$_{Resultant}$ =	$\sqrt{(P_{tx}^2 + P_{ty}^2)}$	
Magnitude P_t =		Units

Calculate the Direction of the Resultant Vector (P_t).

Direction (Angle) =	$\text{Tan}_{(Angle)} = \left(\frac{\text{Rise}}{\text{Run}}\right)$ and $\left(\frac{P_{ty}}{P_{tx}}\right)^{\text{Tan}^{-1}}$ = Angle	
Direction =		°

4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Vector Sum Project No. 2

Calculate the Impact Speed of the Y vehicle.

V_2 =	P_{ty}	W_2	Sin ψ	$V_2 = \left(\frac{P_{ty}}{(W_2 \bullet \text{Sin } \psi)}\right)$

Calculate the Magnitude of the Impact Speed of the Y vehicle.

P_2 =	W_2	V_2		$P_2 = W_2 * V_2$

Calculate the X component of the Y vehicle's impact speed.

P_{2x} =	W_2	V_2	Cos ψ	$P_{2x} = W_2 * V_2 * \text{Cos } \psi$

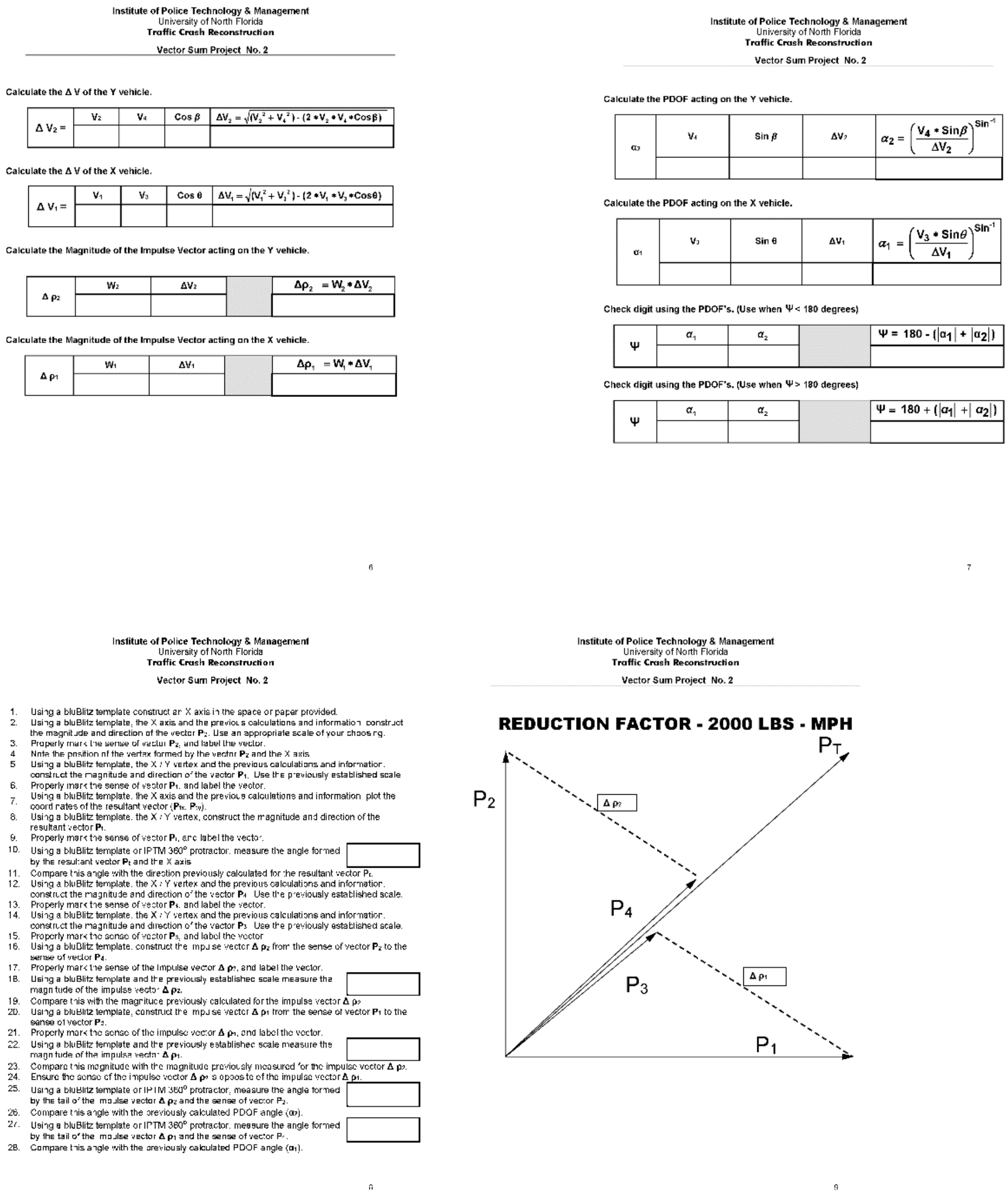
Calculate the Impact Speed of the X vehicle.

V_1 =	P_{tx}	W_1	P_{2x}	$V_1 = \left(\frac{P_{tx} - P_{2x}}{W_1}\right)$

Calculate the Magnitude of the Impact Speed of the X vehicle.

P_1 =	W_1	V_1		$P_1 = W_1 * V_1$

5



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Vector Sum Project No. 2

Calculate the Δ V of the Y vehicle.

$\Delta V_2 =$	V_2	V_4	$\cos\beta$	$\Delta V_2 = \sqrt{(V_2^2 + V_4^2) - (2 * V_2 * V_4 * \cos\beta)}$

Calculate the Δ V of the X vehicle.

$\Delta V_1 =$	V_1	V_3	$\cos\theta$	$\Delta V_1 = \sqrt{(V_1^2 + V_3^2) - (2 * V_1 * V_3 * \cos\theta)}$

Calculate the Magnitude of the Impulse Vector acting on the Y vehicle.

$\Delta \rho_2$	W_2	ΔV_2		$\Delta\rho_2 = W_2 * \Delta V_2$

Calculate the Magnitude of the Impulse Vector acting on the X vehicle.

$\Delta \rho_1$	W_1	ΔV_1		$\Delta\rho_1 = W_1 * \Delta V_1$

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Vector Sum Project No. 2

Calculate the PDOF acting on the Y vehicle.

α_2	V_4	$\sin\beta$	ΔV_2	$\alpha_2 = \left(\frac{V_4 * \sin\beta}{\Delta V_2}\right)^{\sin^{-1}}$

Calculate the PDOF acting on the X vehicle.

α_1	V_3	$\sin\theta$	ΔV_1	$\alpha_1 = \left(\frac{V_3 * \sin\theta}{\Delta V_1}\right)^{\sin^{-1}}$

Check digit using the PDOF's. (Use when $\Psi <$ 180 degrees)

Ψ	α_1	α_2		$\Psi = 180 - (\lvert\alpha_1\rvert + \lvert\alpha_2\rvert)$

Check digit using the PDOF's. (Use when $\Psi >$ 180 degrees)

Ψ	α_1	α_2		$\Psi = 180 + (\lvert\alpha_1\rvert + \lvert\alpha_2\rvert)$

7

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Traffic Crash Reconstruction

Vector Sum Project No. 2

1. Using a bluBlitz template construct an X axis in the space or paper provided.
2. Using a bluBlitz template, the X axis and the previous calculations and information construct the magnitude and direction of the vector P_2. Use an appropriate scale of your choosing.
3. Properly mark the sense of vector P_2, and label the vector.
4. Note the position of the vertex formed by the vector P_2 and the X axis.
5. Using a bluBlitz template, the X / Y vertex and the previous calculations and information construct the magnitude and direction of the vector P_1. Use the previously established scale
6. Properly mark the sense of vector P_1, and label the vector.
7. Using a bluBlitz template, the X axis and the previous calculations and information plot the coordinates of the resultant vector (P_{tx}, P_{ty}).
8. Using a bluBlitz template, the X / Y vertex, construct the magnitude and direction of the resultant vector P_t.
9. Properly mark the sense of vector P_t, and label the vector.
10. Using a bluBlitz template or IPTM 360° protractor, measure the angle formed by the resultant vector P_t and the X axis
11. Compare this angle with the direction previously calculated for the resultant vector P_t.
12. Using a bluBlitz template, the X / Y vertex and the previous calculations and information construct the magnitude and direction of the vector P_4. Use the previously established scale.
13. Properly mark the sense of vector P_4, and label the vector.
14. Using a bluBlitz template, the X / Y vertex and the previous calculations and information construct the magnitude and direction of the vector P_3. Use the previously established scale.
15. Properly mark the sense of vector P_3, and label the vector
16. Using a bluBlitz template, construct the impulse vector $\Delta\rho_2$ from the sense of vector P_2 to the sense of vector P_4.
17. Properly mark the sense of the impulse vector $\Delta\rho_2$, and label the vector.
18. Using a bluBlitz template and the previously established scale measure the magnitude of the impulse vector $\Delta\rho_2$.
19. Compare this with the magnitude previously calculated for the impulse vector $\Delta\rho_2$
20. Using a bluBlitz template, construct the impulse vector $\Delta\rho_1$ from the sense of vector P_1 to the sense of vector P_3.
21. Properly mark the sense of the impulse vector $\Delta\rho_1$, and label the vector.
22. Using a bluBlitz template and the previously established scale measure the magnitude of the impulse vector $\Delta\rho_1$.
23. Compare this magnitude with the magnitude previously measured for the impulse vector $\Delta\rho_2$.
24. Ensure the sense of the impulse vector $\Delta\rho_2$ is opposite of the impulse vector $\Delta\rho_1$.
25. Using a bluBlitz template or IPTM 360° protractor, measure the angle formed by the tail of the impulse vector $\Delta\rho_2$ and the sense of vector P_2.
26. Compare this angle with the previously calculated PDOF angle (α_2).
27. Using a bluBlitz template or IPTM 360° protractor, measure the angle formed by the tail of the impulse vector $\Delta\rho_1$ and the sense of vector P_1.
28. Compare this angle with the previously calculated PDOF angle (α_1).

8

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Traffic Crash Reconstruction

Vector Sum Project No. 2

9

圖 18 向量作業案例

七、 線性動量和二維動量(In line Momentum & Two Dimensional Momentum)

線性動量

線性動量守恆之定義是指，在直線上保持或保持一定量的運動的過程，該

運動量是物體的質量（重量）和速度（速度）的乘積。由線性動量守恆原理指出：當系統在撞擊時的線性動量的總向量和等於碰撞後動量的總向量和，簡單地說，進去的能量必須等於出來的能量，因此動量發生在封閉系統中是“守恆的”。

動量和能量的概念有時會被混淆，因為兩者都被定義為“運動量”，並且都是物體質量（重量）和速度（速度）的乘積，兩者的區別在於某種力的作用是如何進行的，如果力作用在一定「距離」上，則是代表「能量」，若力在「一定時間」內起作用，則表示有一定量的「動量」。

當兩輛車發生碰撞時，這表示進入碰撞的總動量等於離開碰撞的總動量，當假設 P_1、P_2 為第一、二輛車碰撞前之動量，P_3、P_4 為第一、二輛車碰撞後之動量。則定義動量守恆的代數方程式如下：

$$\underbrace{P_1 + P_2}_{\text{PRE}} = \underbrace{P_3 + P_4}_{\text{POST}},$$

只要在整個分析過程中保持單位不變，速度大小的單位可以是任何有效的速度單位（fps 或 mph），通過動量分析，可以求解衝擊速度；為了便於計算，可以用速度 (S,mph) 代替速度 (V,fps) 並將方程更改為：

$$W_1S_1 + W_2S_2 = W_1S_3 + W_2S_4$$

其中：W1、W2 為第一、二輛車之重量；S1、S2 為第一、二輛車碰撞前之速度，S3、S4 為第一、二輛車碰撞後之速度。在線性碰撞之案例中，車輛撞擊後以同方向 180 度的方向離開，則可以用上開簡單的計算公式，計算出車輛碰撞前之速度。其作業案例如圖 19 所示。

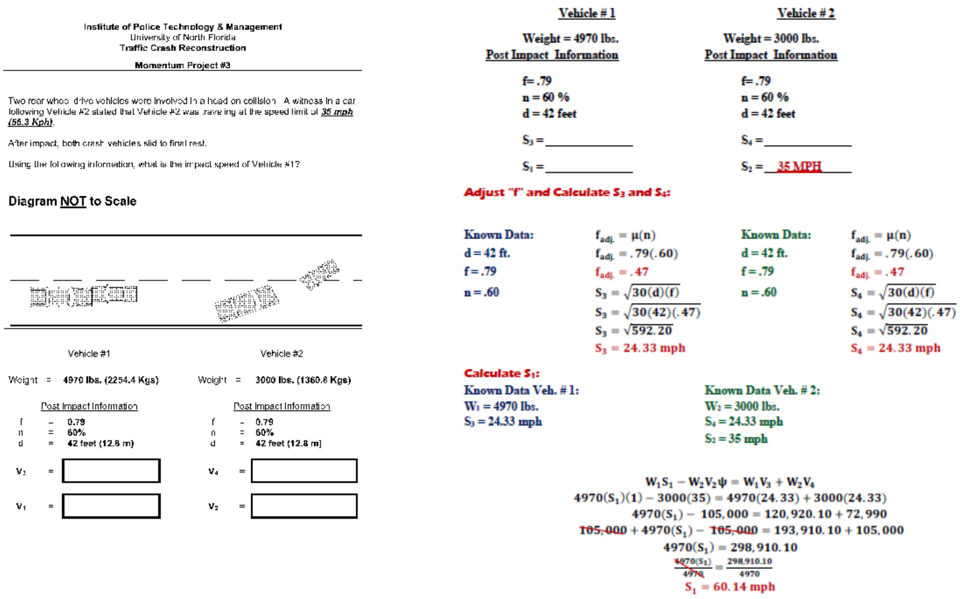

圖 19 線性動量作業案例

二維動量

但是，在大多數交通事故之碰撞時車輛#1 和車輛#2 之間存在角度，且其離開時角度亦不同，可以使用笛卡爾坐標係來測量車輛碰撞時接近角度和碰撞後離開角度，以 α 、Ψ 來定義車輛 1、車輛 2 碰撞前之角度，θ 、Φ 定義車輛 1、車輛 2 碰撞後之角度，車輛碰撞之角度可以利用量角器丈量，如圖 20 所示。二維動量作業案例如圖 21 所示。

