Alberta Distance Learning Centre

Forensic Studies 35 (3 Credit)

Module 3
Arson and Explosives

Module 4
Forensic Ballistics

Forensic Studies 35

LDC 3569

Module 3

Arson and Explosives

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Module 3: Arson and Explosives

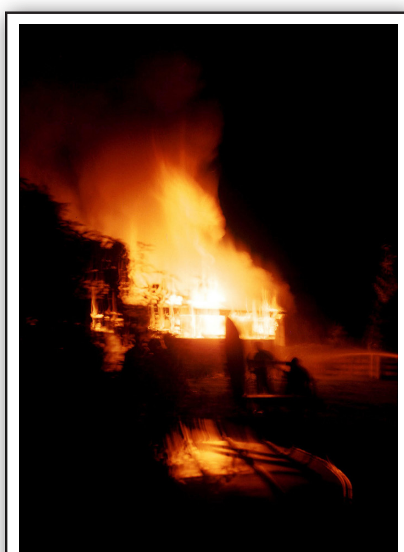
Overview

Arson is the crime of setting a fire for an unlawful or improper purpose. It is a problem because it costs hundreds of millions of dollars annually in increased insurance costs, increased taxes, loss of jobs, loss of business revenue, and treatment of injuries. Arson differs from other crimes in that it is not immediately obvious that a crime has occurred. It is a difficult crime to investigate because the fire frequently destroys evidence. Despite this, numerous telltale clues are often left behind an arson fire that can help investigators find the culprit.

Arson is a relatively easy crime to commit because a fire is easy to light. A small fire quickly becomes a big fire if it is not controlled early. Therefore, the amount of damage caused by an arsonist usually depends on the amount of time that lapses before firefighters arrive.

Explosions occur less frequently than arson fires. The likely reason for this is that, for the most part, creating an explosive device is more difficult than starting a fire, and starting a fire requires very little planning and effort. Law enforcement officers have several unique ways to investigate crimes involving an explosion.

- Lesson 1 examines the nature of a combustion reaction and the motives and profile of an arsonist.
- Lesson 2 outlines the various methods used to investigate arson fires.
- Lesson 3 describes the various types of explosives and identifies some explosive detection techniques.
- Lesson 4 examines the details of two historical crimes that involve arson and explosives.



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Module Learner Objectives

By the end of Module 3, you should be able to…

- identify the components necessary for a combustion reaction
- explain how combustion differs from an explosion
- understand the terminology that relates to arson (such as *accelerant, blast, booster, detonation, endothermic, exothermic, fuel, ignition, pyrolysis, oxidizer*)
- describe the three points and conditions of a fire: flash point, flammable range, and ignition range
- describe the level of oxygen needed to keep a fire burning and the various products of a combustion reaction that can cause a fire to continue
- describe arson and determine the various types of arson by the severity of the damage caused
- identify various motivations for arson and possible strategies to eliminate this crime
- recognize the steps in the investigative process of a possible arson
- identify various tools and methods used in arson investigations (such as *portable arson sampler, chromatography, lasers, solid-phase microextraction, arson profiling, metal oxide sensors, canines, photoionization detectors*)
- compare the numbers of human fatalities and human injuries caused by arson using graphed data
- compile and present various data related to arson (such as *local statistics, common motives, profile of typical arsonist, child arsonists, total cost of arson investigations, arson prevention methods*)
- identify the three basic components of an explosive device: fuel source, oxidizer, and ignition.
- identify and describe various types of explosive devices (including *gunpowder, dynamite, nitroglycerin, saltpetre, guncotton, TNT, PETN, picric acid, plastic explosives*)
- describe various devices or techniques used by forensic experts to detect explosives (such as *robots, EGIS, canines, X-rays, metal detectors, ion mobility spectrometry, honeybees*)
- recognize various types of explosives (such as *explosive bombs, chemical bombs, inert bombs, nuclear bombs*) and understand the function of each.
- explore a historical crime case(s) involving arson and/or explosives (such as *Timothy McVeigh, Frederick Small, U.S. Embassy in Kenya, Pan Am Flight 103, 9/11 World Trade Center Disaster, Unibomber*).

Lesson 1: Combustion and Arson

Lesson Objectives: ***The student will...***

Objective

- identify the components necessary for a combustion reaction
- explain how combustion differs from an explosion
- understand the terminology that relates to arson (such as *accelerant, blast, booster, detonation, endothermic, exothermic, fuel, ignition, pyrolysis, oxidizer*)
- describe the three points and conditions of a fire: flash point, flammable range, and ignition range
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- describe arson and determine the various types of arson by the severity of the damage caused
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- recognize the steps involved in the investigative process of a possible arson
- identify various tools and methods used in arson investigations (such as *portable arson sampler, chromatography, lasers, solid-phase microextraction, arson profiling, metal oxide sensors, canines, photoionization detectors*)

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Did You Know?

In Canada in 2004 and 2005, more than 13 000 acts of arson were reported to police. The rate of arson in Canada has decreased by 8% since 1995..

Combustion

Take Notes

A fire is the result of a chemical reaction called ***combustion*** and is based on the principles of oxidation. In an oxidation reaction, energy is produced in the form of heat, light, noise, or a combination of these. To start a fire, three things must be present: fuel, oxidant, and heat source.

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Fuel in Combustion Reactions

An ***accelerant*** is commonly used to start an arson fire. An accelerant is a liquid or solid fuel source that increases the rate of combustion. An accelerant allows the fire to burn at a higher temperature with an increased rate of spread.

Often arsonists use hydrocarbon-based fuels as accelerants, especially ignitable liquids such as gasoline, diesel fuel, kerosene, turpentine, or butane. The combustion of an ignitable liquid actually happens in the gas phase because the liquid does not actually burn. To ignite, a liquid must be heated to its ***flash point***, the specific temperature at which it changes to a gas and burns.

Ignitable liquids are dangerous accelerants. Given the right circumstances, they ignite easily and can readily explode. Consequently, arsonists who use large amounts of liquid accelerant to start their fires may suffer serious injuries or death.

Did You Know?

A pyromaniac is an individual with an intense obsession with fire and periodically has strong desires to start fires intentionally. Starting fires may serve to relieve pyromaniacs of tensions of sadness, loneliness, and rage. Child pyromaniacs frequently suffer from behavioural disorders and/or learning disabilities and often are cruel to animals.

Ignitable liquids leave very distinctive burn patterns in the fire debris. To the trained eye, these irregular burn patterns can indicate the presence of an ignitable liquid in a fire.

Take Notes

Some accelerants used in arson fires are solid fuel sources such as common household items that contain wicker, foam, paper, or wood. Using large amounts of solid fuel tends to increase the rate of fire growth and spread the fire over a much larger area, thus increasing the amount of damage.

To determine whether arson was the cause of a fire, investigators look for the presence of accelerants in the debris of the fire. In addition, unusual quantities or types of accelerants can indicate arson especially when detected in unusual area(s) .

Oxidants in Combustion Reactions

In combustion reactions, the oxidant is oxygen gas. The simple word equation for combustion in the presence of oxygen is

$$\text{fuel} + \text{oxygen} \rightarrow \text{energy} + \text{water vapour} + \text{carbon dioxide}$$

In most combustion reactions, the necessary oxygen is available in the surrounding air. The air in Earth's atmosphere contains oxygen as well as a mixture of gases: 78% nitrogen, 21% oxygen, 0.93% argon, 0.04% carbon dioxide, trace amounts of other gases and water vapour.

The Products of Combustion Reactions

As a substance burns (undergoes combustion), a complex sequence of exothermic chemical reactions occurs. An exothermic reaction produces heat energy and often light energy as well. When light energy is produced, a flame or glow is visible.

Water and carbon dioxide are also produced during combustion reactions. The water is visible as gas (steam) because of the high temperatures associated with this type of reaction. Carbon dioxide is invisible.

Did You Know?

A decelerant or fire retardant inhibits the rate of combustion. Water is the most commonly used fire retardant. Aluminum hydroxide is also a common fire retardant because it breaks down to give off water vapour, it absorbs a vast amount of heat, and it creates a residue (Al_2O_3) that forms a protective layer.

Speed of Ignition

Take Notes

Ignition occurs when the heat produced by the reaction between the fuel and oxygen becomes sufficient to sustain combustion. Three terms are used to describe a fire's speed of ignition: *flash point, ignition range*, and *flammable range*.