使用 360 度二維系統通過角度測量求解衝擊速度 V2 的基本方程為：

$$V_2 = \frac{W_1 V_3 \sin\theta}{W_2 \sin\psi} + \frac{V_4 \sin\phi}{\sin\psi}$$

使用 360 度二維系統通過角度測量求解衝擊速度 V1 的基本方程為：

$$V_1 = V_3 \mathrm{Cos}\,\theta + \frac{W_2 V_4 \cos\phi}{W_1} - \frac{W_2 V_2 \cos\psi}{W_1}$$

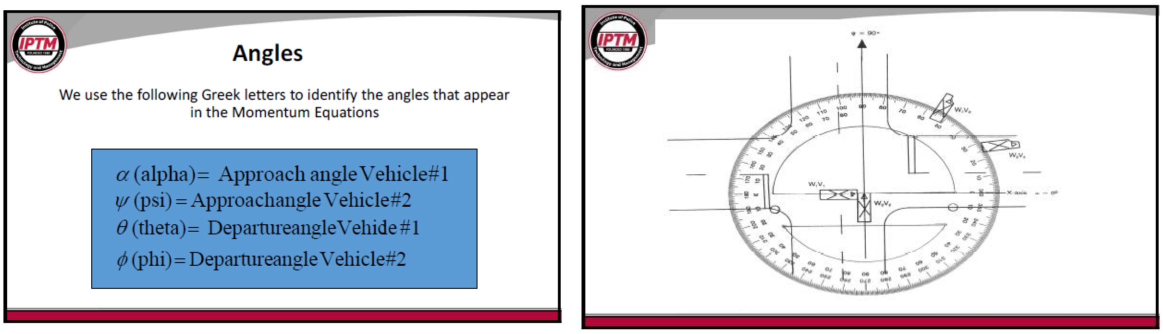

圖 20 車輛碰撞前後之角度定義

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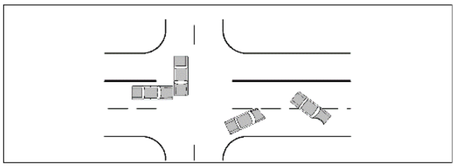
Two Dimensional (360) Momentum Project #1-Online

Two vehicles were involved in a collision. Both vehicles were moving when the impact took place.

After impact, both crash vehicles slid to final rest.

Using the following information, calculate the impact speeds of both vehicles.

Diagram NOT to Scale



Vehicle #1				Vehicle #2			
Weight	=	**2400 lbs. / 1088.6 Kgs**		Weight	=	**4100 lbs./1859.7 Kgs**	
Approach	**α**	=	0º	Approach	**Ψ**	=	270º
Departure	**θ**	=	310º	Departure	**Φ**	=	320º

Post Impact Information (Vehicle #1)
f = **0.65**
n = **100%**
d = **30 feet (9.1 m)**

Post Impact Information (Vehicle #2)
f = **0.65**
n = **100%**
d = **26 feet (7.9 m)**

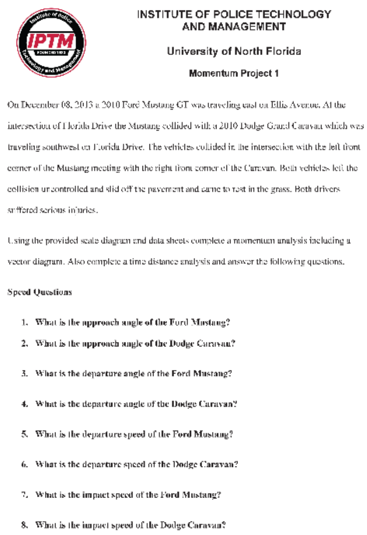
1. V_3 = ☐ **2. V_4 =** ☐

3. V_1 = ☐ **4. V_2 =** ☐

圖 21 二維動量作業案例

八、 功動量(Working Momentum)

第七週之課程大綱為功動量，本週以實作為主，講師以紙、筆、量角器等，先行示範 2 個案例，讓學員利用案例了解車輛碰撞後的動量變化情形，再由學員完成 2 個測驗並繪製車輛碰撞之向量圖方能完成本週的課程，其中之一作業案例如圖 22 所示，其解答如圖 23 所示。



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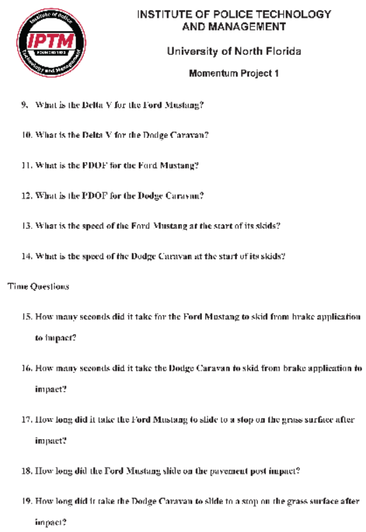
Momentum Project 1

On December 08, 2013 a 2010 Ford Mustang GT was traveling east on Ellis Avenue. At the intersection of Florida Drive the Mustang collided with a 2010 Dodge Grand Caravan which was traveling southwest on Florida Drive. The vehicles collided in the intersection with the left front corner of the Mustang meeting with the right front corner of the Caravan. Both vehicles left the collision uncontrolled and slid off the pavement and came to rest in the grass. Both drivers suffered serious injuries.

Using the provided scale diagram and data sheets complete a momentum analysis including a vector diagram. Also complete a time distance analysis and answer the following questions.

Speed Questions

1. **What is the approach angle of the Ford Mustang?**
2. **What is the approach angle of the Dodge Caravan?**
3. **What is the departure angle of the Ford Mustang?**
4. **What is the departure angle of the Dodge Caravan?**
5. **What is the departure speed of the Ford Mustang?**
6. **What is the departure speed of the Dodge Caravan?**
7. **What is the impact speed of the Ford Mustang?**
8. **What is the impact speed of the Dodge Caravan?**



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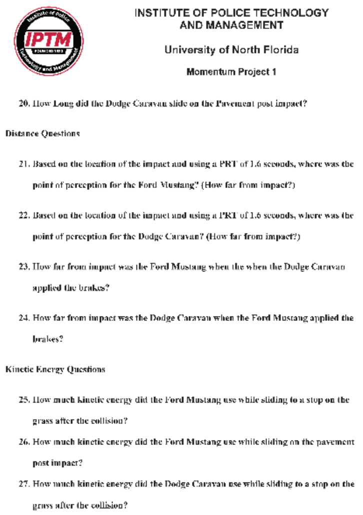
Momentum Project 1

9. **What is the Delta V for the Ford Mustang?**
10. **What is the Delta V for the Dodge Caravan?**
11. **What is the PDOF for the Ford Mustang?**
12. **What is the PDOF for the Dodge Caravan?**
13. **What is the speed of the Ford Mustang at the start of its skids?**
14. **What is the speed of the Dodge Caravan at the start of its skids?**

Time Questions

15. **How many seconds did it take for the Ford Mustang to skid from brake application to impact?**
16. **How many seconds did it take the Dodge Caravan to skid from brake application to impact?**
17. **How long did it take the Ford Mustang to slide to a stop on the grass surface after impact?**
18. **How long did the Ford Mustang slide on the pavement post impact?**
19. **How long did it take the Dodge Caravan to slide to a stop on the grass surface after impact?**

8



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Momentum Project 1

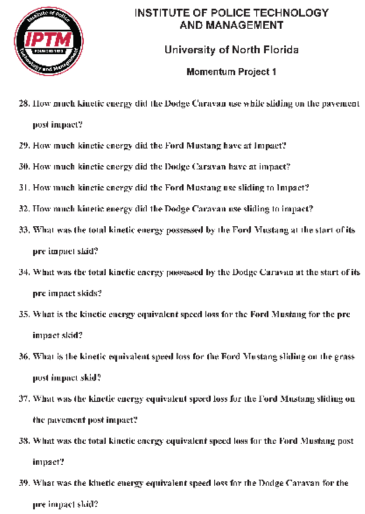
20. **How Long did the Dodge Caravan slide on the Pavement post impact?**

Distance Questions

21. **Based on the location of the impact and using a PRT of 1.6 seconds, where was the point of perception for the Ford Mustang? (How far from impact?)**
22. **Based on the location of the impact and using a PRT of 1.6 seconds, where was the point of perception for the Dodge Caravan? (How far from impact?)**
23. **How far from impact was the Ford Mustang when the when the Dodge Caravan applied the brakes?**
24. **How far from impact was the Dodge Caravan when the Ford Mustang applied the brakes?**

Kinetic Energy Questions

25. **How much kinetic energy did the Ford Mustang use while sliding to a stop on the grass after the collision?**
26. **How much kinetic energy did the Ford Mustang use while sliding on the pavement post impact?**
27. **How much kinetic energy did the Dodge Caravan use while sliding to a stop on the grass after the collision?**



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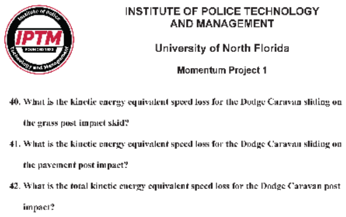
Momentum Project 1

28. **How much kinetic energy did the Dodge Caravan use while sliding on the pavement post impact?**
29. **How much kinetic energy did the Ford Mustang have at Impact?**
30. **How much kinetic energy did the Dodge Caravan have at impact?**
31. **How much kinetic energy did the Ford Mustang use sliding to Impact?**
32. **How much kinetic energy did the Dodge Caravan use sliding to impact?**
33. **What was the total kinetic energy possessed by the Ford Mustang at the start of its pre impact skid?**
34. **What was the total kinetic energy possessed by the Dodge Caravan at the start of its pre impact skids?**
35. **What is the kinetic energy equivalent speed loss for the Ford Mustang for the pre impact skid?**
36. **What is the kinetic equivalent speed loss for the Ford Mustang sliding on the grass post impact skid?**
37. **What was the kinetic energy equivalent speed loss for the Ford Mustang sliding on the pavement post impact?**
38. **What was the total kinetic energy equivalent speed loss for the Ford Mustang post impact?**
39. **What was the kinetic energy equivalent speed loss for the Dodge Caravan for the pre impact skid?**



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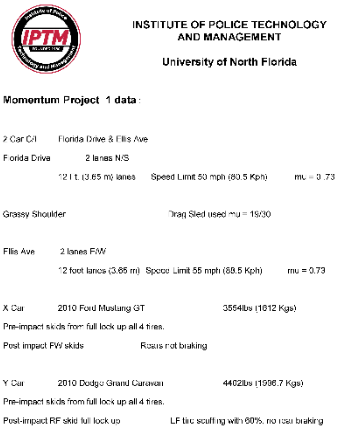
Momentum Project 1

40. What is the kinetic energy equivalent speed loss for the Dodge Caravan sliding on the grass post impact skid?

41. What is the kinetic energy equivalent speed loss for the Dodge Caravan sliding on the pavement post impact?

42. What is the total kinetic energy equivalent speed loss for the Dodge Caravan post impact?



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Momentum Project 1 data:

2 Car C/I Florida Drive & Ellis Ave

Florida Drive 2 lanes N/S

12 ft. (3.65 m) lanes Speed Limit 50 mph (80.5 Kph) mu = 0.73

Grassy Shoulder Drag Sled used mu = 19/30

Ellis Ave 2 lanes E/W

12 foot lanes (3.65 m) Speed Limit 55 mph (88.5 Kph) mu = 0.73

X Car 2010 Ford Mustang GT 3554lbs (1612 Kgs)

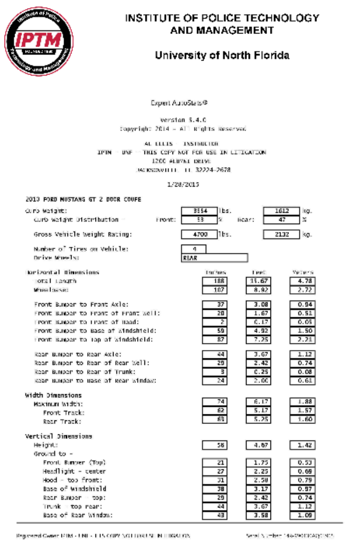
Pre-impact skids from full lock up all 4 tires.

Post impact FW skids Rears not braking

Y Car 2010 Dodge Grand Caravan 4402lbs (1996.7 Kgs)

Pre-impact skids from full lock up all 4 tires.

Post-impact RF skid full lock up LF tire scuffing with 60%, no rear braking



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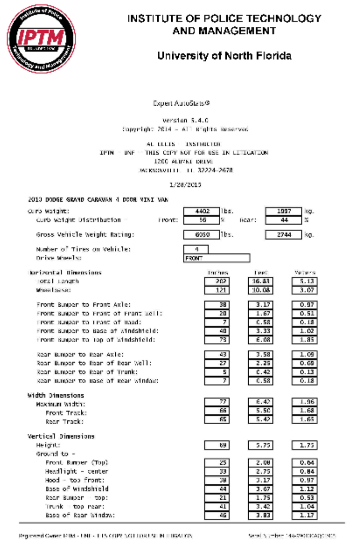
1200 ALUMNI DRIVE
JACKSONVILLE FL 32224-2678

1/28/2015

2010 FORD MUSTANG GT 2 DOOR COUPE

Curb Weight:		3554 lbs.		1612 kg.
Curb Weight Distribution –	Front:	53 %	Rear:	47 %
Gross Vehicle Weight Rating:		4700 lbs.		2132 kg.
Number of Tires on Vehicle:		4		
Drive Wheels:		REAR		

	Inches	Feet	Meters
Horizontal Dimensions			
Total Length	188	15.67	4.78
Wheelbase:	107	8.92	2.72
Front Bumper to Front Axle:	37	3.08	0.94
Front Bumper to Front of Front Well:	20	1.67	0.51
Front Bumper to Front of Hood:	2	0.17	0.05
Front Bumper to Base of Windshield:	59	4.92	1.50
Front Bumper to Top of Windshield:	87	7.25	2.21
Rear Bumper to Rear Axle:	44	3.67	1.12
Rear Bumper to Rear of Rear Well:	29	2.42	0.74
Rear Bumper to Rear of Trunk:	3	0.25	0.08
Rear Bumper to Base of Rear Window:	24	2.00	0.61
Width Dimensions			
Maximum Width:	74	6.17	1.88
Front Track:	62	5.17	1.57
Rear Track:	63	5.25	1.60
Vertical Dimensions			
Height:	56	4.67	1.42
Ground to –			
Front Bumper (Top)	21	1.75	0.53
Headlight – center	27	2.25	0.69
Hood – top front:	31	2.58	0.79
Base of Windshield	38	3.17	0.97
Rear Bumper – top:	29	2.42	0.74
Trunk – top rear:	44	3.67	1.12
Base of Rear Window:	43	3.58	1.09



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1200 ALUMNI DRIVE
JACKSONVILLE FL 32224-2678

1/28/2015

2010 DODGE GRAND CARAVAN 4 DOOR MINI VAN

Curb Weight:		4402 lbs.		1997 kg.
Curb Weight Distribution –	Front:	56 %	Rear:	44 %
Gross Vehicle Weight Rating:		6050 lbs.		2744 kg.
Number of Tires on Vehicle:		4		
Drive Wheels:		FRONT		

	Inches	Feet	Meters
Horizontal Dimensions			
Total Length	202	16.83	5.13
Wheelbase:	121	10.08	3.07
Front Bumper to Front Axle:	38	3.17	0.97
Front Bumper to Front of Front Well:	20	1.67	0.51
Front Bumper to Front of Hood:	7	0.58	0.18
Front Bumper to Base of Windshield:	40	3.33	1.02
Front Bumper to Top of Windshield:	73	6.08	1.85
Rear Bumper to Rear Axle:	43	3.58	1.09
Rear Bumper to Rear of Rear Well:	27	2.25	0.69
Rear Bumper to Rear of Trunk:	5	0.42	0.13
Rear Bumper to Base of Rear Window:	7	0.58	0.18
Width Dimensions			
Maximum Width:	77	6.42	1.96
Front Track:	66	5.50	1.68
Rear Track:	65	5.42	1.65
Vertical Dimensions			
Height:	69	5.75	1.75
Ground to –			
Front Bumper (Top)	25	2.08	0.64
Headlight – center	33	2.75	0.84
Hood – top front:	38	3.17	0.97
Base of Windshield	44	3.67	1.12
Rear Bumper – top:	21	1.75	0.53
Trunk – top rear:	41	3.42	1.04
Base of Rear Window:	46	3.83	1.17

圖 22 功動量作業案例

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Traffic Crash Reconstruction

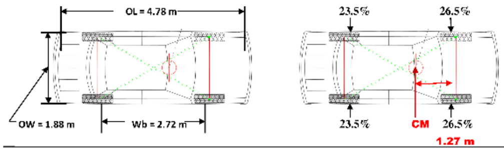
Working Momentum Project No. 1-Online TCR
Metric Units Solution Guide

2010 Ford Mustang GT
(Vehicle # 1) Dimensions

OL	OW	Wb	TW	Weight%	FO
4.78 m	1.88 m	2.72 m	1.60 m	53/47	.94 m

W_r = 47% Total Weight $W_r = 1612(.47)$ W_r = 757.64 Kgs

$$X_f = \frac{W_r(W_b)}{W} \quad X_f = \frac{757.64(2.72)}{1612} \quad X_f = \frac{2060.78}{1612} \quad X_f = 1.27\ m$$

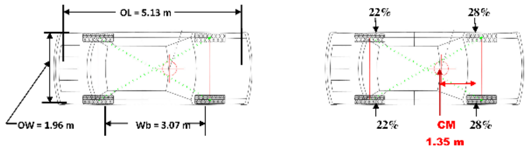


2010 Dodge Grand Caravan
(Vehicle # 2) Dimensions

OL	OW	Wb	TW	Weight%	FO
5.13 m	1.96 m	3.07 m	1.65 m	56/44	.97 m

W_r = 44% Total Weight $W_r = 1997(.44)$ W_r = 878.68 Kgs

$$X_f = \frac{W_r(W_b)}{W} \quad X_f = \frac{878.68(3.07)}{1997} \quad X_f = \frac{2697.54}{1997} \quad X_f = 1.35\ m$$



Ford (V1) Pre and Post Impact Info
Finding and Adjusting "f"

W1-1612 Kgs
Pre Impact Info
D-29.8 m
µ=.73
Post Impact Info
D Road-4.2 m
µ(road)-.73
D Grass-3.2 m
µ(Grass)-.63

Drag sled-Grass

$$f = \frac{F}{W}$$

$$f = \frac{19}{30}$$

$$f = 0.633\ g's$$

Brake Info
"n"=.53

~~26.5~~	53%	~~26.5~~
23.5	47%	23.5

"f" Adj.-Grass
"f" Adj. = (µ x n) +/- m
"f" Adj. = (.63 x.53) +/- 0
"f" Adj. = .33

"f" Adj.-Road
"f" Adj. = (µ x n) +/- m
"f" Adj. = (.73 x.53) +/- 0
"f" Adj. = .38

Speed @ Grass

$$S = \sqrt{254 \times D \times f}$$
$$S = \sqrt{254 \times 3.2 \times 0.33}$$
$$S = \sqrt{268.22}$$
$$S = 16.37\ km/h$$

Speed Combined-Post Impact – S3

$$S = \sqrt{S_0^2 \pm 254 \times D \times f}$$
$$S = \sqrt{16.37^2 + 254 \times 4.2 \times 0.38}$$
$$S = \sqrt{267.97 + 405.38}$$
$$S = \sqrt{673.35}$$
$$S = 25.94\ km/h$$

Dodge (V2) Pre and Post Impact Info
Finding and Adjusting "f"

W1-1997 Kgs
Pre Impact Info
D-13.6 m
µ=.73
Post Impact Info
D Road-4.4 m
µ(road)-.73
D Grass-22.2 m
µ(Grass)-.63

Drag sled-Grass

$$f = \frac{F}{W}$$

$$f = \frac{19}{30}$$

$$f = 0.633\ g's$$

Brake Info

28	56%	~~28~~
22	44%	22

"f" R/F Tire-Grass
"f" Adj. = (µ x n) +/- m
"f" Adj. = (.63 x.28) +/- 0
"f" Adj. = .17

"f" L/F Tire-Grass
"f" Adj. = (µ x n) +/- m
"f" Adj. = (.63 x.28) +/- 0
"f" Adj. = .17

"f" L/F Tire @ 60 %
"f" Adj. = f x n
"f" Adj. = (.17 x.60)
"f" Adj. = .10

"f" Adj.-Grass
"f" Adj. R/F = .17
"f" Adj. L/F(60%) = .10
"f" Adj. Grass = .27

"f" R/F Tire-Road
"f" Adj. = (µ x n) +/- m
"f" Adj. = (.73 x.28) +/- 0
"f" Adj. = .20

"f" L/F Tire-Road
"f" Adj. = (µ x n) +/- m
"f" Adj. = (.73 x.28) +/- 0
"f" Adj. = .20

"f" L/F Tire @ 60 %
"f" Adj. = f x n
"f" Adj. = (.20 x.60)
"f" Adj. = .12

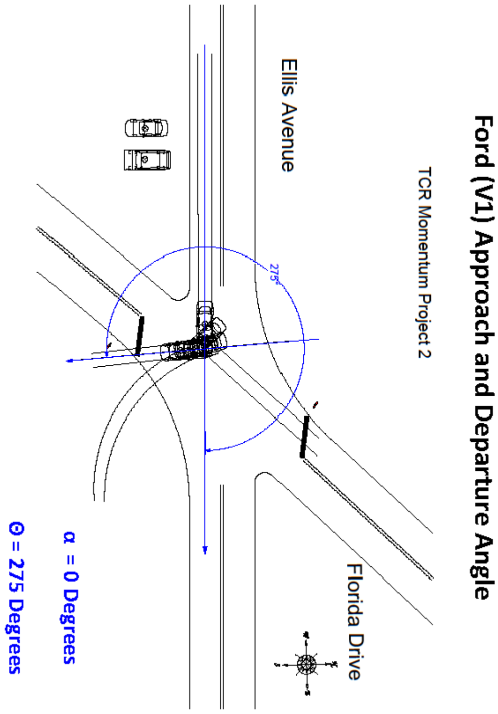
"f" Adj.-Road
"f" Adj. R/F = .20
"f" Adj. L/F(60%) = 12
"f" Adj. Road = .32

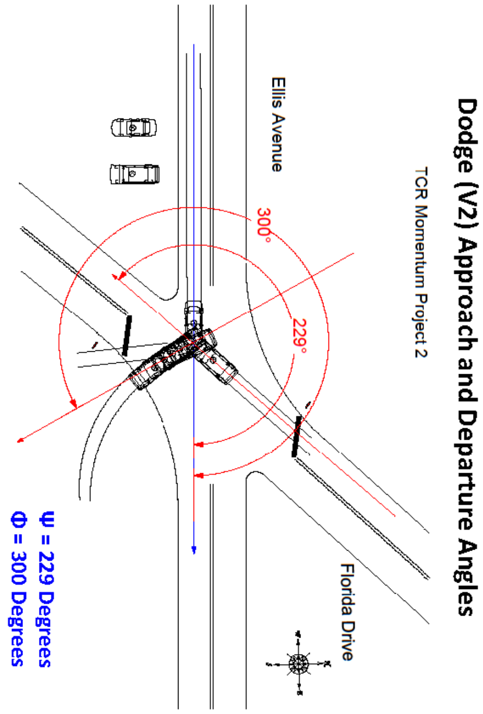
Speed @ Grass

$$S = \sqrt{254 \times D \times f}$$
$$S = \sqrt{254 \times 22.2 \times 0.27}$$
$$S = \sqrt{1522.47}$$
$$S = 39.01\ km/h$$

Speed Combined-Post Impact - S4

$$S = \sqrt{S_0^2 \pm 254 \times D \times f}$$
$$S = \sqrt{39.01^2 + 254 \times 4.4 \times 0.32}$$
$$S = \sqrt{1521.78 + 357.63}$$
$$S = \sqrt{1879.41}$$
$$S = 43.35\ km/h$$





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Vector Sum Solution-Momentum Project 2 Online-Metric Units

Mathematically determine the X and Y components of each departure vector and record them in the chart below.

Vector	Weight	Speed	Magnitude	Angle		Cos	Sin
P_1	1612	92.00	148,304.00	α	0º	1.00	0
P_2	1997	77.38	154,533.53	ψ	229	-.6561	-.7547
P_3	1612	25.94	41,815.28	θ	300	.0872	-.9962
P_4	1997	43.35	86,569.95	ϕ	275	.5000	-.8660
				β	71	.3256	.9455

P_n ($Cos_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***cosine*** of the departure angle formed by that vector and the "X" axis.

P_n ($Sin_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***sine*** of the departure angle formed by that vector and the "X" axis.

Vector	X Components	Y Components
P_3	$P_{3_X} = Pn(Cos\Theta)$	$P_{3_Y} = Pn(Sin\Theta)$
	3,646.29	-41,656.38
P_4	$P_{4_X} = Pn(Cos\phi)$	$P_{4_Y} = Pn(Sin\phi)$
	43,284.97	-74,969.57

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Vector Sum Project

P_t (Resultant vector) co-ordinates are represented by the sums of the P_3 and P_4 components. Calculate the coordinates of P_t and record them in the chart below.

	X Components			Y Components	
P_{3x} =	3,646.29	(X)	P_{3y} =	-41,656.38	(Y)
P_{4x} =	43,284.97	(X)	P_{4y} =	-74,969.57	(Y)
+			+		
Pt_x =	46,931.26	(X)	Pt_y =	-116,625.95	(Y)

Calculate the Magnitude of the Resultant Vector (P_t).

$Magnitude_{Resultant}$ =	$P_t = \sqrt{P_{t_X}^2 + P_{t_Y}^2}$	
Magnitude Pt =	125,714.57	Units

Calculate the Direction of the Resultant Vector (P_t).

Direction (Angle) =	$Tan_{(Angle)} = \left(\frac{Rise}{Run}\right)$ and $\tan^{-1}\left(\frac{P_{t_Y}}{P_{t_X}}\right)$ = Angle°	
Direction =	-68.07	º

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Vector Sum Project

Calculate the Impact Speed of the Y vehicle.

	Pt_Y	W_2	Sin ψ	$S_2 = \left(\frac{P_{t_Y}}{W_2 Sin\psi}\right)$
S_2 =	-116,625.95	1997	-.7547	77.38 Kph

Calculate the Magnitude of the Impact Speed of the Y vehicle.

	W_2	S_2		$P_2 = W_2 S_2$
P_2 =	1997	77.38		154,527.86

Calculate the X component of the Y vehicle's impact speed.

	W_2	S_2	Cos ψ	$P_{2_X} = W_2 S_2 Cos\psi$
P_{2x} =	1997	77.38	-.6561	-101,385.72

Calculate the Impact Speed of the X vehicle.

	P_{tx}	W_1	P_{2x}	$S_1 = \left(\frac{P_{t_X} - P_{2_X}}{W_1}\right)$
S_1 =	46,931.26	1612	-101,385.72	92.00 Kph

Calculate the Magnitude of the Impact Speed of the X vehicle.

	W_1	S_1		$P_1 = W_1 S_1$
P_1 =	1612	92.00		148,304.00

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Vector Sum Project

Calculate the ΔS of the Y vehicle.

	S_2	S_4	Cos β	$\Delta S_2 = \sqrt{[S_2{}^2 + S_4{}^2] - [2(S_2)(S_4)(Cos\beta)]}$
ΔS_2 =	77.38	43.35	.3256	75.38 Kph

Calculate the ΔS of the X vehicle.