- The *flash point* is the lowest temperature at which enough vapour is produced to permit ignition. The lower the flash point, the greater the risk of fire. The flash point can be reached only if enough fuel, oxygen, and heat are available to support a combustion reaction.
- The *ignition range* is the temperature at which a combustion reaction can sustain itself without the addition of more fuel or oxygen.
- The *flammable range* is the relatively high temperature at which ample amounts of fuel produce flames.

The speed of the reaction is determined by how quickly combustion moves through these three ranges. Increasing the temperature can double or even triple the reaction rate.

For a fire to remain ignited, it must have oxygen. If oxygen levels fall below 16%, most fires will extinguish. However, depending on the material(s) being burned, the chemical reaction in a fire can produce substances that contain oxygen which allow the reaction to continue. For example, burning wood produces carbon dioxide (CO_2), carbon monoxide (CO), sulphur monoxide (SO), nitrogen monoxide (NO), and water (H_2O). The oxygen released from these gases can continue a fire in the absence of air or oxygen gas (O_2).

Sites Targeted by Arsonists

Arson is the intentional burning of private or public property. Half of arson fires are set outdoors (such as wooded or grassy areas, parks, construction sites), 30% are set inside houses or other buildings, and 20% involve vehicles. Vacant and abandoned buildings are often targets for arsonists. Arson incidents are fourteen times more likely in poor neighbourhoods than in high income neighbourhoods.

Did You Know?

The flames of a wood fire are due to combustion of gases and not to combustion of the wood itself.

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Take Notes

Sometimes arsonists target forested or grassy areas. Such uncontrolled fires have a number of different names usually depending upon which type of vegetation is set on fire (such as forest fire, grass fire, peat fire, or bushfire). Often these wildfires get out of control and destroy nearby houses or agricultural resources. Heat waves, droughts, and high winds can dramatically increase the size of the area consumed by a wildfire.

Motives for Arson

The motivations for committing acts of arson vary. Psychiatrists and social and behavioural researchers have found five main motivations for arson. These are revenge, excitement, vandalism, crime concealment, and financial profit.

Arson for Revenge: The majority of arson crimes are acts of revenge. The incident that causes an arsonist to seek revenge may be real or imagined and often occurs months or years before the arson.

Disagreements or feelings of jealousy are common causes of this crime. Revenge arson is focused often on an individual's home, property, or place of business. However, domestic violence is also a common cause of revenge arson. The goal of the culprit in this case may be to cause personal injury or to commit murder. Disgruntled young arsonists often will set fire to school property. This type of arson tends not to be well planned, and the culprit's attempt to conceal his or her identity is often ineffectual.

Did You Know?

Burning plastic of various types produces poisonous gases such as hydrogen cyanide (HCN) and hydrogen chloride (HCl).

Take Notes

Cases of revenge-seeking arson fires have also been documented as being started by firefighters hoping to injure a superior or co-worker. In these cases, the disgruntled firefighter usually is extremely angry because he/she has lost his/her job or had grievances or complaints filed against him/her.

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Arson for Excitement: Sadly, the second leading motive of arsonists is simply the need for excitement. Boredom, the need for attention, and the enjoyment that the arsonist gets from watching firefighters fight the blaze are all possible compounding factors. In these cases, the targets tend to be large and often outdoors (such as wooded areas, parks, construction sites, arenas). Sometimes these arsonists target a number of homes in a residential area (such as garages, backyards, dumpsters). Usually, this type of arson occurs at night and the arsonist is intoxicated at the time of the offence.

Some arsonists set fires because they are excited by the prospects of being seen as heroes. After these arsonists set fire to their targets, they attempt to rescue endangered people or try to extinguish the fire. The "hero effect" is often a desire of firefighters who are bored by a lack of fires or are seeking attention for their supposed bravery.

Arson for Vandalism: The third leading motive of arson is vandalism. This type of arson tends to be caused by two or more male juveniles who set the fire together. Reasons for these youngsters to commit such crimes include family difficulties or peer pressure from 'friends'. Targets in these cases are often vacant or abandoned buildings. Fire departments must respond to there fires promptly and aggressively out of concern for any transient or homeless people who may be inside. Sometimes arson vandals are brazen and will attack non-vacant buildings such as schools, homes, or churches.

Did You Know?

In 1933, the Nazis allegedly burned the Reichstag (Germany's parliament building.) The incident gave the Nazi Party an excuse to introduce the Reichstag Fire Decree, one of the key steps that led the Nazi Party to take control of German government.


Take Notes

Arson for Crime Concealment: Crime-concealment arsonists set fire to places in which they have committed crimes in an attempt to destroy evidence that might implicate them or prove that crimes have occurred. The crime that such an arsonist tends to conceal is burglary, but sometimes it can be a murder. Such fires are usually set at night in unoccupied homes or places of business.

Arson for Profit: Interestingly, arson motivated by profit is the least common motive for arson. In these cases, the possibility of financial gain drives an arsonist to set fire to his or her own property (home or business) with the intention of filing a fraudulent insurance claim afterwards. Arson for profit is usually committed by adults and rarely is committed by juveniles because they seldom own any property. Very often, the arsonist in these cases is under extreme financial pressure. In general, such fires are set during the day in unoccupied homes or other buildings.

Motives for Arson

More than 90% of arsons are committed by males, the majority of which are under the age of 18. Usually those arsonists who are under 18 have also been charged with property offences in the past. Those few females who have committed arson are most often motivated by revenge. Adult male arsonists tend to be under the age of 35 and their motive for arson is often for revenge or for profit.

A great number of male arsonists tend to have ***interpersonal*** problems with females. They tend to exhibit a lack of ***remorse*** especially when they are setting a fire often because of their ***disassociative*** trance-like states.

Most arsonists are from lower to working class families. Arsonists who have a middle class background tend to commit arson for vandalism or excitement. Often arsonists have absentee or abusive fathers and a history of emotional difficulties with their families.

About 90% of arsonists have only a high school education or less. The majority of arsonists have ***IQ***s slightly below average; 22% are considered to be developmentally delayed. In school, arsonists usually have had learning problems and often were held back a grade—usually in grades 6, 7, 8, or 10.

Arsonists that set a fire for excitement, vandalism, or profit tend to be unemployed. Those that are employed tend to be in subservient positions that they resent.

Did You Know?

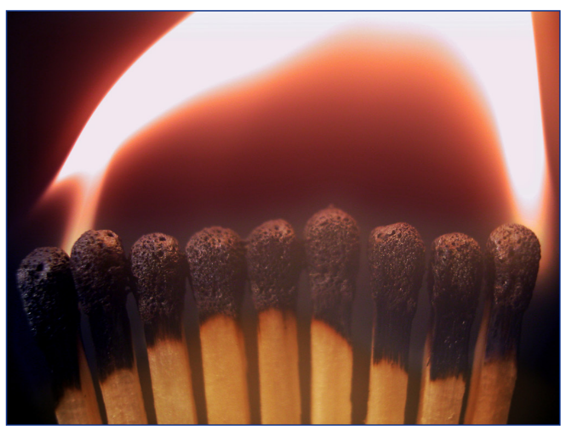
A massive forest fire thought to be caused by an arsonist in Indonesia in 1997 and 1998 was responsible for about 2.57 gigatonnes or 42% of the total amount of carbon dioxide found in the Earth's atmosphere during that period.

Young Arsonists

Most of these young arsonists (juvenile males under the age of 18) begin exhibiting interest in fire between 3 and 10 years of age. Motives for young arsonists include boredom, curiosity about fire, accidents, peer pressure, or expressions of anger and stress. A fire deliberately set by a young child is usually considered an accident or a result of misbehaviour instead of arson. Depending on the motivation behind the fire setting, how the child is disciplined and/or counselled can have a large impact on whether or not that child continues to set fires as a teenager or adult.

Fires set by children are usually located in or near the family home. If a child arsonist extinguishes the fire before it gets out of control they often will feel remorse for their actions and try to conceal any related evidence. Child arsonists often stop their behaviour when counselled by an adult. When a child who sets fires is not helped to change, he or she can develop into a teenage arsonist. Teenage arsonists often have an average intelligence, but they exhibit poor academic progress due to learning difficulties or behavioural and/or psychological problems. They often commit their crimes to seek revenge or as responses to traumatic events such as divorce or death. Setting fires becomes an outlet for their troubled emotions.

Recognizing and identifying children who set fires deliberately is important because their behaviour often may be modified through counselling. Even if a child is not a problem fire setter, parents should teach and establish rules regarding fire safety.



© *photos.com*

Did You Know?

In New Brunswick in February of 2005, Frederick Vandebrand, a 45-year-old father of three and volunteer Deputy Fire Chief, pleaded guilty to three charges of arson and two counts of theft. He lit several garages and barns on fire. Neighbours were shocked by the news because they considered Vandebrand to be a friendly and helpful man.