	S_1	S_3	Cos θ	$\Delta S_1 = \sqrt{[S_1{}^2 + S_3{}^2] - [2(S_1)(S_3)(Cos\theta)]}$
ΔS_1 =	92.00	25.94	.0872	98.38 Kph

Calculate the Magnitude of the Impulse Vector acting on the Y vehicle.

	W_2	ΔS_2		$\Delta\rho_2 = W_2(\Delta S_2)$
$\Delta \rho_2$	1997	75.38		150,533.86

Calculate the Magnitude of the Impulse Vector acting on the X vehicle.

	W_1	ΔS_1		$\Delta\rho_1 = W_1(\Delta S_1)$
$\Delta \rho_1$	1612	93.38		150,528.56

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Vector Sum Project

Calculate the PDOF acting on the Y vehicle.

	S_4	Sin β	ΔS_2	$\alpha_2 = Sin^{-1}\left(\frac{S_4 Sin\beta}{\Delta S_2}\right)$
α_2	43.35	.9455	75.38	32.93 º

Calculate the PDOF acting on the X vehicle.

	S_3	Sin θ	ΔS_1	$\alpha_1 = Sin^{-1}\left(\frac{S_3 Sin\theta}{\Delta S_1}\right)$
α_1	25.94	-.9962	98.38	-16.06 º

Check digit using the PDOF's.

	α_1	α_2		$\Psi = 180 +/- (\alpha_1 + \alpha_2)$
Ψ	-16.06 º	32.93 º		228.99 º

$\psi = 180 - (\alpha_1 + \alpha_2)$ - **Use this formula if PSI is between 0 and 180 degrees**

$\psi = 180 + \alpha_1 + \alpha_2$ - **Use this formula if PSI is between 180 and 360 Degrees**

a1 and a2 are entered as absolute values in these equations

Momentum Project 2 – Momentum Solution

$W_1 = 1612$ Kgs
$S_3 = 25.94$ Kph

$W_2 = 1997$ Kgs
$S_4 = 43.35$ Kph

Angle	Cos	Sin
α = 0°	1	0
ψ = 229°	-.6561	-.7547
θ = 275°	.0872	-.9962
ϕ = 300°	.5000	-.8660

$$W_2 S_2 Sin\psi = W_1 S_3 Sin\theta + W_2 S_4 Sin\phi$$
$$1997(S_2)\,^{-}.7547 = 1612(25.94)\,^{-}.9962 + 1997(43.35)\,^{-}.8660$$
$$^{-}1507.13(S_2) = \,^{-}41,656.38 + \,^{-}74,969.57$$
$$^{-}1507.13(S_2) = \,^{-}116,625.95$$
$$\frac{^{-}1504.13(S_2)}{^{-}1504.13} = \frac{^{-}116,625.95}{^{-}1504.13}$$
$$S_2 = 77.53 \text{ Kph}$$

$$W_1 S_1 Cos \propto + W_2 S_2 Cos\psi = W_1 S_3 Cos\theta + W_2 S_4 Cos\phi$$
$$1612(S_1)(1) + 1997(77.53)\,^{-}.6561 = 1612(25.94)(.0872) + 1997(43.35)(.5000)$$
$$1612(S_1) + \,^{-}101,582.26 = 3,646.29 + 43,284.97$$
$$1612(S_1) + \,^{-}101,582.26 = 46,931.26$$
$$101,582.26 + 1612(S_1) + \,^{-}101,582.26 = 46,931.26 + 101,582.26$$
$$1612(S_1) = 148,513.52$$
$$\frac{1612(S_1)}{1612} = \frac{148,513.52}{1612}$$
$$S_1 = 92.12 \text{ Kph}$$

$$S_2 = \frac{W_1 S_3 \ Sin\ \theta}{W_2\ Sin\ \psi} + \frac{S_4\ Sin\ \phi}{Sin\ \psi}$$
$$S_2 = \frac{1612(25.94)(^{-}.9962)}{1997(^{-}.7547)} + \frac{43.35(^{-}.8660)}{^{-}.7547}$$
$$S_2 = \frac{^{-}41,656.38}{^{-}1,507.13} + \frac{^{-}37.45}{^{-}.7547}$$
$$S_2 = 27.63 + 49.62$$
$$S_2 = 77.25 \text{ Kph}$$

$$S_1 = S_3\ Cos\ \theta + \frac{W_2 S_4\ Cos\ \phi}{W_1} - \frac{W_2 S_2\ Cos\ \psi}{W_1}$$
$$S_1 = 25.94(.0872) + \frac{1997(43.35)(.5000)}{1612} - \frac{1997(77.25)(^{-}.6561)}{1612}$$
$$S_1 = 1.62 + \frac{43,284.97}{1612} - \frac{^{-}101,215.39}{1612}$$
$$S_1 = 2.26 + 26.85 - \,^{-}62.78$$
$$S_1 = 91.89 \text{ Kph}$$

Traffic Crash Reconstruction Working Momentum Project #2 – Online – U.S. Units

Question # 1 – 0 Degrees

Question # 2 – 229 Degrees

Question # - 3 - 275 Degrees

Question # - 4 – 300 Degrees

Question # - 5 – 25.94 Kph

Question # - 6 – 43.35 Kph

Question # - 7 – 92.00 Kph

Question # - 8 – 77.38 Kph

Question # - 9 – 93.38 Kph

Question # - 10 – 45.37 Kph

Question # -11 – -16.06 Degrees

Question # - 12 – -32.93 Degrees

Question # -13 – 118.27 Kph

Question # - 14 – 92.24 Kph

Question # 13

Ford Impact Speed
S = 54.67 Mph
V = 80.14 Fps
Skid Distance
D = 91 Ft.
“f” = .73
“a” = 23.50 Fps/s

$$S = \sqrt{S_0^2 \pm 254 \times D \times f}$$

$$S = \sqrt{92.00^2 + 254 \times 29.8 \times 0.73}$$

$$S = \sqrt{8464 + 5525.51}$$

$$S = \sqrt{13989.51}$$

$$S = 118.27 \quad km/h$$

Question # 14

Dodge Impact Speed
S = 47.16 Mph
V = 69.13 Fps
Skid Distance
D = 42 Ft.
“f” = .73
“a” = 23.50 Fps/s

$$S = \sqrt{S_0^2 \pm 254 \times D \times f}$$

$$S = \sqrt{77.38^2 + 254 \times 13.6 \times 0.73}$$

$$S = \sqrt{5987.66 + 2521.71}$$

$$S = \sqrt{8509.37}$$

$$S = 92.24 \quad km/h$$

Question # 15

Ford Data
S Impact = 92.00 Kph
S Initial = 118.27 Kph
V1= 25.55 Mps
V2 = 32.85 Mps
“f” = .73
“a” = 7.16 Mps/s

Ford Start of Skid to Impact

$$t = \frac{V_f - V_i}{A}$$

$$t = \frac{32.85 - 25.55}{7.16}$$

$$t = \frac{7.3}{7.16}$$

$$t = 1.01 \quad seconds$$

Question # 16

Dodge Data
S Impact = 77.38 Kph
S Initial = 92.24 Kph
V1= 21.49 Mps
V2 = 25.62 Mps
“f” = .73
“a” = 7.16 Mps/s

Dodge Start of Skids to Impact

$$t = \frac{V_f - V_i}{A}$$

$$t = \frac{25.62 - 21.49}{7.16}$$

$$t = \frac{4.13}{7.16}$$

$$t = 0.57 \quad seconds$$

Question # 17

Ford Data
S End = 0 Mph
S Grass = 16.37ph
V1= 4.54ps
V2 = 0 Fps
“f” = .33
“a” = 3.23 Mps/s

Ford Time On Grass

$$t = \frac{V_f - V_i}{f \times g}$$

$$t = \frac{4.54 - 0}{0.32 \times 9.81}$$

$$t = \frac{4.54}{3.13}$$

$$t = 1.45 \quad seconds$$

Question # 18

Ford Data
S Grass= 16.37 Kph
S Road = 25.94 Kph
V1= 4.54 Mps
V2 = 7.20 Mps
“f” = .38
“a” = 3.72 Mps/s

Ford Time On Road

$$t = \frac{V_f - V_i}{A}$$

$$t = \frac{7.2 - 4.54}{3.72}$$

$$t = \frac{2.66}{3.72}$$

$$t = 0.71 \quad seconds$$

Question # 19

Dodge Data
S End = 0 Mph
S Grass = 39.01ph
V1= 0 Fps
V2 = 10.84 Mps
“f” = .27
“a” = 2.64 Mps/s

Dodge Time On Grass

$$t = \frac{V_f - V_i}{A}$$

$$t = \frac{10.84 - 0}{2.64}$$

$$t = \frac{10.84}{2.64}$$

$$t = 4.1 \quad seconds$$

Question # 20

Dodge Data
S Road = 49.35 Kph
S Grass = 39.01 Kph
V1= 12.04 Mps
V2 = 10.84 Mps
“f” = .32
“a” = 3.13 Mps/s

Dodge Time On Road

$$t = \frac{V_f - V_i}{A}$$

$$t = \frac{12.04 - 10.84}{3.13}$$

$$t = \frac{1.2}{3.13}$$

$$t = 0.38 \quad seconds$$

Question # 21

Ford Data
S @ Start = 118.27 Kph
V = 32.85 Mps
“f” = .73
“a” = 7.16 Mps/s
D Slide = 29.8 m

Ford Distance From Impact Including PRT

$$D = V \times t$$

$$D = 32.85 \times 1.6$$

$$D = 52.56 \quad meters$$

PRT Dist. = 52.56
Slide Dist. = 29.8
Dist. To POI = 82.36 M

Dodge Distance From Impact Including PRT

Question # 22

Dodge Data
S @ Start = 92.24 Kph
V = 25.62 Mps
"f" = .73
"a" = 7.16 Mps/s
D Slide = 13.6 M Ft.

$$D = V \times t$$

$$D = 25.62 \times 1.6$$

$$D = 40.99 \text{ meters}$$

PRT Dist. = 40.99
Slide Dist. = 13.6
Dist. To POI = 54.59 m

Ford Distance From Impact When Dodge Began To Brake

Question # 23

Dodge Data
S @ Start = 92.24 Kph
V = 25.62 Mps
"f" = .73
"a" = 7.16 Mps/s
D Slide = 13.6 m
"t" - .57 Secs (#16)

$$D = V_i \times t \pm 0.5 \times a \times t^2$$

$$D = 25.92 \times 0.57 - 0.5 \times 7.16 \times 0.57^2$$

$$D = 14.77 - 0.5 \times 7.16 \times 0.32$$

$$D = 14.77 - 1.14$$

$$D = 13.63 \text{ meters}$$

Dodge Distance From Impact When Ford Began To Brake

Question # 24

Ford Data
Vo = 32.85 Mps
"t" = 1.01 Sec
"f" = .73
D = 13.6 m

Dodge Time @ Constant Speed
"t" V1 – 1.01 (#15)
"t" V2 - .57 (#16)
Time Diff. -.44

$$D = V \times t$$

$$D = 32.85 \times 0.44$$

$$D = 14.45 \text{ meters}$$

D total = D1 + D2
D total = 14.45 + 13.6
D Total = 28.05 m

Question # 25

Ford Data
"f" - .33
W – 1612 Kgs
D – 3.2 m

Ford Wk Grass

$$W_s = w \times f \times g \times D$$

$$W_s = 1612 \times 0.33 \times 9.81 \times 3.2$$

$$W_s = 16699.28 \text{ N-m}$$

Question # 26

Ford Data
"f" - .38
W – 1612 Kgs
D – 4.2 m

Ford Wk Road

$$W_s = w \times f \times g \times D$$

$$W_s = 1612 \times 0.38 \times 9.81 \times 4.2$$

$$W_s = 25238.69 \text{ N-m}$$

Question # 27

Dodge Data
"f" - .27
W – 1997 Kgs
D – 22.2 m

Dodge Wk Grass

$$W_s = w \times f \times g \times D$$

$$W_s = 1997 \times 0.27 \times 9.81 \times 22.2$$

$$W_s = 117425.87 \text{ N-m}$$

Question # 28

Dodge Data
"f" - .32
W – 1997 Kgs
D – 4.4 m

Dodge Wk Road

$$W_s = w \times f \times g \times D$$

$$W_s = 1997 \times 0.32 \times 9.81 \times 4.4$$

$$W_s = 27583.52 \text{ N-m}$$

Question # 29

Ford Data
Speed @ Imp.
92.00 Kph
W – 1612 Kgs

Ford Ke at Impact

$$KE = \frac{W \times S^2}{26}$$

$$KE = \frac{1612 \times 92.00^2}{26}$$

$$KE = \frac{1612 \times 8464}{26}$$

$$KE = \frac{13643968}{26}$$

$$KE = 524768 \text{ N-m}$$

Question # 30

Dodge Data
Speed @ Imp.
77.38 KPH
W – 1997 Kgs

Dodge Ke at Impact

$$KE = \frac{W \times S^2}{26}$$

$$KE = \frac{1997 \times 77.38^2}{26}$$

$$KE = \frac{1997 \times 5987.66}{26}$$

$$KE = \frac{11957357.02}{26}$$

$$KE = 459898.34 \text{ N-m}$$

Question # 31

Ford Data
"f" - .73
W – 1612 Kgs
D – 29.8

Ford Wk Pre Impact Slide

$$W_s = w \times f \times g \times D$$

$$W_s = 1612 \times 0.73 \times 9.81 \times 29.8$$

$$W_s = 344011.66 \text{ N-m}$$

Question # 32

Dodge Data
"f" - .73
W – 1997 Kgs
D – 13.6

Dodge Wk Pre impact Slide

$$W_s = w \times f \times g \times D$$

$$W_s = 1997 \times 0.73 \times 9.81 \times 13.6$$

$$W_s = 194495.17 \text{ N-m}$$

Question # 33

Ford Data
Speed @ Start
118.27 KPH
W – 1612 Kgs

Ford Ke @ Start

$$KE = \frac{W \times S^2}{26}$$

$$KE = \frac{1612 \times 118.27^2}{26}$$

$$KE = \frac{1612 \times 13987.79}{26}$$

$$KE = \frac{22548317.48}{26}$$

$$KE = 867242.98 \text{ N-m}$$

Question # 34

Dodge Data
Speed @ Start
92.24 KPH
W – 1997 Kgs

Dodge Ke @ Start

$$KE = \frac{W \times S^2}{26}$$

$$KE = \frac{1997 \times 92.24^2}{26}$$

$$KE = \frac{1997 \times 8508.21}{26}$$

$$KE = \frac{16990895.37}{26}$$

$$KE = 653495.97 \text{ N-m}$$

Question # 35
Ford Data
"f" - .73
D – 29.8 m

$$S=\sqrt{254\times D\times f}$$
$$S=\sqrt{254\times 29.8\times 0.73}$$
$$S=\sqrt{5525.51}$$
$$S=74.33\ \text{km/h}$$

Question # 39
Dodge Data
"f" - .73
D – 13.6 m

$$S=\sqrt{254\times D\times f}$$
$$S=\sqrt{254\times 13.6\times 0.73}$$
$$S=\sqrt{2521.71}$$
$$S=50.21\ \text{km/h}$$

Question # 36
Ford Data
"f" - .33
D – 3.2 m

$$S=\sqrt{254\times D\times f}$$
$$S=\sqrt{254\times 3.2\times 0.33}$$
$$S=\sqrt{268.22}$$
$$S=16.37\ \text{km/h}$$

Question # 40
Dodge Data
"f" - .27
D – 22.2 m

$$S=\sqrt{254\times D\times f}$$
$$S=\sqrt{254\times 22.2\times 0.27}$$
$$S=\sqrt{1522.47}$$
$$S=39.01\ \text{km/h}$$

Question # 37
Ford Data
"f" - .38
D – 4.2 m

$$S=\sqrt{254\times D\times f}$$
$$S=\sqrt{254\times 4.2\times 0.38}$$
$$S=\sqrt{405.38}$$
$$S=20.13\ \text{km/h}$$

Question # 41
Dodge Data
"f" - .32
D – 4.4 m

$$S=\sqrt{254\times D\times f}$$
$$S=\sqrt{254\times 4.4\times 0.32}$$
$$S=\sqrt{357.63}$$
$$S=18.91\ \text{km/h}$$

Question # 38
Ford Data
S1 – 16.37 Kph
S2 – 20.13 Kph

$$S_c=\sqrt{S_1^2+S_2^2}$$
$$S_c=\sqrt{16.37^2+18.64^2}$$
$$S_c=\sqrt{267.97+347.44}$$
$$S_c=\sqrt{615.41}$$
$$S_c=24.8\ \text{km/h}$$

Question # 42
Ford Data
S1 – 39.01 Kph
S2 – 18.91 Kph

$$S_c=\sqrt{S_1^2+S_2^2}$$
$$S_c=\sqrt{39.01^2+18.91^2}$$
$$S_c=\sqrt{1521.78+357.58}$$
$$S_c=\sqrt{1879.36}$$
$$S_c=43.35\ \text{km/h}$$

圖 23 功動量作業解答案例

九、 多次碰撞之離開方向與動量(Multiple Departures)

第八週之課程為多次碰撞之離開方向與動量，講師以實際案例演算示範後，學員需繪製車輛碰撞後之向量大小、角度、製作動量圖表及車輛之輪胎滑痕，作業案例如圖 24 所示，其解答如圖 25 所示。

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Multiple Departure Momentum Project

A 2007 Chevrolet 1500 Silverado, vin: 2GCEC13C77156XXXX , was travelling west on Main Street. The pickup was hauling a 2009 Puma RBKS 5th wheel camper, VIN #: 4X4TPUG219P02XXXX.

A 2010 Ford Expedition 4x4 bearing VIN: 1FMJU1G57AEB6XXXX, was travelling south on River Street.

The Ford struck the Chevrolet on the right rear quarter with sufficient force as to dislodge the travel trailer.

Main Street is a level, 4 lane asphalt, East/West road with 12 foot lanes and 8 foot shoulders. A 0.72 drag factor was found. The posted speed limit is 45 mph.

River Street is a level, 4 lane asphalt North/South road with 12 foot lanes and 8 foot shoulders. A 0.72 drag factor was found. The posted speed limit is 45 mph.

A manicured lawn was found on the southwest corner of this intersection. Drag sled tests found the grass to have a 0.55 drag factor.

The impact circle was identified as being within the intersection.

No Pre-impact skid marks were found for any vehicle in this crash. The Chevrolet Pickup truck left the impact using only 66% of its braking efficiency. The Puma Trailer left the impact using a full lock up of its rear tandems. The Ford Expedition left the impact with a full wheel lockup.

A scale diagram was completed and is included here. Vehicle Specs were obtained and are included here.

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Multiple Departure Momentum Project

Multiple Departure Momentum Project data

2 Car Crash Investigation Main and River Street

River Street – 4 Lanes N / S

12 Foot Lanes Speed Limit – 45 MPH / 72.4 KPH Mu = 0.72

Main Street – 4 Lanes E / W

12 Foot Lanes Speed Limit 45 MPH / 72.4 KPH Mu = 0.72

Grass Shoulder – "f" = 0.55

X Car – 2007 Chevrolet 1500 Silverado – 4448 Lbs. / 2018 Kgs.

2009 Puma 281 RBKS 5th Wheel Camper – 7670 Lbs / 3479.1 Kgs.

Trailer is 30ft (9.1 m) long and 8ft (2.4 m) wide, TW is 72 inches (1.8 m), CM is 5ft (1.5 m) in front of front axle. Kingpin is 26ft (7.9 m) from back edge of trailer. Center of rear axle is 6.0ft (1.8 m) in front of rear edge of trailer. Center of front axle is 8.5ft (2.6 m) in front of rear edge of trailer.

Pre-impact no skids

Post impact skids full lock up all 4 tires for trailer

All tires are scuffing at 66% for Pick up.

Y Car - 2010 Ford Expedition – 5805 Lbs. / 2633 Kgs.

No pre-impact tire marks

Post-impact full Lock up all 4 tires

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Multiple Departure Momentum Project

NADA GUIDES	2009 Palomino	Puma Fifth Wheel Series 281 RBKS

~~ValuesSpecifications~~Floor PlanSpecial Notes

	Specs	Investigation
RV Type	**Fifth Wheel**	
Length x Width	**30Ft (9.1m) x 8Ft (2.4m)**	**6 Ft. (1.8 m) Track**
Tandem Axles	**2**	
Weight Lbs/Kgs	**7102 Lbs. / 3221.4 Kgs**	**7670 Lbs. / 3479.1**
Self-Contained	**Yes**	
Slides	**1**	
Lead Tandem Axle		**8.5 Ft. (2.6 m) From rear of trailer**
Center of Mass		**5Ft. (1.5 m) In front of Lead Tandem Axle**
King Pin		**26 Ft. (7.9 m) From rear of trailer**

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Multiple Departure Momentum Project

Expert AutoStats®

Version 5.4.0

AL ELLIS - INSTRUCTOR
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1200 ALUMNI DRIVE
JACKSONVILLE FL 32224-2678

11/17/2015

2007 CHEVROLET C1500 SILVERADO 119WB 2 DOOR 4X2 PICKUP

Curb Weight:		4448 lbs.		2018 kg.
Curb Weight Distribution -	Front:	58 %	Rear:	42 %
Gross Vehicle Weight Rating:		6400 lbs.		2903 kg.
Number of Tires on Vehicle:		4		
Drive Wheels:		REAR		

Horizontal Dimensions	Inches	Feet	Meters
Total Length	206	17.17	5.23
Wheelbase:	119	9.92	3.02
Front Bumper to Front Axle:	39	3.25	0.99
Front Bumper to Front of Front Well:	20	1.67	0.51
Front Bumper to Front of Hood:	5	0.42	0.13
Front Bumper to Base of Windshield:	52	4.33	1.32
Front Bumper to Top of Windshield:	79	6.58	2.01
Rear Bumper to Rear Axle:	48	4.00	1.22
Rear Bumper to Rear of Rear Well:	27	2.25	0.69
Rear Bumper to Rear of Trunk:	5	0.42	0.13
Rear Bumper to Base of Rear Window:	90	7.50	2.29
Width Dimensions			
Maximum Width:	80	6.67	2.03
Front Track:	68	5.67	1.73
Rear Track:	67	5.58	1.70
Vertical Dimensions			
Height:	74	6.17	1.88
Ground to -			
Front Bumper (Top)	28	2.33	0.71
Headlight - center	37	3.08	0.94
Hood - top front:	46	3.83	1.17
Base of Windshield	52	4.33	1.32
Rear Bumper - top:	29	2.42	0.74
Trunk - top rear:	55	4.58	1.40
Base of Rear Window:	53	4.42	1.35

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Multiple Departure Momentum Project

Expert AutoStats®

Version 5.4.0

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1200 ALUMNI DRIVE
JACKSONVILLE FL 32224-2678

11/17/2015

2010 FORD EXPEDITION 4 DOOR 4X4 UTILITY

Curb Weight:	5805 lbs.		2633 kg.
Curb Weight Distribution -	Front: 54 %		Rear: 46 %
Gross Vehicle Weight Rating:	7700 lbs.		3493 kg.
Number of Tires on Vehicle:	4		
Drive Wheels:	4 Wheel Drive		

Horizontal Dimensions	Inches	Feet	Meters
Total Length	207	17.25	5.26
Wheelbase:	119	9.92	3.02
Front Bumper to Front Axle:	38	3.17	0.97
Front Bumper to Front of Front Well:	18	1.50	0.46
Front Bumper to Front of Hood:	7	0.58	0.18
Front Bumper to Base of Windshield:	51	4.25	1.30
Front Bumper to Top of Windshield:	80	6.67	2.03
Rear Bumper to Rear Axle:	50	4.17	1.27
Rear Bumper to Rear of Rear Well:	29	2.42	0.74
Rear Bumper to Rear of Trunk:	3	0.25	0.08
Rear Bumper to Base of Rear Window:	5	0.42	0.13
Width Dimensions			
Maximum Width:	79	6.58	2.01
Front Track:	67	5.58	1.70
Rear Track:	67	5.58	1.70
Vertical Dimensions			
Height:	77	6.42	1.96
Ground to -			
Front Bumper (Top)	20	1.67	0.51
Headlight - center	38	3.17	0.97
Hood - top front:	46	3.83	1.17
Base of Windshield	51	4.25	1.30
Rear Bumper - top:	27	2.25	0.69
Trunk - top rear:	44	3.67	1.12
Base of Rear Window:	51	4.25	1.30

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Multiple Departure Momentum Project

Speed Questions

1. What is the approach angle of the Chevrolet Silverado and Puma trailer?
2. What is the approach angle of the Ford Expedition?
3. What is the departure angle of the Chevrolet Silverado?
4. What is the departure angle for the Puma trailer?
5. What is the departure angle of the Ford Expedition?
6. What is the departure speed of the Chevrolet Silverado?
7. What is the departure speed for the Puma trailer?
8. What is the departure speed of the Ford Expedition?
9. What is the impact speed of the Chevrolet Silverado and Puma trailer?
10. What is the impact speed of the Ford Expedition?
11. What is the Delta V for the Chevrolet Silverado?
12. What is the Delta V for the Ford Expedition?
13. What is the PDOF for the Chevrolet Silverado?
14. What is the PDOF for the Ford Expedition?

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Multiple Departure Momentum Project

Time Questions

15. How long did it take the Chevrolet Silverado to slide to a stop after the collision?
16. How long did it take the Puma trailer to slide to a stop after the collision?
17. How long did it take the Ford Expedition to slide to a stop on the grass after the collision?
18. How long did the Ford Expedition slide on the pavement after the

collision. Kinetic Energy

19. How much kinetic energy did the Chevrolet Silverado use while sliding to a stop after the collision?
20. How much kinetic energy did the Puma trailer use while sliding to a stop after the collision?
21. How much kinetic energy did the Ford Expedition use while sliding on the grass to a stop after the collision.
22. How much kinetic energy did the Ford Expedition use while sliding on the pavement after the collision?

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Multiple Departure Momentum Project

23. How much kinetic energy did the Chevrolet Silverado and Puma trailer have at Impact?
24. How much kinetic energy did the Ford Expedition have at impact?
25. What is the kinetic energy equivalent speed loss for the Chevrolet Silverado post impact skid?
26. What is the kinetic energy equivalent speed loss for the Puma trailer post impact?
27. What is the kinetic energy equivalent speed loss for the Ford Expedition on the grass post impact skid?
28. What is the kinetic energy equivalent speed loss for the Ford Expedition on the pavement post impact?
29. What is the total kinetic energy equivalent speed loss for the Ford Expedition post impact?