GRAPHING ACTIVITY: Fatal Home Fires in Alberta

Problem: What are the causes of fatal home fires in Alberta from 2001 to 2005?

Procedure:


Take Notes

- Use the data in the table below to create a ***bar graph***.
- Label the x-axis with the causes of fire.
- Label the y-axis with the total number of deaths.
- Incorporate a title and a legend into your graph.

Related Questions: (Note that this does not have to be submitted for marks.)

1. What were the top three leading causes of fatal home fires in Alberta from 2001 to 2005?

Causes of Fatal Home Fires in Alberta (2001 - 2005)	
Appliances: dryer or cooking devices	3
Arson, suspected arson, or other set fires	10
Candles: ignition of furniture or paper decorations	2
Child fire play: matches, lighter, or stove	4
Cooking: stove-top involving cooking oil	7
Electrical wiring	7
Heating equipment: furnace, space heater, fireplace	5
Ignition of natural or propane gas	6
Smoking: ignition of furniture, bedding, or other materials	29
Unknown	30

Chart courtesy of Alberta Emergency Management Agency

Did You Know?

More than half of arsonists observe the blaze they have set either at the scene or from a nearby location. Approximately 15% of arsonists turn themselves into police.

Causes of Fatal Home Fires in Alberta (2001 - 2005)


Take Notes

2. What percent of the total deaths was the result of arson from 2001 to 2005 in Alberta?

3. Arson is a deliberately set fire. Explain what other cause of fire could also be considered to be a deliberately set fire.


Assignment

Check your answers in the Module 3 Appendix in the back of this book.

When you are ready, please complete the assignment for Lesson 1 in the Assignment Booklet.

Lesson 2: Investigating Arson Fires

Lesson Objectives: ***The student will...***

Objective

- recognize the steps in the investigative process of a possible arson
- identify various tools and methods used in arson investigations (such as *portable arson sampler, chromatography, lasers, solid-phase microextraction, arson profiling, metal oxide sensors, canines, photoionization detectors*)

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Take Notes

Arson is difficult to solve because arsonists are usually careful to avoid eyewitnesses and often much evidence is destroyed. Investigators must discover evidence in the ash and debris left by the fire. This evidence is often ***circumstantial***, meaning that facts support the evidence but no conclusive proof is available.

The successful arrest and prosecution of an arsonist involves extensive investigation of circumstantial evidence. Prosecutors are willing to accept this type of evidence and are committed to taking these circumstantial cases to trial.

Did You Know?

Prior to the development of fire hydrants in the 1600s, city firefighters would dig down to a water main, bore a hole in it, then fill buckets or use hand pumps to put water on the flames. After the fire, the holes in the water main were plugged with wooden stoppers known as *fire plugs*.

A Forest Fire Burning at Night

© *Thinkstock*

Recognition of an Arson Fire

Take Notes

Obviously not all fires are caused by arson. In fact, most fires are accidental. The single, most common human cause of fires is careless smoking. Certain telltale signs indicate that an arson fire has occurred.

Fire investigators look for these signs when they first arrive upon a fire scene:

- Multiple points of origin
- Point of origin near a good supply of oxygen (such as an open window)
- Evidence that fire burned quickly and for a relatively long time
- Empty fuel cans or other evidence of the use of accelerants
- Unusual odours caused by the use of accelerants

Did You Know?

The dominant colour in a flame changes with temperature. This can be seen in a photograph of a forest fire. Near the ground, the fire appears white or bright yellow because this is where most of the burning occurs; hence, it is the hottest region of the fire. Above the yellow region, the colour changes to orange, which is cooler. Above this, the fire appears red, which is cooler still. Above the red region, combustion is no longer occurring; therefore, the carbon particles are visible as black smoke.

Four Areas of an Arson Investigation

Take Notes

To prove that arson was the cause of a fire, investigators look for evidence in the following four areas:

1. **Proof of Incendiarism:** Fire investigators classify the cause of a fire as natural, accidental, unknown, or incendiary. An incendiary fire is one deliberately set by an arsonist. To classify a fire, investigators first try to locate the origin of the fire. To do this, photographs and diagrams of burn patterns are made and physical evidence is collected and analyzed at the fire scene. The origin of the fire along with other physical evidence can help determine the cause and the approximate time the fire was ignited.

2. **Proof of Opportunity:** To identify suspects in arson investigation, fire investigators consider everyone who had opportunity to set the fire. They examine building security. Everyone with access to the site before the fire is asked to provide an alibi for the period of the fire. If all alibis are confirmed, investigators conclude that the arsonist must have gained access to the site illegally; consequently, other evidence must be used to identify the suspects(s).

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Did You Know?

To ensure fire safety, all building products, materials, and furnishings in North America must be tested for fire resistance, combustibility, and flammability before they can be used in construction. The same applies to upholstery, carpeting, and plastics used inside vehicles.

Take Notes

3. **Proof of Motive:** Arsonists set fires for several reasons, such as financial gain, revenge, crime concealment, or vandalism. An owner may become a suspect if he or she gained financially from properties destroyed by fire in the past or if he or she is having financial difficulties and stands to gain from an insurance claim for the property under investigation. Investigators examine the owner's current insurance policies, insurance history, and current financial situation.

4. **Circumstantial Evidence:** Because the evidence related to arson is often circumstantial, investigators collect as many different types of evidence as possible to support their case. Following is a list of several types of evidence that investigators may use to support their case:

   - On-site fire or burglar detection systems are inspected for evidence of malfunction or tampering.
   - If the fire was reported, the identity of the caller is determined and a background check is completed.
   - The licence plates of automobiles in the area surrounding the fire may be checked.
   - Previous police activity conducted in the area is reviewed, as well as any reports of vandalism.
   - Hospitals in the local area may be asked if any patients with fire-related injuries were treated soon after the fire was set.
   - If an accelerant is identified, investigators may question local gas stations or hardware stores to see if a similar accelerant (such as gasoline or paint thinner) was purchased locally.

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Did You Know?

Estimates in North America are that fires started by cigarettes are responsible for 1500 deaths, 7000 injuries, and half a billion dollars in property losses every year. Cigarette companies have recently attempted to design cigarettes with a lower propensity to ignite large fires.

Indoor Fire Scene Investigation Tasks

Take Notes

After a fire has been extinguished and arson investigators can enter the site safely, access to the fire scene is controlled by police and fire department personnel to avoid scene contamination.

Arson investigators create an evidence collection area near the fire scene where they store any physical evidence found. Furniture, appliances, and other materials are often placed back in their pre-fire positions using the maps drawn by the occupants. This helps investigators examine and document every potential accidental ignition source or origin of arson in the rooms. In general, fire will burn longer at or near the point of origin. Therefore, damage will generally be more severe at the point of origin. Often physical evidence of the cause of the fire is found at or near the point of origin.

When the origin of the fire has been determined, a detailed diagram of the site is drawn. Windows, walls, floors, doors, ceiling composition, and the locations of key items are noted. All the entrance and exit points with lock types and conditions are identified. Sometimes, investigators call in experts to inspect and examine electrical wiring, appliances, or furnaces.

Burn Patterns

An interpretation of burn patterns may help investigators determine the cause and origin of a fire. Three burn patterns that are often identified during an arson fire are *the classic V, the doughnut,* and the *ignitable liquid pour*. Examination of burn patterns may reveal important information regarding the cause of the fire.

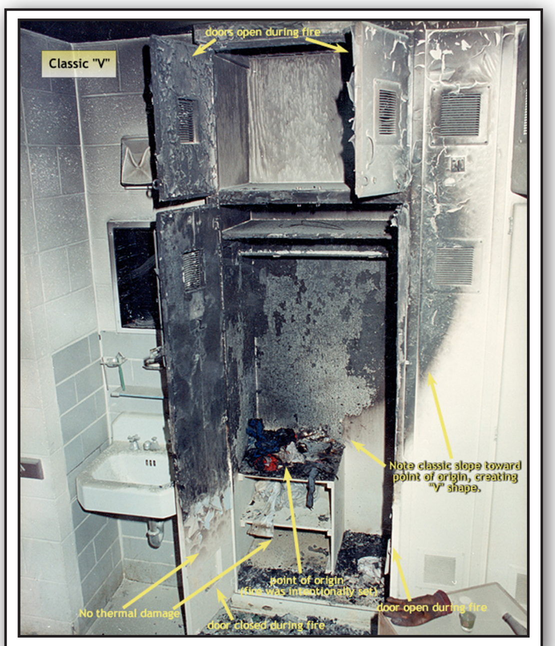

Image courtesty of Robert A. Corry, Director, Fire Investigation Specialist
http://www.interfire.org/res_file/patt_igl.asp

Lesson 2

Take Notes

Classic V pattern: As a fire moves upwards on a vertical surface, it creates a distinct V pattern. The most severe physical damage is usually found at the bottom of the V pattern. Because this is likely the point of origin, investigators focus their investigation on this area for evidence of accelerants or other possible causes of the fire.

Doughnut pattern: When a liquid accelerant is poured on carpet and lit, it tends to create a circular 'doughnut' type pattern. After the fire has been extinguished, evidence of accelerant is often found inside the 'doughnut' because the melted carpet material in the doughnut interior protects the carpet padding (which is saturated with fuel) from the effects of the fire.

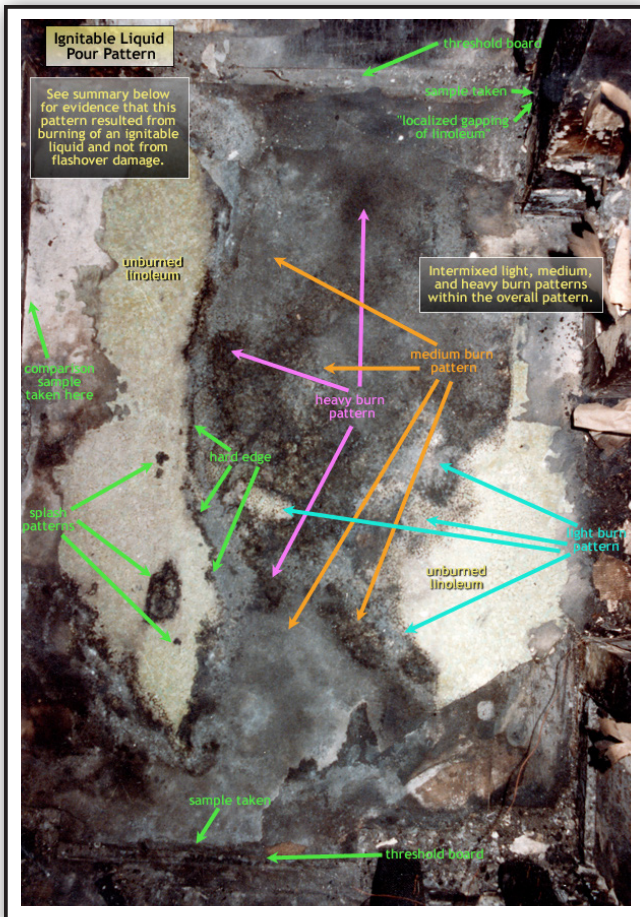

Image courtesy of Robert A. Corry, Director, Fire Investigation Specialist www.interfire.org.

Ignitable liquid pour pattern: Intense burn patterns are caused by ignitable liquid hydrocarbon accelerants such as gasoline, kerosene, or diesel that have high boiling points. When hydrocarbons burn, they tend to cause physical damage and distinct dark-coloured patterns (see photograph above). Accelerants with high vapour pressures, such as alcohol, acetone, and paint thinner, tend to 'flash and scorch' surfaces. Therefore, they cause less physical damage and more superficial scorching

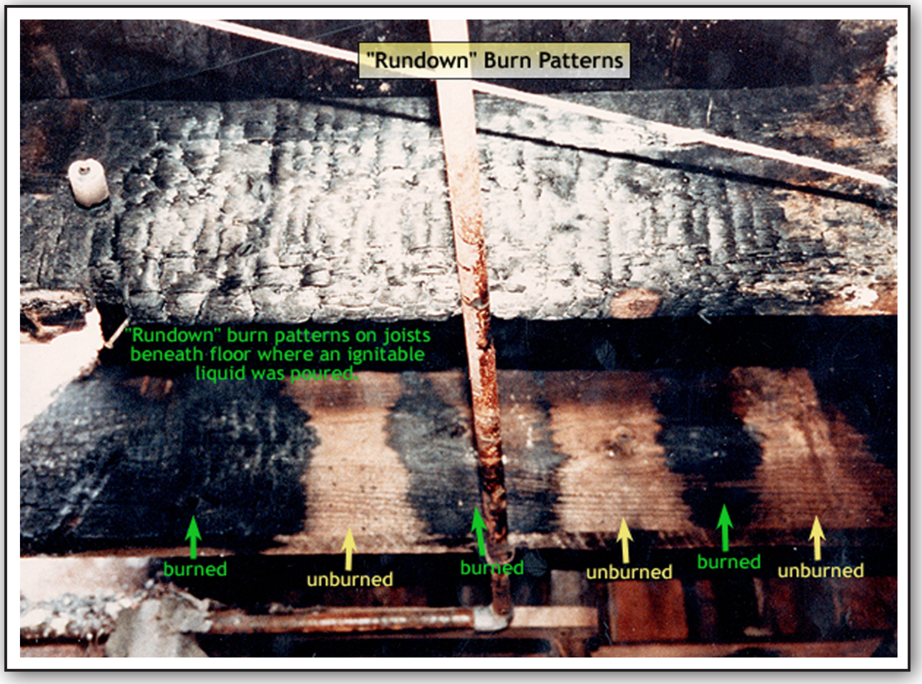

Image courtesy of Robert A. Corry, Director, Fire Investigation Specialist
www.interfire.org


Take Notes

When an ignitable liquid fuel source has been used to start a fire, intense burn patterns often appear on the areas where the liquid has been poured directly. Dark-coloured burn patterns tend to occur at the lower locations of uneven surfaces where fuel may have pooled before it ignited. These burn patterns are especially common on ***nonporous*** surfaces such as linoleum floors, tiles, and laminates. When an ignitable liquid fuel is poured onto ***porous*** surfaces such as carpets and wood floors, it may be absorbed into the materials as well as wood joists below the floor creating dark, distinct rundown burn patterns as shown in the photograph above.

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Collection and Analysis of Fire Scene Evidence

Take Notes

The physical evidence collected from a fire scene is analyzed and interpreted by forensic lab specialists. These forensic experts use specialized scientific equipment or techniques to help determine the cause of the fire. The most common service provided by laboratories to fire investigators is the analysis of fire debris for suspected accelerants. Arsonists often use an excess of accelerant to start a fire. Accelerant residues remain, and they may be detected by laboratory analysis. Unfortunately, if only a small amount of accelerant is used or if the accelerant is poured onto highly flammable substrates such as paper or plastic), laboratory analysis may be ineffective because no residues are left in the debris.

Collection of Evidence from a Fire Scene

Proper collection and storage of evidence is crucial to ensure that evidence is not contaminated. The ideal containers for fire scene evidence suspected of containing volatile accelerants are clean metal paint cans, sealable glass jars, or plastic bags. Fire investigators use several unique ways to find and collect physical evidence.

Ruins of the Great Chicago Fire, 1871

Canadian Press

Did You Know?

The Great Chicago Fire burned out of control for two days in 1871. The fire killed more than 300 people and destroyed about four square miles of wooden buildings and homes in Chicago, Illinois, USA. The cause of the fire has never been confirmed although arson is suspected. *(Traditionally, the fire is said to have been started by a cow kicking over a lantern in the O'Leary family's barn, but Michael Ahern, the Chicago Republican reporter who created the cow story, admitted in 1893 that he had invented the story!)*

Accelerant Detection Dogs: Dogs used in arson cases are trained to search for any type of accelerant that may have been used to start a fire. Accelerant detection dogs search the entire fire scene. If an accelerant was used, they alert their handlers to this by barking or sitting. The site that the accelerant detection dog identifies is usually the ignition point of the fire.


Take Notes

Photo Ionization Detectors (PID): Hydrocarbons such as gasoline, kerosene, and paint solvents used as accelerants can be detected using PIDs. A PID is a sensitive portable device that can detect hydrocarbon vapours at concentrations of 100 parts per billion, although similar devices used in a laboratory may be able to detect hydrocarbon levels in the 1 part per trillion range. The PID helps narrow the location of the hydrocarbon, and then this evidence may be collected and analyzed further.

The PID contains an ultraviolet lamp that emits ***photons***, which are absorbed by hydrocarbon compounds. Photoionization occurs in a PID when hydrocarbon molecules absorb light energy, which causes them to break apart and emit an electron(s) thus creating positively charged ***ions***. Electrodes in the PID, which generates an electrical current that is converted into a digital measurement reading, collect these ions. PID results are almost immediate; however, they cannot identify the type of hydrocarbon used so a sample must be collected and analyzed for further identification. PIDs may also give a false positive reading for water vapour, especially in humid conditions.