圖 24 多次碰撞之離開方向與動量作業案例

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Multiple Departure Project

Speed Questions

1. What is the approach angle of the Chevrolet Silverado and Puma trailer? 0 degrees
2. What is the approach angle of the Ford Expedition? 90 degrees
3. What is the departure angle of the Chevrolet Silverado? 50 degrees
4. What is the departure angle for the Puma trailer? 81 degrees
5. What is the departure angle of the Ford Expedition? 61 degrees
6. What is the departure speed of the Chevrolet Silverado? 24.58mph/7.49 Kph
7. What is the departure speed for the Puma trailer? 29.58mph/9.01 Kph
8. What is the departure speed of the Ford Expedition? 34.66mph/10.56 kph
9. What is the impact speed of the Chevrolet Silverado and Puma trailer? 16.77mph/5.11 kph
10. What is the impact speed of the Ford Expedition? 83.33mph/25.39 kph
11. What is the Delta V for the Chevrolet Silverado? 18.85mph/5.73 Kph
12. What is the Delta V for the Puma Trailer? 31.63mph/9.64 Kph
13. What is the Delta V for the Chevrolet Silverado/ Puma Trailer combination? 27.01mph/8.23 kph

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14. What is the Delta V for the Ford Expedition? 55.61mph/16.94 kph
15. What is the PDOF for the Chevrolet Silverado/ Puma Trailer combination? 72.40 degrees
16. What is the PDOF for the Ford Expedition? 17.58 degrees

Time Questions

17. How long did it take the Chevrolet Silverado to slide to a stop after the collision? 1.58 seconds
18. How long did it take the Puma trailer to slide to a stop after the collision? 1.87 seconds
19. How long did it take the Ford Expedition to slide to a stop on the grass after the collision? 1.90 seconds
20. How long did the Ford Expedition slide on the pavement after the collision. 0.73 seconds

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Multiple Departure Project

Kinetic Energy

21. How much kinetic energy did the Chevrolet Silverado use while sliding to a stop after the collision? 89543 ft-lbs/121404.00 Nm
22. How much kinetic energy did the Puma trailer use while sliding to a stop after the collision? 223657 ft-lbs/303238.17 Nm
23. How much kinetic energy did the Ford Expedition use while sliding on the grass to a stop after the collision. 103445 ft-lbs/140252.58 Nm
24. How much kinetic energy did the Ford Expedition use while sliding on the pavement after the collision? 129024 ft-lbs/174933.05 Nm
25. How much kinetic energy did the Chevrolet Silverado and Puma trailer have at Impact? 113599 ft-lbs/154019.56 Nm
26. How much kinetic energy did the Ford Expedition have at impact? 1343642 ft-lbs/1821733.93 Nm
27. What is the kinetic energy equivalent speed loss for the Chevrolet Silverado post impact skid? 24.58mph/39.55 Kph
28. What is the kinetic energy equivalent speed loss for the Puma trailer post impact? 29.58mph/47.60 Kph

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Multiple Departure Project

29. What is the kinetic energy equivalent speed loss for the Ford Expedition on the grass post impact skid? 23.12mph/37.20 Kph
30. What is the kinetic energy equivalent speed loss for the Ford Expedition on the pavement post impact? 25.82mph/40.68 Kph
31. What is the total kinetic energy equivalent speed loss for the Ford Expedition post impact? 34.66mph/55.77 Kph

Distances used for analysis: WILL VARY!!

Silverado Post Impact – RF = 22ft/6.7 m, LF = 23ft/7.0 m,
RR = 35ft/10.6 m, LR = 36ft/10.9 m

Puma Trailer Post Impact – RF = 41ft/12.4 m, LF = 41ft/ 12.4 m,
RR = 40ft/12.1 m, LR = 40ft/12.1 m

Expedition Post Impact – Grass – RF = 36ft/10.9 m, LF = 38ft/11.5 m,
RR = 26ft/7.9 m, LR = 28ft/8.5 m

Expedition Post Impact – Pavement – RF = 28ft/8.5 m, LF = 25ft/7.6 m,
RR = 38ft/11.58 m, LR = 34ft/10.36 m

There were no Pre Impact tire Marks

圖 25 多次碰撞之離開方向與動量作業解答案例

十、 摩托車、商用車和行人/自行車碰撞(Motorcycles, Commercial Vehicles & Pedestrian/Bicycle Crashes)

事實上交通事故除一般小汽車事故外摩托車(機車)、商用車和行人/自行車碰撞肇事占比一非常高，特別是機車事故，在台灣約占 50%~60%，行人/自行車肇事死亡每年一約 400 人，大型商用車之肇事所造成之死亡事故比率亦較高，因此，本課程額外增加此三類之事故調查重建課程，說明此三類之事故特性。

摩托車碰撞

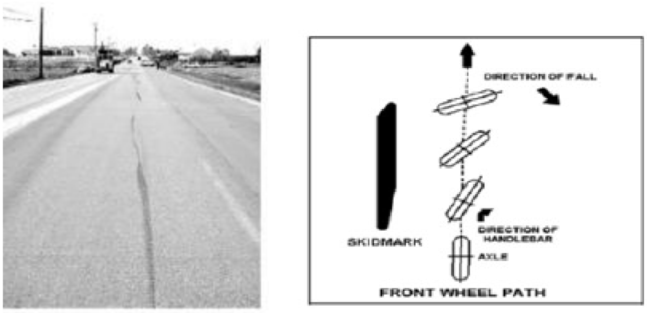
課程內容從摩托車之種類、車行、動力型態及操作等皆有詳盡說明。當摩托車的前輪因硬制動而被鎖定時，煞車痕跡打滑標記的長度會很短，反之，若只有後煞車鎖死，則後輪胎留下的打滑痕跡將留下一條長長鬆散的 S 曲線，向路面坡度方向拖尾的痕跡，如圖 26 所示。

摩托車之事故調查須就事故車輛作描述性數據，包括製造商和一般類別（如旅行、越野或直升機）確定摩托車的類型，描述發動機設計的類型，例如二衝程或四衝程，及包括氣缸數量和氣缸佈局；並記錄印在車架轉向頭上或連接在車架下管上的金屬板上之車輛識別號 (VIN) 。輪胎胎痕是計算車輛速度的要素，需記錄製造商、類型、尺寸、序列號、胎側數據、壓力、胎面深度、設計、輪胎的旋轉箭頭方向、是否安裝在輪輞上，以及是否有內胎或無內胎。另外煞車系統之記錄亦相當重要，目前所有摩托車都在前後輪上都裝有製動器。前製動器負責摩托車 60%到 70%的制動力，有碟式、鼓式兩種類型的制動器，現在大多數前輪制動器採用碟式設計，後製動器通常為碟式或鼓式，許多製造商已將 ABS 制動器作為標準設備或可選附提供。

檢查前照燈開關設置（遠光燈/近光燈）和燈絲狀況。注意燈泡的類型和任何輔助燈及其位置，尋找額外的非標準配備開關，檢視車主是否重新接線系統，以便前照燈可以獨立打開和關閉，確定摩托車是否配備前照燈調製器。這個售後市場設備被連接到前照燈電路中，控制單元使燈以一定的頻率發出脈

衝，希望能引起其他駕駛者的注意。轉向燈需注意鏡頭和燈泡的位置和狀況，許多轉向信號燈通常使用橡膠或鋁製支架安裝，這些支架會脫離撞擊方向。檢視剎車燈和尾燈，記錄剎車燈和尾燈燈絲狀況、燈泡數量、鏡頭狀況以及任何特殊燈的狀況。事故現場車輛須以多角度，不同距離方式照相取證，如圖 27 所示。

機車事故損害分析須檢視前輪與輪輞，輻條輪和輪輞會以適應撞擊的物體而彎曲，降低衝擊力。車輛前叉在直接正面碰撞中，前叉管將均勻地壓在車架或發動機排氣管上，具體取決於碰撞速度。可依據事故摩托車上管正常延伸的高度標記，評估撞擊時是否有前輪制動之動作。檢視油箱，在座位區域前方出現鈍的凹痕通常是由騎手的腹股溝造成的，因為在撞擊時被沖力向前推進。檢視排氣管，鍍鉻區域的刮痕表示滑道的方向和滑行過程中摩托車的方向。檢視後減震器、擋泥板、車輪，後減震器會沿與受力方向相同的方向彎曲。



(A)前輪煞車鎖死之痕跡　　(B)後輪煞車鎖死之痕跡

圖 26 機車煞車痕跡

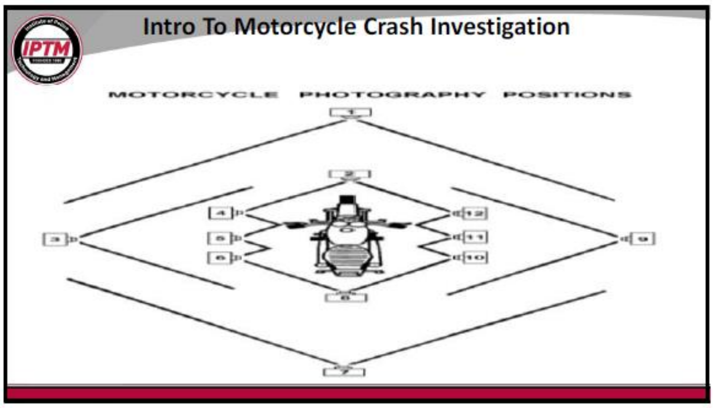


圖 27 機車事故照相取證之示意圖

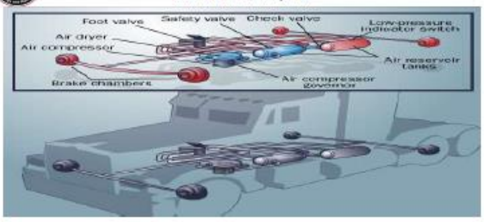
<u>商用車碰撞</u>

商用車會造成重大之交通事故，尤其是大貨車、半聯結車、全聯結車及砂石車，因此不論是美國或是台灣，在相關法規上皆已要求每輛商用機動車輛的駕駛員都必須對車輛進行行前檢查，並確認車輛上路行駛前之檢查結果符合規定。此外，司機必須在每個工作日結束時填寫並簽署檢查表。

在商用機動車輛碰撞事故調查中，必須對車輛進行更詳細的檢查，以確定或消除與車輛機械狀況相關的交通碰撞事故的造成因素。惟調查人員幾乎不可能在交通事故現場對車輛進行徹底檢查，需在事故後將車輛扣留進行詳細檢查。調查人員進行的最重要的碰撞後檢查之一是車輛的空氣製動系統及其組件。熟悉商用機動車輛上使用的不同類型的基礎制動器，以及構成空氣製動系統的各個組件至關重要。如果維護得當，商用機動車輛開發的空氣製動系統是一種高效且具有成本效益的系統。整體制動效率的損失通常是由於維護不善或製動調整不當造成的。空氣製動系統由五個主要部件組成：1.壓縮機、2.水箱、3.腳踏閥（剎車踏板）、4.制動室、5.剎車蹄和鼓，如圖 28 所示。

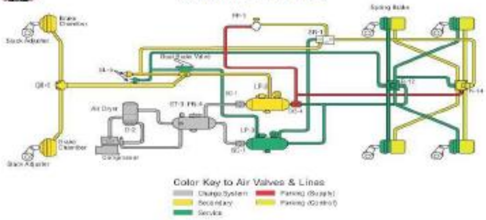
Vehicle Evidence

Common Air Brake System



Vehicle Evidence

Common System Schematic



Vehicle Evidence

The compressor pumps air into the reservoir, where it is stored

Compressor

Storage Tanks

Vehicle Evidence

The governor controls the air compressor cut-in and cut-out pressure

The operating pressure range for vehicle air brake systems must be between 80 psi and 145 psi

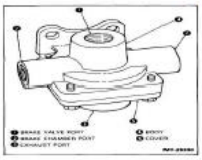
An air-pressure gauge indicating air pressure in the main reservoir system is usually mounted on the dashboard of the vehicle cab and also has a low air warning device

Vehicle Evidence

The foot valve draws the compressed air from the reservoir when the brake is applied.

Vehicle Evidence

Upon brake application, the compressed air is directed through a series of lines and valves to the brake chambers



Vehicle Evidence

Brake Lines for Trailer

Glad hand Connectors

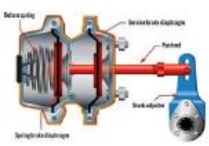
Vehicle Evidence

Air Brake Chambers

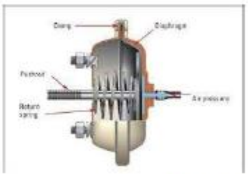
Common Rear Chamber

Vehicle Evidence

Internal view of rear chambers



Vehicle Evidence



Common front brake chambers

圖 28 商用車煞車系統

商用車因其重心較高，其造成之事故有一大部分是翻覆所造成，如圖 29 所示。翻覆事故之車輛可依據下列公式求得其事故前之速度。

Velocity Required for a vehicle to roll over (in fps)

$$V = \sqrt{R \times g \times P_r}$$

其中：

V = Velocity in fps
R = Radius of path of the CM in Feet
g = Gravity constant
Pr = Propensity to Roll

圖 29 商用車翻覆事故案例

行人/自行車碰撞

行人/騎自行車者碰撞事故調查，由於證據更難找到，所面對的額外挑戰更加困難，在行人/騎自行車發生碰撞後，對於有限的物證的蒐尋可以以多種不同的形式被發現。

事故現場長期存在的證據，包括：人行道的位置、路邊交通標誌、號誌、標線、輪胎痕跡、鑿痕、其他相關標記、路邊障礙物、樹木、灌木、樹籬，及路邊停車等。短暫的證據，包括：行人/騎自行車者事故後之位置狀態、車輛和自行車最後之位置狀態、行人/騎自行車者在路面滑行的證據，最重要的是在停車之前所有痕跡證據的位置。另外，調查時需追踪相關證據，如車輛證據（格柵、大燈玻璃、後視鏡、油漆碎片等）、行人/騎自行車者證據、攜帶或磨損的物品、帽子、眼鏡、鞋子、個人物品等。衣服破損情形、道路證據（車輛制動、臨界速度磨損、旋轉等）、血液和頭髮、皮膚和組織、服裝印痕、自行車碰撞輪胎磨損、行人/騎自行車者首次接觸路面的區域、行人/騎自行車的人在最後狀態(final rest)前在地面上滑行痕跡等。其中最常被忽視的證據之一是行人或騎自行車的人在他們到達最後狀態(final rest)時沿路面的滑動動作，滑動證據可能有助於確定事故撞擊時區域的位置。

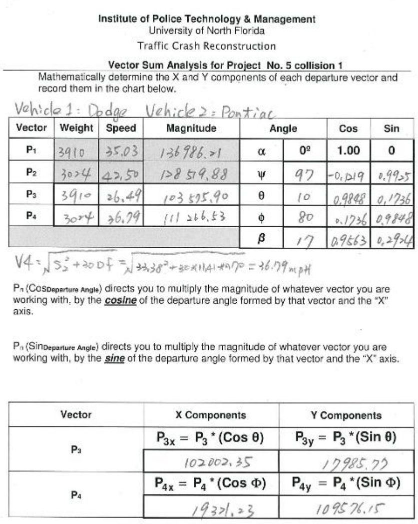
涉及騎自行車者的碰撞與涉及行人的碰撞沒有太大區別，事故調查需盡快找到並正確記錄物證，亦包含上開之考慮要項。自行車碰撞後檢查應從識別撞擊車輛或路面的接觸點開始，如圖 30 所示。

圖 30 行人、自行車撞擊時現場示意圖

十一、 課程複習、考題練習與期末考(Course Review, Optional Project, Final Exam)

第十週為期末考週，先進行所有課程之簡單複習，所有的公式概述講解，並進行複習測驗，之後即期末考試測驗，考試題目共計 60 題是非或選擇題，考

試題目約 70%為計算題，測驗時間為 4 小時，考試成績計入期末整體成績，需要獲得 80% 或更高的分數才能通過，且不得重考。期末考試前預習之作答，需上傳網站經講師檢視合格後方能進行期末考試，預習練習題目如圖 31 所示。通過考試取得證書如圖 32 所示。



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Traffic Crash Reconstruction

Vector Sum Analysis for Project No. 5 collision 1

Mathematically determine the X and Y components of each departure vector and record them in the chart below.

Vehicle 1: Dodge Vehicle 2: Pontiac

Vector	Weight	Speed	Magnitude	Angle		Cos	Sin
P_1	3910	35.03	136986.21	α	0º	1.00	0
P_2	3074	42.50	128519.88	ψ	97	-0.1219	0.9925
P_3	3910	26.49	103575.90	θ	10	0.9848	0.1736
P_4	3074	36.79	111266.53	φ	80	0.1736	0.9848
				β	17	0.9563	0.2924

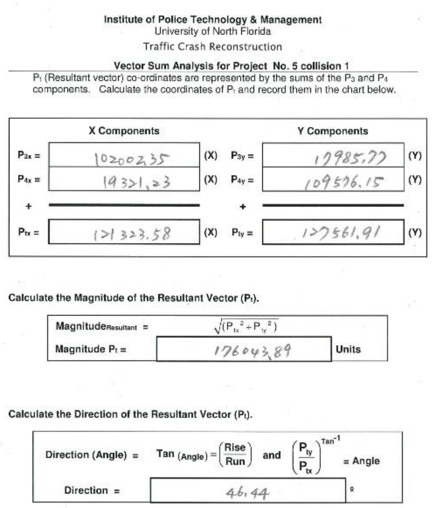
V4 = $\sqrt{S_2^2 + 30Df}$ = $\sqrt{33.38^2 + 30 \times 11.41 \times 0.70}$ = 36.79 mpH

P_n ($Cos_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***cosine*** of the departure angle formed by that vector and the "X" axis.

P_n ($Sin_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***sine*** of the departure angle formed by that vector and the "X" axis.

Vector	X Components	Y Components
P_3	$P_{3x} = P_3 * (\text{Cos}\ \theta)$	$P_{3y} = P_3 * (\text{Sin}\ \theta)$
	102002.35	17985.77
P_4	$P_{4x} = P_4 * (\text{Cos}\ \Phi)$	$P_{4y} = P_4 * (\text{Sin}\ \Phi)$
	19321.23	109576.15

1



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Vector Sum Analysis for Project No. 5 collision 1

P_t (Resultant vector) co-ordinates are represented by the sums of the P_3 and P_4 components. Calculate the coordinates of P_t and record them in the chart below.

X Components			Y Components		
P_{3x} =	102002.35	(X)	P_{3y} =	17985.77	(Y)
P_{4x} =	19321.23	(X)	P_{4y} =	109576.15	(Y)
+			+		
P_{tx} =	121323.58	(X)	P_{ty} =	127561.91	(Y)

Calculate the Magnitude of the Resultant Vector (P_t).

$Magnitude_{Resultant} = \sqrt{(P_{tx}^2 + P_{ty}^2)}$

Magnitude P_t = 176043.89 Units

Calculate the Direction of the Resultant Vector (P_t).

Direction (Angle) = $\text{Tan}_{(Angle)} = \left(\frac{\text{Rise}}{\text{Run}}\right)$ and $\left(\frac{P_{ty}}{P_{tx}}\right)^{\text{Tan}^{-1}}$ = Angle

Direction = 46.44 º

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Vector Sum Analysis for Project No. 5 collision 1

Calculate the Impact Speed of the Y vehicle.

$V_2 =$	P_{1y}	W_2	Sin ψ	$V_2 = \left(\frac{P_{1y}}{(W_2 * \text{Sin } \psi)}\right)$
	127561.91	3024	0.9925	42.50

Calculate the Magnitude of the Impact Speed of the Y vehicle.

$P_2 =$	W_2	V_2		$P_2 = W_2 * V_2$
	3024	42.50		128519.88

Calculate the X component of the Y vehicle's impact speed.

$P_{2x} =$	W_2	V_2	Cos ψ	$P_{2x} = W_2 * V_2 * \text{Cos } \psi$
	3024	42.50	-0.1219	-15662.63

Calculate the Impact Speed of the X vehicle.

$V_1 =$	P_{1x}	W_1	P_{2x}	$V_1 = \left(\frac{P_{1x} - P_{2x}}{W_1}\right)$
	121323.58	3910	-15662.63	35.03

Calculate the Magnitude of the Impact Speed of the X vehicle.

$P_1 =$	W_1	V_1		$P_1 = W_1 * V_1$
	3910	35.03		136,986.21

3

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Vector Sum Analysis for Project No. 5 collision 1

Calculate the Δ V of the Y vehicle.

$\Delta V_2 =$	V_2	V_4	Cos β	$\Delta V_2 = \sqrt{(V_2^2 + V_4^2) - (2 * V_2 * V_4 * \text{Cos } \beta)}$
	42.50	36.79	0.9563	13.01

Calculate the Δ V of the X vehicle.

$\Delta V_1 =$	V_1	V_3	Cos θ	$\Delta V_1 = \sqrt{(V_1^2 + V_3^2) - (2 * V_1 * V_3 * \text{Cos}\theta)}$
	35.03	26.49	0.9848	10.06

Calculate the Magnitude of the Impulse Vector acting on the Y vehicle.

$\Delta \rho_2$	W_2	ΔV_2		$\Delta \rho_2 = W_2 * \Delta V_2$
	3024	13.01		39336.48

Calculate the Magnitude of the Impulse Vector acting on the X vehicle.

$\Delta \rho_1$	W_1	ΔV_1		$\Delta \rho_1 = W_1 * \Delta V_1$
	3910	10.06		39336.48

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Vector Sum Analysis for Project No. 5 collision 1

Calculate the PDOF acting on the Y vehicle.

α_2	V_4	Sin β	ΔV_2	$\alpha_2 = \left(\frac{V_4 * \text{Sin}\beta}{\Delta V_2}\right)^{\text{Sin}^{-1}}$
	36.79	0.2924	13.01	55.79

Calculate the PDOF acting on the X vehicle.

α_1	V_3	Sin θ	ΔV_1	$\alpha_1 = \left(\frac{V_3 * \text{Sin}\theta}{\Delta V_1}\right)^{\text{Sin}^{-1}}$
	26.49	0.1736	10.06	27.21

Check digit using the PDOF's.

Ψ	α_1	α_2		Ψ = 180 - (α_1 + α_2)
	55.79	27.21		97

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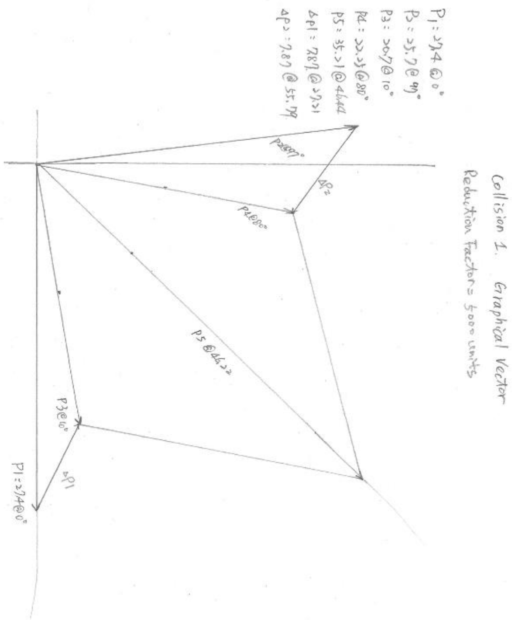

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Vector Sum Analysis for Project No. 5 collision 2

Mathematically determine the X and Y components of each departure vector and record them in the chart below.

Vehicle 1 : chevy   vehicle 2 : Pontiac

Vector	Weight	Speed	Magnitude	Angle		Cos	Sin
P_1	3680	33.81		α	0º	1.00	0
P_2	3074	33.38		ψ	260°	-0.1736	-0.9848
P_3	3680	29.2	102456.00	θ	335°	0.9063	-0.4226
P_4	3074	18.13	54831.85	ϕ	280°	0.1736	-0.9848
				β	20°	0.9396	0.3420

V4: $\sqrt{14.23^2 + 30*6*0.70}$ = 18.12 mpH   β = |ψ − ϕ| = 20°

P_r ($Cos_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***cosine*** of the departure angle formed by that vector and the "X" axis.

P_r ($Sin_{Departure\ Angle}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***sine*** of the departure angle formed by that vector and the "X" axis.

Vector	X Components	Y Components
P_3	$P_{3x} = P_3 * (\text{Cos } \theta)$	$P_{3y} = P_3 * (\text{Sin } \theta)$
	97388.21	-45412.87
P_4	$P_{4x} = P_4 * (\text{Cos } \Phi)$	$P_{4y} = P_4 * (\text{Sin } \Phi)$
	9521.45	-53998.83

1

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Vector Sum Analysis for Project No. 5 collision 2

P_t (Resultant vector) co-ordinates are represented by the sums of the P_3 and P_4 components. Calculate the coordinates of P_t and record them in the chart below.

	X Components			Y Components	
P_{3x} =	97388.21	(X)	P_{3y} =	-45412.87	(Y)
P_{4x} =	9521.45	(X)	P_{4y} =	-53998.83	(Y)
+			+		
P_{tx} =	106909.66	(X)	P_{ty} =	99411.70	(Y)

Calculate the Magnitude of the Resultant Vector (P_t).

$Magnitude_{Resultant}$ =	$\sqrt{(P_{tx}^2 + P_{ty}^2)}$	
Magnitude P_t =	145987.54	Units

Calculate the Direction of the Resultant Vector (P_t).

Direction (Angle) = $\text{Tan}_{(Angle)} = \left(\frac{Rise}{Run}\right)$ and $\left(\frac{P_{ty}}{P_{tx}}\right)^{Tan^{-1}}$ = Angle

Direction = -42.92 º

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Vector Sum Analysis for Project No. 5 collision 2

Calculate the Impact Speed of the Y vehicle.

V_2 =	P_{ty}	W_2	Sin ψ	$V_2 = \left(\frac{P_{ty}}{(W_2 * \text{Sin } \psi)}\right)$
	-99411.70	3024	-0.9848	33.38

Calculate the Magnitude of the Impact Speed of the Y vehicle.

P_2 =	W_2	V_2		$P_2 = W_2 * V_2$
	3074	33.38		100945.28

Calculate the X component of the Y vehicle's impact speed.

P_{2x} =	W_2	V_2	Cos ψ	$P_{2x} = W_2 * V_2 * \text{Cos } \psi$
	3024	33.38	-0.1736	-17528.96

Calculate the Impact Speed of the X vehicle.

V_1 =	P_{tx}	W_1	P_{2x}	$V_1 = \left(\frac{P_{tx} - P_{2x}}{W_1}\right)$
	106909.66	3680	-17528.96	33.81

Calculate the Magnitude of the Impact Speed of the X vehicle.

P_1 =	W_1	V_1		$P_1 = W_1 * V_1$
	3680	33.81		12[illegible]438.63

3

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Vector Sum Analysis for Project No. 5 collision 2

Calculate the Δ V of the Y vehicle.

Δ V_2 =	V_2	V_4	Cos β	$\Delta V_2 = \sqrt{(V_2^2 + V_4^2)} - (2 * V_2 * V_4 * \text{Cos } \beta)$
	33.83	18.13	0.9397	17.48

Calculate the Δ V of the X vehicle.

Δ V_1 =	V_1	V_3	Cos θ	$\Delta V_1 = \sqrt{(V_1^2 + V_3^2)} - (2 * V_1 * V_3 * \text{Cos}\theta)$
	33.81	29.20	0.9063	14.36

Calculate the Magnitude of the Impulse Vector acting on the Y vehicle.

Δ ρ_2	W_2	ΔV_2		$\Delta \rho_2 = W_2 * \Delta V_2$
	3024	17.48		52858.81

Calculate the Magnitude of the Impulse Vector acting on the X vehicle.

Δ ρ_1	W_1	ΔV_1		$\Delta \rho_1 = W_1 * \Delta V_1$
	3680	14.36		52858.81

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Vector Sum Analysis for Project No. 5 collision 2

Calculate the PDOF acting on the Y vehicle.

α_2	V_4	Sin β	ΔV_2	$\alpha_2 = \left(\frac{V_4 * \sin\beta}{\Delta V_2}\right)^{\sin^{-1}}$
	18.13	− 0.3420	17.48	− 20.78

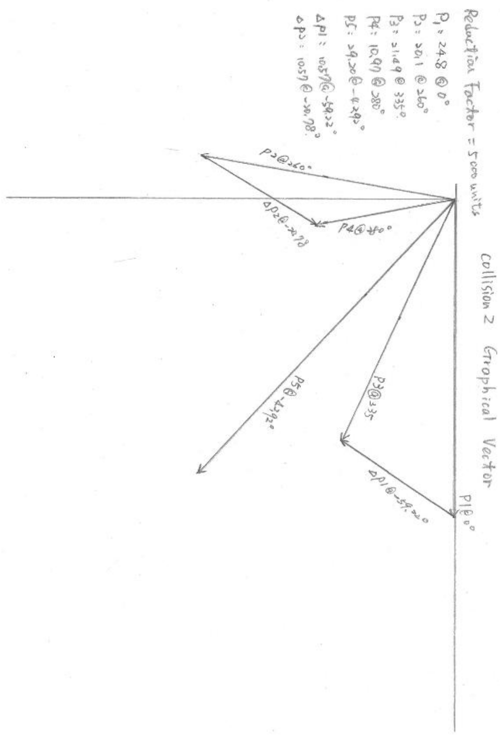
Calculate the PDOF acting on the X vehicle.