Portable Arson Sampler (PAS): PASs are used to collect any smouldering vapours or residue from a fire scene. A PAS consists of a series of special glass sampling tubes about the size of short pencils and contain an absorbent material (usually charcoal) that readily absorbs vapours. Inside a PAS sampling tube, vapours are separated from unwanted debris and kept away from metal surfaces where they might decompose. The entire sample is then sent to a laboratory for analysis and identification.

Solid-Phase Microextraction (SPME): SPME uses fibres that work like 'chemical dipsticks' to capture unknown vapours or residue. The fibres inside a syringe are coated with a polymer that readily absorbs thousands of compounds when exposed to the environment for a time. After the fibres have absorbed evidence, they are sent to a lab for analysis and identification.

Did You Know?

The appearance of a flame under normal gravity conditions depends on convection. As soot rises to the top of a flame, it is cone-shaped and appears yellow. In zero gravity, such as in outer space, convection no longer occurs, and the flame appears round, spherical, and blue.

Analysis of Fire Scene Evidence

Take Notes

After evidence from a suspicious fire scene has been collected, forensic experts analyze it in laboratories.

In most cases, arson investigators try to confirm if an accelerant was used and the type of accelerant used. Specific identification of accelerants used in arson fires is a challenging task. Often the accelerant can be detected and identified. However, at times an accelerant cannot be detected because all traces of accelerant were destroyed by the fire.

Gas Chromatography: Gas chromatography can be used to confirm the presence of an accelerant and to identify the type of accelerant. Several devices use the principles of gas chromatography; some are portable, but others operate only in laboratory settings. No matter the type, each device functions similarly.

Gas chromatography separates mixtures of compounds based on the differences in their physical or chemical properties. A stream of nitrogen or helium gas moves a mixture of unknown gaseous materials through a long tube coated with an absorbent separating compound. Depending on how strongly the unknown gaseous materials adhere to the separating compound, the length of time necessary for the components of the mixture to exit the column will vary. The unknown mixture is then introduced into the detector where there is a small flame. An electrical charge is produced and detected each time the flame meets a different compound within the unknown mixture. The identity of the component is determined by comparing the chromatogram that is produced to a databank of chromatograms of various accelerants and matching the amount of time the component required to pass through the separating compound.

Metal Oxide Sensors (MOS): Semi-conductor or metal oxide sensors (MOS) are the oldest and least expensive measurement technologies used in arson investigations. Gas fumes from an arson scene are exposed to the MOS, which consist of a thin film of a metal oxide on a substrate. The substrate is heated, which causes a chemical reaction between the gas and the metal oxide. This reaction changes the electrical conductivity of the metal oxide. The resistance of the metal oxide film is measured using electrodes. Although MOS sensors can detect a broad range of chemical contaminants very quickly, they may also respond to moisture or carbon dioxide, which results in false measurements.

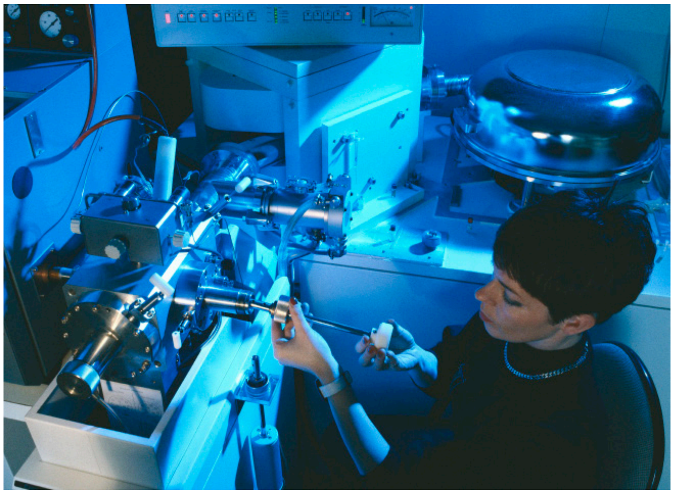
Did You Know?

Fire protection engineering is the application of science and engineering principles to protect people and their property from the destructive effects of fire and smoke. Fire protection engineers identify risks and design safeguards that help prevent, control, and minimize the effects of fire. Fire protection engineers assist architects with building safety evaluations and often function as fire investigators. For example, fire protection engineers investigated the collapse of the World Trade Center.

Take Notes

Mass Spectrometry: In mass spectrometry, the ionized components of unknown molecules are separated. This is done by passing the charged ions through either a magnetic or an electrical field. Each type of ion is then detected and used to identify the unknown compound. The disadvantage of mass spectrometry is that it can identify only one compound at a time. Mass spectrometry cannot be used to identify mixtures. However, gas chromatography is excellent at simultaneously separating several compounds in an unknown mixture. Most accelerant residues found in fire debris involve complex mixtures. Therefore, using both gas chromatography and mass spectrometry is currently the best way to identify accelerants found at arson scenes.

Lab Technician Inserts a Sample into a Mass Spectrometer



(cpimages.com/Phototake)

Did You Know?

In Massachusetts in 1916, Frederick Small strangled and shot his wife to death in their home. To destroy the evidence and divert all suspicion, he left his wife's body in the house with a time-delayed incendiary device. The device worked perfectly, setting his house on fire while Mr. Small was out of town. However, the fire caused a weak spot in the floor to collapse. Because of this collapse, Mrs. Small's body fell into the cellar where it was protected from the fire in a pool of water. Frederick Small was found guilty of arson and murder and was sentenced to death.

Take Notes

ARSON CASE STUDY: The Expert Fire Setter

During the 1980s and early 1990s, a string of baffling arson fires in Southern California, USA, took the lives of four people and caused more than several million dollars damage. The identity of the person responsible for these horrendous crimes was a shock to everyone.

On an afternoon in October 1984, a major fire occurred in a hardware store in South Pasadena, California, USA. The store was completely destroyed and four people, including a two year-old child, died in the blaze. All but one of the fire investigators assigned to the case thought the cause of the fire was faulty electrical wiring. The one fire investigator who disagreed was John Orr, the Captain of the Arson Unit with the *Glendale Fire Department*. Orr insisted very early in the investigation that the cause of the fire was arson. Although initial findings did not support Orr's assumption, further investigation revealed that the fire was started by an expert in fire setting. The arsonist started a small fire in an area of the store in which polyurethane products such as varnish and glue were stored. Because of the highly flammable nature of these products, the fire spread so quickly that four people died. The arsonist was not caught, and as time passed, more fires were set.

The next series of fires set by the arsonist occurred during January 1987 in Los Angeles. No one was killed or injured in these fires, but they caused thousands of dollars damage. Each fire occurred in the middle of the day at various businesses and each was started with a time-delayed device. Ironically, the fires were set during a major arson investigators conference in nearby Fresno, a city near Los Angeles. Luckily for investigators, a fingerprint on a small piece of paper inside a small time-delay explosive device was discovered at one of the fires. However, the single print could not be matched to any criminals in the fingerprint database that investigators used. Evidently, the suspect had no criminal record.

In March 1989, another four arsons occurred in various cities along the southern California coast. Yet again, the arsons were caused by time-delayed devices, and they occurred the same time as a conference of arson investigators in nearby Pacific Grove. This raised suspicions that the culprit was possibly an arson investigator from the Los Angeles area. Working with this assumption, investigators compared a list of attendees from the Fresno conference with the list of attendees from the Pacific Grove conference. By April 1991, a short list of ten suspects was compiled. Each suspect was asked for fingerprints. All the arson experts on this short list except Captain John Orr of the *Glendale Fire Department* were cleared of suspicion when their prints were compared with the fingerprint from the Fresno fire.

Orr then became the subject of an intensive investigation and surveillance until his arrest. Investigators installed a tracking device behind his dashboard when he had his vehicle serviced in November 1991. Shortly thereafter, in December 1991 Orr was tracked to the scene of another suspicious fire before dispatchers were made aware of the blaze. The surveillance ended, and an arrest warrant was obtained.

Take Notes

Bizarre pieces of evidence used to convict John Orr included

- secret videotapes taken by Orr of suspicious fires including those he was accused of starting
- an unpublished manuscript written by Orr about a serial arsonist who is a fire investigator (This manuscript contained detailed descriptions of many of the fire Orr was accused of setting.)