α_1	V_3	Sin θ	ΔV_1	$\alpha_1 = \left(\frac{V_3 * \sin\theta}{\Delta V_1}\right)^{\sin^{-1}}$
	29.20	−0.4226	14.36	− 59.22

Check digit using the PDOF's.

Ψ	α_1	α_2		$\Psi = 180 - (\alpha_1 + \alpha_2)$
	−20.78	−59.22		260

5



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Vector Sum Analysis for Project No. 5 collision 3

Mathematically determine the X and Y components of each departure vector and record them in the chart below.

vehicle1 = GMC vehicle2 = Pontiac

Vector	Weight	Speed	Magnitude	Angle		Cos	Sin
P_1	4100	42.55	174443.11	α	0º	1.00	0
P_2	3024	14.24	43058.22	ψ	280°	0.1736	−0.9848
P_3	4100	28.46	116686.00	θ	345°	0.9659	−0.2588
P_4	3024	23.24	70277.76	ϕ	350°	0.9848	−0.1736
				β	70°	0.3420	0.9397

P_n ($\cos_{\text{Departure Angle}}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***cosine*** of the departure angle formed by that vector and the "X" axis.

P_n ($\sin_{\text{Departure Angle}}$) directs you to multiply the magnitude of whatever vector you are working with, by the ***sine*** of the departure angle formed by that vector and the "X" axis.

Vector	X Components	Y Components
P_3	$P_{3x} = P_3 * (\cos\theta)$	$P_{3y} = P_3 * (\sin\theta)$
	112710.02	−30200.56
P_4	$P_{4x} = P_4 * (\cos\Phi)$	$P_{4y} = P_4 * (\sin\Phi)$
	69210.08	−12203.60

1

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Vector Sum Analysis for Project No. 5 collision 3

P_t (Resultant vector) co-ordinates are represented by the sums of the P_3 and P_4 components. Calculate the coordinates of P_t and record them in the chart below.

X Components			Y Components		
P_{3x} =	112710.02	(X)	P_{3y} =	− 30200.56	(Y)
P_{4x} =	69210.08	(X)	P_{4y} =	− 12203.60	(Y)
+			+		
P_{tx} =	181920.10	(X)	P_{ty} =	− 42404.16	(Y)

Calculate the Magnitude of the Resultant Vector (P_t).

Magnitude$_{\text{Resultant}}$ =	$\sqrt{(P_{tx}^2 + P_{ty}^2)}$	
Magnitude P_t =	186796.78	Units

Calculate the Direction of the Resultant Vector (P_t).

Direction (Angle) =	Tan $_{(\text{Angle})} = \left(\frac{\text{Rise}}{\text{Run}}\right)$ and $\left(\frac{P_{ty}}{P_{tx}}\right)^{\tan^{-1}}$ = Angle	
Direction =	−13.12°	º

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Vector Sum Analysis for Project No. 5 collision 3

Calculate the Impact Speed of the Y vehicle.

V_2 =	P_{ty}	W_2	Sin ψ	$V_2 = \left(\frac{P_{ty}}{(W_2 * \text{Sin } \psi)}\right)$
	-424404.16	3024	-0.9848	14.24

Calculate the Magnitude of the Impact Speed of the Y vehicle.

P_2 =	W_2	V_2		$P_2 = W_2 * V_2$
	3024	14.24		43058.32

Calculate the X component of the Y vehicle's impact speed.

P_{2x} =	W_2	V_2	Cos ψ	$P_{2x} = W_2 * V_2 * \text{Cos } \psi$
	3024	14.24	0.1736	7477.00

Calculate the Impact Speed of the X vehicle.

V_1 =	P_{tx}	W_1	P_{2x}	$V_1 = \left(\frac{P_{tx} - P_{2x}}{W_1}\right)$
	181920.10	4100	7477.0	42.55

Calculate the Magnitude of the Impact Speed of the X vehicle.

P_1 =	W_1	V_1		$P_1 = W_1 * V_1$
	4100	42.55		174443.11

3

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Vector Sum Analysis for Project No. 5 collision 3

Calculate the Δ V of the Y vehicle.

Δ V_2 =	V_2	V_4	Cos β	$\Delta V_2 = \sqrt{(V_2^2 + V_4^2) - (2 * V_2 * V_4 * \text{Cos } \beta)}$
	14.24	23.24	0.3420	22.73

Calculate the Δ V of the X vehicle.

Δ V_1 =	V_1	V_3	Cos θ	$\Delta V_1 = \sqrt{(V_1^2 + V_3^2) - (2 * V_1 * V_3 * \text{Cos}\theta)}$
	42.55	28.46	0.9659	16.76

Calculate the Magnitude of the Impulse Vector acting on the Y vehicle.

Δ ρ_2	W_2	ΔV_2		$\Delta\rho_2 = W_2 * \Delta V_2$
	3024	22.73		68724.43

Calculate the Magnitude of the Impulse Vector acting on the X vehicle.

Δ ρ_1	W_1	ΔV_1		$\Delta\rho_1 = W_1 * \Delta V_1$
	4100	16.76		68724.43

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Vector Sum Analysis for Project No. 5 collision 3

Calculate the PDOF acting on the Y vehicle.

α_2	V_4	Sin β	ΔV_2	$\alpha_2 = \left(\frac{V_4 * \text{Sin}\beta}{\Delta V_2}\right)^{\text{Sin}^{-1}}$
	23.24	-0.9397	22.73	-73.93

Calculate the PDOF acting on the X vehicle.

α_1	V_3	Sin θ	ΔV_1	$\alpha_1 = \left(\frac{V_3 * \text{Sin}\theta}{\Delta V_1}\right)^{\text{Sin}^{-1}}$
	28.46	-0.2588	16.76	-26.07

Check digit using the PDOF's.

Ψ	α_1	α_2		$\Psi = 180 - (\alpha_1 + \alpha_2)$
	-73.93	-26.07		280°

5

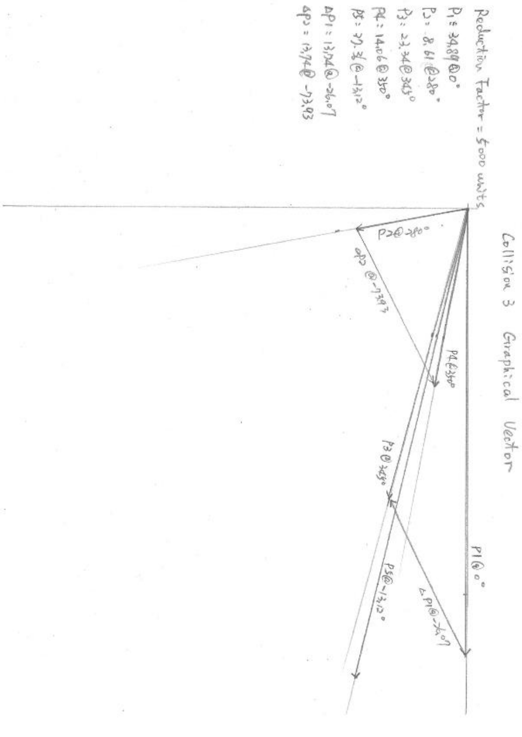
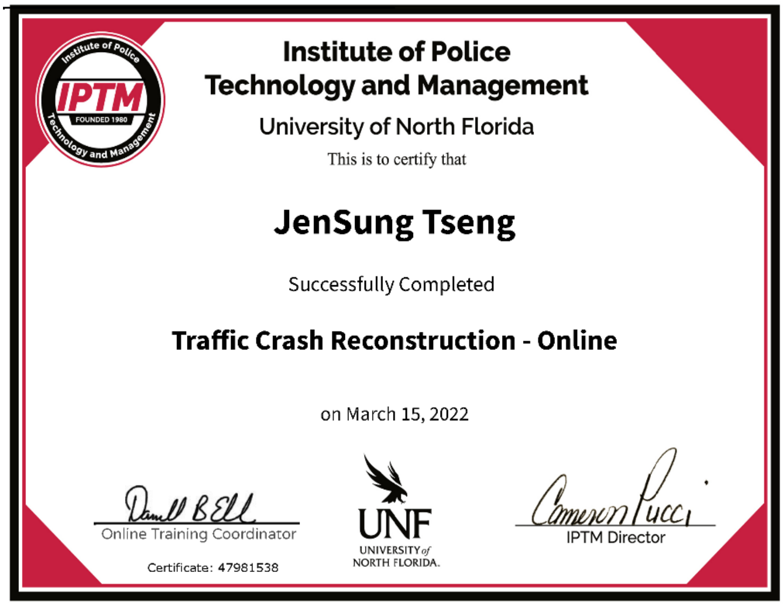


圖 31 期末預習考試題目及解答過程



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Technology and Management
University of North Florida
This is to certify that

JenSung Tseng

Successfully Completed

Traffic Crash Reconstruction - Online

on March 15, 2022

Online Training Coordinator
Certificate: 47981538

UNF
UNIVERSITY of NORTH FLORIDA.

IPTM Director

圖 32 通過考試取得證書

十二、 心得

雖然現在的科學發展快速，車輛的速度可以透過其他設備如 EDR(event data recorder)、數位行車紀錄器、行車影像紀錄器、路邊監控 CCVT 等輔助設備取證，然最基本的調查，仍需在無任何輔助設備下進行，當無法取得科技設備之支援證據下，調查人員仍須獨力完成調查成果，另外，所有的數學計算公式，目前已可以使用電腦輔助或是商用軟體協助，然而，本課程仍要求學員以最簡單的計算及測繪工具，不依賴電腦軟體協助下完成數學計算，是因調查員所處的環境，不一定能即時獲得的科技、電腦支援，調查員仍須依靠一支筆、一張紙完成調查工作。

在通過課程最後的考試，取得證書後，發覺除調查的基本概念更加清新外，也對於調查員的工作有更明確的認知，調查員實事求是，搜尋相關證物，不能錯過事故現場任何的蛛絲馬跡，方能完成艱鉅的事故調查。

肆、 建議

本次課程完成後，學員可以獲取完成的交通事故重建知識，對於未來事故調查必然有所精進，課程完成後有下列幾點建議，說明如後。

一、配合改制運安會，本會調查業務新成立重大公路事故調查模組，為精進公路調查同仁在事故調查重建之專業知能，建議日後應參照交通事故重建認證委員會 (ACTAR, The Accreditation Commission for Traffic Accident Reconstruction) 之建議，所有公路事故調查人員應完成本課程之訓練。

二、建議派員參加 IPTM 的 Bosch© CDR 工具技術員培訓(Bosch© CDR Tool Technician Training by IPTM)、事故調查員取證取證(VoD)(Forensic Evidence Recovery for Crash Investigators)、事件數據記錄器在交通事故重建中的使用(Event Data Recorder Use in Traffic Crash Reconstruction)、重型車輛電子控制模塊數據在碰撞重建中的應用(Heavy Vehicle Electronic Control Module Data Use in Crash Reconstruction)等 IPTM 事故調查之相關課程，進一步瞭解重大公路事故調查之細節，以培養公路事故調查之專業知識。

三、本課程主要以事故現場調查之基本技能與調查之重點，對於事故調查之事實資料收集有相當之助益，未來將配合事故調查的分析作業與分析方法，即能完成整體之調查報告。

四、本課程談及行人、自行車、機車及商用車的調查僅提供基本認知資料，其詳細的調查過程與案例，仍可參加其另外開設之課程加強訓練，惟機車、行人、自行車事故，除非與汽車運輸業之車輛合併發生事故，否則尚非本會調查之範圍。惟機車、行人、自行車之肇事率及傷亡人數占我國交通事故肇事之主因，因此，

未來仍有須派員參加此類專題課程，加強公路組之調查能量。

參加美國警察科技及管理研究所(IPTM)「交通事故重建(Traffic Crash Reconstruction) Online」線上課程報告

服　務　機　關：國家運輸安全調查委員會

出 國 人 職 稱：**公路調查組首席調查官**

姓　　　　　名：**曾仁松**

出　國　地　區：臺灣，中華民國（線上訓練課程）

出　國　期　間：**民國 111 年 01 月 10 日至 03 月 20 日**

報　告　日　期：**民國 111 年 06 月 15 日**

建議事項：

	建議項目	處理
1	配合改制運安會，本會調查業務新成立重大公路事故調查模組，為精進公路調查同仁在事故調查重建之專業知能，建議日後應參照交通事故重建認證委員會（ACTAR, The Accreditation Commission for Traffic Accident Reconstruction）之建議，公路事故調查人員應完成本課程之訓練。	□ 已採行 √ 研議中 □ 未採行

2	建議派員參加 IPTM 的 Bosch© CDR 工具技術員培訓(Bosch© CDR Tool Technician Training by IPTM)、事故調查員取證取證(VoD)(Forensic Evidence Recovery for Crash Investigators)、事件數據記錄器在交通事故重建中的使用(Event Data Recorder Use in Traffic Crash Reconstruction)、重型車輛電子控制模塊數據在碰撞重建中的應用(Heavy Vehicle Electronic Control Module Data Use in Crash Reconstruction)等 IPTM 事故調查之相關課程，進一步瞭解重大公路事故調查之細節，以培養公路事故調查之專業知識。	□ 已採行 √ 研議中 □ 未採行
3	事故現場調查之基本技能與調查之重點，對於事故調查之事實資料收集有相當之助益，未來將配合事故調查的分析作業與分析方法，即能完成整體之調查報告。	√ 已採行 □研議中 □ 未採行
4	行人、自行車、機車及商用車的調查本課程僅提供基本認知資料，且其經常汽車運輸業之車輛合併發生事故，肇事率及傷亡人數為我國交通事故肇事之主因，未來仍有須派員參加此類專題課程，加強公路組之調查能量。	□ 已採行 √ 研議中 □ 未採行