In July 1992, a jury found John Orr guilty of three counts of arson; he was sentenced to thirty years in prison. Orr adamantly maintained his innocence; however, he still pleaded guilty to three other counts of arson in March 1993. In June 1998, a jury convicted Orr of four counts of first-degree murder for the 1984 Fresno fire. As a result, he was sentenced to life in prison without the possibility of parole.

In 2003, a novel about John Orr entitled *Fire Lover: A True Story* was written by acclaimed crime novelist Joseph Wambaugh. This novel was later adapted into an HBO movie entitled *Point of Origin* in which Ray Liotta portrayed the serial arsonist John Orr.

Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

1. In the deadly 1984 arson fire, was John Orr's assumption correct about the cause of the fire? Explain.

2. What piece of individualized evidence linked the culprit directly with the arson fire?

3. How did investigators create a short list of arson suspects?

4. What finally lead investigators to arrest John Orr?

Check your answers in the Module 3 Appendix in the back of this book.

Assignment

When you are ready, please complete the assignment for Lesson 2 in the Assignment Booklet.

Lesson 3: Explosives

Lesson Objectives: ***The student will...***

Objective

- identify the three basic components of an explosive device: fuel source, oxidizer, and ignition.
- identify and describe various types of explosive devices (including *gunpowder, dynamite, nitroglycerin, saltpetre, guncotton, TNT, PETN, picric acid, plastic explosives*)
- describe various devices or techniques used by forensic experts to detect explosives (such as *robots, EGIS, canines, X-rays, metal detectors, ion mobility spectrometry, honeybees*)
- recognize various types of explosives (such as *explosive bombs, chemical bombs, inert bombs, nuclear bombs*) and understand the function of each.

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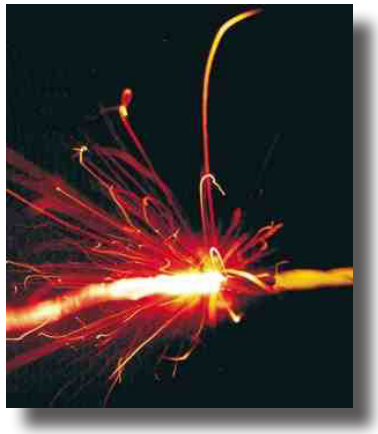
Take Notes

Explosives contain one or more chemical compounds that when detonated decompose or react very rapidly releasing gas, heat, and violent destructive shock waves. Detonation of an explosive device involves exposing the chemical compounds to heat or movement (mechanical shock or friction). Often explosives are placed within a metal casing that, when exposed to heat or shock, allows the pressure inside to increase until it bursts and fragments. The pieces of the explosive casing that blast outward at very high speeds are called shrapnel and can cause extensive damage to people, buildings, airplanes, vehicles, and anything else in the immediate area of the explosive blast.

Did You Know?

Explosives used for criminal activity and those used by the military are different. Military explosives are mass-produced. They are developed and constructed using standard designs and components and are intended to be deployed in standard ways. An explosive used by a criminal suspect(s) is known as a civilian bomb or *improvised explosive device* (IED). IEDs are usually custom-made using a wide range of explosives. These explosives have varying levels of explosive power and chemical stability and are used in many ways.

A Burning Fuse



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Parts of an Explosive

Take Notes

An explosive device has an ignition source or a fuse that when ignited causes a reaction between the compounds in the metal casing. A fuse is simply a length of cord either filled with combustible material or made from combustible material. The length of a fuse determines its burn time. For example, a fuse 30 cm long takes 60 seconds to burn and then detonates the explosive. Some fuses detonate after set periods by using mechanical, electronic, or chemical timers. Other fuses are point-detonating fuses; they combust upon impact such as when dropped or thrown.

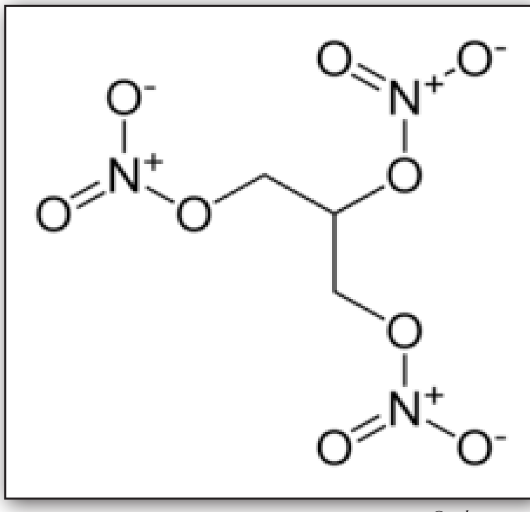
Some explosives have remote detonators that use wires or radio waves to detonate the explosive device from a distance. Bombs hidden in containers such as packages, suitcases, boxes, or portable stereos are usually triggered by battery-powered ignition switches (such as clocks) that are activated by opening the containers or by time-delay switches. Car bombs are usually detonated when the vehicle is started by the ignition switch. Usually, most of the time and effort that goes into making an explosive device is spent on the ignition source.

Inside the casing of an explosive is either a pure compound or a mixture containing an oxidizer and a fuel source. An example of a pure explosive compound is nitroglycerin, a highly unstable, heavy, colourless, oily liquid. Nitroglycerin is faster to ignite and more powerful than gunpowder. Nitroglycerin combined with sawdust makes dynamite. Dynamite is used for controlled blasting of dam sites, canal beds, and mines or demolishing large buildings by imploding their foundations.

Did You Know?

Explosive weapons used by military air forces and naval aviation that are airdropped and free-fall are called "bombs" by the military. Other military explosive devices are grenades, shells, depth charges, or warheads (when in missiles or land mines).

Nitroglycerin



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An oxidizer is a molecule that releases some atoms of one or more oxidizing elements allowing the fuel source of the explosive to continue burning. The fuel source of an explosive is an unstable chemical compound that when ignited produces an explosion. Two examples of oxidizer and fuel source mixtures found in explosives are the following:

Take Notes

- Black powder = potassium nitrate + charcoal and sulfur
- Flash powder = potassium nitrate + aluminium or magnesium

Fire versus Explosions

A fire and an explosion are often mistakenly considered to be the same thing. If explosive compounds are present where a fire is occurring, an explosion can occur. Heat and gas generated by an explosion often lead to a fire.

Differences between a Fire and an Explosion:

- An explosion is detonated. A fire cannot be detonated. An explosion occurs after compounds are exposed to heat or shock. A fire is initiated after being exposed to a heat source only.

Did You Know?

The burning fuse is the simplest and oldest type of fuse. This simple fuse, invented in tenth century China, consisted of lightweight paper filled with loose gunpowder. This type of fuse was used by the Chinese to ignite fireworks, and it is still found in fireworks today.

- Because of how quickly the reaction occurs in an explosion, shock waves are produced. A fire does not produce shock waves.
- Explosives usually have less potential energy than combustible hydrocarbons, but explosives release energy at a higher rate, which produces a greater blast pressure.

Similarities between a Fire and an Explosion:


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- Both require oxygen.
- Both require a fuel source.
- Both create heat and light.
- Both usually damage the environment in which they occur.

Categories of Explosives

For a compound to be considered explosive, it must react rapidly when exposed to heat or shock and it must produce gas and heat rapidly. An explosion is the oxidation and combustion of at least two unstable substances that produces a violent reaction.

Two general types of explosives are labelled **high** and **low**. Each is categorized by how quickly the explosive compound ignites and how fast the chemical reaction occurs. The speed of the chemical reaction that generates each type of explosion influences various other aspects of the blast.

Did You Know?

Nitroglycerin is used as a medication for a heart condition called *angina pectoris*. When nitroglycerin is consumed, the body converts to nitric oxide, which is a natural vasodilator causing widening of the blood vessels allowing increased blood flow.

Take Notes

Low explosives are sensitive to heat, friction, and temperature. The speed of the shock waves generated by a low explosive blast is approximately 2300 metres per second. Low explosive materials are usually lethal only when confined to a sealed container in which a huge increase in pressure occurs. Generally, explosives used in criminal activities are low explosives because they are small and are often created with easy-to-find materials such as fertilizer, gunpowder, or gasoline. Examples of low explosives include pipe bombs, car bombs, gunpowder, flares, and illumination devices.

Example of a Low Explosive: Pipe Bomb

© photos.com

High explosives tend to be larger, more complex, and more powerful. They also have a much greater speed of reaction than low explosives. Because high explosives react so quickly, the build-up of pressure and gas is almost instantaneous. High explosives tend to be less sensitive to heat, friction, and temperature. They create powerful shock waves that have speeds of up to 6900 metres per second. Examples of high explosives include compounds such as nitroglycerin and TNT. Both of these explosives are used for mining, and demolition and are used in military warheads.

Did You Know?

Plastic explosive material can be moulded into various shapes because it has a consistency similar to play dough. Most plastic explosive material contains the explosive compound cyclotrimethylenetrinitramine (RDX). Plastic explosives are expensive and require powerful detonators.

Example of a High Explosive: A Military Warhead

© *photos.com*

Forensic Explosive Detection and Identification

Take Notes

The location of explosive devices can be determined in several ways. The most common methods of explosive detection used today include bomb detection dogs, bomb detection robots, X-ray machines, and metal detectors.

After a bomb has been located, be it detonated or not, investigators must identify specifically the type of chemical compounds that caused or could cause an explosion. This information may help to identify the suspect(s) and/or help prove which suspect committed the crime. The two most popular methods used to identify explosive compounds involve gas chromatography and mass spectrometry.

Bomb Detection Dogs: Because a dog's sense of smell is thousands of times better than a human's, most police departments use specially trained police service dogs to identify the location of explosives. These dogs are trained to detect the odour of hundreds of different explosive compounds. They cannot identify the type of explosive. When a bomb detection dog detects an explosive substance, it is safely and carefully detonated.

Did You Know?

If a match is lit under zero-gravity conditions, it must be continually moved or the flame will go out. The reason for this is that the carbon dioxide created from combustion does not rise from the flame. Instead, it remains near the flame and smothers it.

Security agent demonstrates the use of an EGIS separation chamber that can detect trace amounts of explosives

(AP/Elise Amendola)

Take Notes

EGIS: Erieye Ground Interface Segment, a military software package, is a highly accurate device that uses gas chromatography and mass spectrometry to detect the presence of plastic, commercial, or military explosives. To operate, a residue is collected by rubbing a special wipe on an object or a person. The sample is heated until it is becomes gaseous. Then, it is transferred into a separation chamber in which individual compounds are separated using gas chromatography. All the compounds containing nitro-groups are selected and identified using mass spectrometry. Many high explosives contain one or more nitro-groups [that is, nitrogen (N), nitrate (NO_3), nitrite (NO_2)], which is why the EGIS system focuses upon these. EGIS can positively identify a mass of these explosives as small as one trillionth of a gram. Hence, it is a highly effective detection method. The system's primary disadvantage is that analysis requires quite a long time.

X-ray Machines: Specially designed X-ray machines can detect and identify explosives determining the density of a suspicious object and comparing it to known densities of various explosives. These X-ray machines use special computer software to make positive readings. However, ultimately, the operator determines if the object contains an explosive. X-ray machines are used by some police departments, most airports, highly secure government facilities, and some schools.

Did You Know?

Eric Robert Rudolph is an American anti-abortion and anti-gay extremist and domestic terrorist who committed a series of bombings across the southern United States in the late 1990s. His most notorious bombing was in Atlanta during the 1996 Summer Olympics when Rudolph detonated a pipe bomb killing one person and wounding 111 others. Rudolph also bombed two abortion clinics and a gay nightclub in Atlanta in 1997 and 1998. These bombings injured five people and killed two others. The bombs used in each incident were made of dynamite surrounded by nails. The Rudolph family believed Eric was innocent of all charges. In a strange show of support, Eric's older brother videotaped himself cutting off one of his own hands with a radial arm saw.

Take Notes

Metal Detectors: Most explosives are contained within a metal casing. Therefore, a metal detector alerts its operators to the presence of metals—which might contain explosives. When this occurs, a suspicious object is then examined to determine if it is actually an explosive and not just a device that happens to contain metal. Similar to X-ray machines, metal detectors are also used by some police departments, most airports, highly secure government facilities, and some schools.

Remote Mechanical Investigator: Remote Mechanical Investigator (RMI) units are robotic devices that are used to locate and safely remove explosive devices. An RMI is commonly used in situations where a bomb threat has been made or a suspicious package detected. In these instances, the area near the bomb is cleared to prevent human casualties. Several small cameras are mounted on an RMI to allow the operator to control its movements using a television monitor. The robot's operator uses its extendable arm and oscillating hand to disarm, remove a bomb, and/or safely detonate a bomb. A RMI robot is expensive, and its use is often limited to large police departments.

Lesson 3

Ion Mobility Spectrometry (IMS): IMS technology can detect small quantities of explosives accurately and quickly. This technique uses jets of air to blow molecules from skin, clothes, or objects such as luggage. The molecules become electrically charged during this process and are drawn into a detector that identifies the explosives (or drugs) according to their distinct electrical properties. The error rate of the IMS is said to be less than 0.1%. Devices that use IMS technology come in various forms such as hand-held units, tabletop models, or walk-through systems that resemble the metal detectors used in airports.

IMS Scanner that can detect trace amounts of explosives without physical contact

(AP/Matt York)

Did You Know?

A 'dirty bomb' is a radiological weapon (RDD) that combines radioactive material with conventional explosives. RDDs are designed to disperse radioactive material over a large area.

CRIME CASE STUDY 3.1: The Lockerbie Air Disaster

Crash of Pan Am Flight 103 on Dec. 21, 1988, Lockerbie Scotland *(AP/Martin Cleaver)*

Example

In 1988, the Lockerbie air disaster became the deadliest terrorist attack on U.S. civilians until the 9-11 World Trade Center tragedy occurred in 2001.

Take Notes

Pan Am flight 103 was a large Boeing 747 that flew daily between London's Heathrow International Airport and New York's John F. Kennedy International Airport. Just a few days before Christmas 1988, an explosive device was detonated on the airplane, which caused the aircraft to explode in mid-air. The plane's fuselage and the bodies of the 270 crew and passengers were scattered across an area near Lockerbie, Scotland. Eleven inhabitants of the small town were also killed.

The Explosion: The ***fuselage*** of the aircraft was reconstructed by air accident investigators. It revealed a 45 cm hole in the front cargo hold of the airplane. Examination of fragments from front cargo hold showed an area of blackening, pitting, and severe damage. Investigators conducted a series of test explosions to confirm the precise location and quantity of explosive used.

Did You Know?

Saltpetre is composed of the ionic compound *potassium nitrate*. Saltpetre is found naturally in limestone caves and is used to make matches, gunpowder, explosives, and fertilizers.

Take Notes

Investigators concluded that the nose separated from the main section of the aircraft within three seconds of the explosion. Because the explosion happened so quickly, the crew were unable to place a distress call. Winds of 190 kilometres per hour scattered victims and plane debris over approximately 2189 square kilometres.

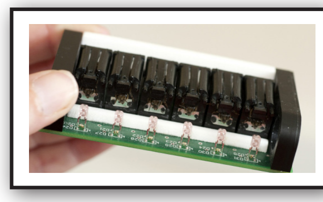
The nose of the airplane, which was found in Lockerbie, contained all the bodies of the flight crew and several first class passengers. Examination of the cockpit showed that no crewmember was wearing an oxygen mask. This is further evidence that indicating there was no time to begin any emergency procedures.

As it fell from the sky, the main section of the plane broke into smaller pieces. A large section attached to the wings landed in the middle of a residential area of Lockerbie. Aviation fuel in the tanks in the wings ignited to cause a huge fire destroying several houses. The fire was so intense that nothing remained of the left wing and the only way investigators were able to determine where the plane's wings had landed was by finding a large number of large screws used only in the wings in the fire debris.

The initial crash site was investigated by local police. However, the military also helped by providing helicopter surveys and satellite imaging. More than 10 000 pieces of evidence was found, tagged, and entered into a computer tracking system.

Cause of the Explosion

Forensic investigators determined that about 450 grams of a plastic explosive called Semtex hidden inside an unaccompanied piece of luggage was responsible for the explosion. Fragments of a Samsonite suitcase believed to have contained the explosive device were recovered, as were pieces of a circuit board from a radio cassette player. The time-delay explosive device was concealed inside the radio cassette player that was hidden in the suitcase along with some baby clothes.



Six sniffer bees (capable of detecting explosives like Semtex by scent) are mounted into tiny cartridges with perfectly sized stalls and a gate.
Louise Murray / Rex Features

Did You Know?

Honeybees have been trained to detect traces of explosives. A bee is trained to prefer different scents using sugar as a reward. After the one bee learns the cue, it passes this information to other bees, leading an entire hive to search for the new scent in a few hours. Honeybees are able to cover a large territory in a short time and are inexpensive. Some disadvantages to the use of bees include the inability to work at night, in storms, or in cold weather. They cannot be used in airports to sniff luggage. Currently, most of the detection work done by honeybees is the identification of landmines. Future uses of bees may include the detection of truck bombs.


Take Notes

Semtex is a general-purpose plastic explosive developed in the Czech Republic in the 1960s. Semtex was originally designed for commercial blasting and demolition; however, it became popular with terrorists because it cannot be detected by metal detectors and it is easy to obtain. Prior to the 1990s, Semtex could not be detected by X-ray machines. Semtex is considered very effective for attacks on airplanes because only a small amount is needed to destroy a large commercial passenger airplane. Semtex has been used in attacks by Middle Eastern Islamic militant groups, the Irish Republican Army (IRA), and the Irish National Liberation Army. Prior to 2002, Semtex was widely exported. The country receiving the most of this explosive was Libya with over 700 tonnes being imported between 1975 and 1981.

Because Semtex has been associated with terrorist attacks, production and export of Semtex today has been restricted to about 10 tonnes per year only. In addition, the chemical compound, ethylene glycol dinitrate, which is easily identified by explosive detection devices, is now added to Semtex.

The Warning: A few weeks prior to the explosion, a man with an Arabic accent phoned the U.S. Embassy in Finland and warned them that a Pan Am flight from Frankfurt to the United States would be blown up within the next two weeks by someone associated with the *Abu Nidal Organization*, a Palestinian terrorist group. The caller said a woman passenger would unknowingly carry the bomb aboard. The threat was taken seriously, and bulletins were sent to dozens of embassies and American airline companies. Unfortunately, despite the warnings the bomb slipped on board Pan Am flight 103.

The Bombers: After a three-year joint investigation by local police agencies in Scotland and the FBI, indictments for murder were issued for two men from Libya. Both men worked for *Libyan Arab Airlines* (LAA). One suspect was the head of security while the other was a station manager for LAA. Extradition of the two culprits from Libya to Scotland where they were tried took more than eight years. The extradition involved United Nations ***sanctions*** against Libya and direct negotiations with the Libyan leader Colonel Muammar al-Gaddafi.

In 2001, one of the culprits was convicted of murder and sentenced to 27 years in prison by a panel of three Scottish judges. The other suspect was acquitted.

Did You Know?

During World War II, allied bombers dropped high explosives to expose the wooden timbers in buildings and to rupture water mains. This was followed immediately by a wave of incendiary cluster bombs to start a large fire. After fifteen minutes, a third wave dropped fragmentation bombs. This time delay between bombings intentionally allowed firefighters and their equipment to be caught in the open and destroyed. The furnace-like conditions created in these fires were often hot enough to cremate the corpses they created.

Take Notes

Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

1. Why did investigators reconstruct parts of the airplane involved in this explosion?

2. Where was the site of origin of the explosion? How was this determined?

3. What type of bomb was used—high or low?

Assignment

Check your answers in the Module 3 Appendix in the back of this book.

When you are ready, please complete the assignment for Lesson 3 in the Assignment Booklet.

Did You Know?

A security screener from the Frankfurt airport, whose job it was to spot explosive devices under X-ray, told *ABC News* after the explosion that she did not know what Semtex was.

Lesson 4: Crime Case Studies Involving Arson and Explosives

Lesson Objectives: ***The student will...***

Objective

- explore a historical crime case(s) involving arson and/or explosives (such as *California Arson Fires, Timothy McVeigh, US Embassy in Kenya, 9/11 World Trade Center Disaster, Unibomber*)

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Did You Know?

In December 1991, an activist group called the *Animal Liberation Front* committed an arson attack against a fish company in Edmonton, Alberta. The deliberately set fire caused $46 000 damage and ironically killed several live lobsters and crabs.

HISTORICAL CRIME CASE STUDY 3.2: A Deadly Serial Arsonist

Burned-out Dept. of Forestry crew transport vehicle in which five firefighters lost their lives, Esperanza Fire, California, 2006 *(AP / Reed Saxon)*

Example

Take Notes

Old Fire

In October 2003, an arsonist in the San Bernardino Mountains of California started a blaze known as the Old Fire. The fire burned 369.4 km^2, destroyed 993 homes, forced nearly 80 000 people from their homes, and caused 6 deaths and $42 million of damage.

Esperanza Fire

In October 2006, the Esperanza Fire occurred in the Banning area of California. The cost to extinguish the fire was more than $8 million. It burned more than 160 km^2, destroyed 34 houses and 20 buildings, and killed five firefighters protecting a vacant, partially built home that eventually burned. The firefighters were overwhelmed when the winds shifted and blew a wall of flames towards them. Three firefighters died at the scene; the two others were found alive with severe injuries but died later in hospital.

The Arrest

Shortly after the deadly *Esperanza Fire* was determined to have been caused by arson, a $600 000 reward was offered for information leading to the arrest and conviction of the arsonist(s). The reward worked. In early November 2006, law enforcement officials arrested and charged Raymond Lee Oyler, a 36-year-old auto mechanic, with setting the *Old Fire*, the *Esperanza Fire*, and 20 other wildfires in the area. In addition to arson, Oyler was charged with five counts of first-degree murder. Fifty-five arson fires were reported from May 2006 until the time of Oyler's arrest. No arson fires occurred in the area after his arrest.

Oyler denied all the charges, telling investigators that, on the night of the *Esperanza Fire*, he was at a casino, and then he stopped at a gas station before driving to the wildfire to watch it.

The Evidence


Take Notes

Finding evidence in cases of arson is difficult because the fires usually destroy the evidence. However, the forensic arson experts in the *Old Fire* and *Esperanza Fire* investigations were ***meticulous***. Consequently, they found several pieces of evidence to support their case.

Serial arsonists are often predictable because they tend to use the same type of ***incendiary*** device for each fire. All but one of the fires Oyler was charged with were started with nearly identical homemade incendiary devices consisting of five to seven paper or wood matches attached around a Marlboro cigarette with duct tape or a rubber band. When the cigarette was lit, it burned slowly until it reached the matches, ignited them, and started a brush fire. Each device allowed a time delay of more than 10 minutes, during which Oyler would leave the scene and create an ***alibi***. On cigarette butts in two of the incendiary devices found, investigators discovered DNA evidence that matched Oyler.

Investigators also had video footage from secret cameras atop utility poles that filmed Oyler's car leaving the scene of one of the fires. Ironically, surveillance videos from the casino and the gas station that Oyler said he was at during the *Esperanza Fire* showed he was not at either location during these times.

Oyler's cousin and his girlfriend provided evidence that incriminated Oyler. Both acknowledged that Oyler owned a book called *Anarchist Cookbook* that discussed how to make devices to start fires. They acknowledged that he had boasted about lighting fires. Four days before the *Esperanza Fire*, Oyler said he wanted to set some fires near an animal facility where his pit bull was being held after it had bitten a woman.

The Trial

At the trial, Oyler's sister testified that he was at home when the *Esperanza Fire* began. Despite this testimony, in 2009, a jury convicted Raymond Lee Oyler of five counts of first-degree murder, nineteen counts of arson, and sixteen counts of possessing incendiary devices. The court sentenced Oyler to death despite the pleas of Oyler's lawyer that he should receive a reduced sentence of life in prison without the possibility of parole.

Criticism

After the tragic death of five firefighters in the *Esperanza Fire*, many criticized the decision to send a firefighting crew to protect a single vacant, partially built house. Some suggested that firefighters should not be sent to protect vacant houses or isolated individual homes. If this suggestion had been followed, five firefighters would very likely be alive today.

Did You Know?

The *Esperanza Fire* spread extremely rapidly due to windy conditions and highly flammable vegetation, charring 97 km^2 in 18 hours. In comparison, the *Ventura County Fire* burned 97 km^2 in two weeks.

HISTORICAL CRIME CASE STUDY 3.3: The Oklahoma City Bombing

Alfred P. Murrah Federal Building, Oklahoma City, Shortly after the 1995 attack. (AP / David Longstreath)

Example

The Oklahoma City bombing was a terrorist attack occurring in April 1995. The *Alfred P. Murrah Federal Building*, a U.S. government highrise in downtown Oklahoma City, was bombed, the explosion killing 168 people, including children, and injuring over 800 more.

Take Notes

Planning and Preparation

Timothy McVeigh rented a truck in Kansas and drove it to Oklahoma City with Terry Nichols, his accomplice. When they arrived in Oklahoma City, they rented a car and parked it a few blocks from the *Alfred P. Murrah Federal Building*. They removed the licence plate from the car and left it. This car would become their getaway vehicle. McVeigh and Nichols then returned to Kansas in their rented truck for two days. They spent two days creating a time-delayed explosive device that they put in the rented truck that they packed with explosives. After finishing the truck-bomb, the two men separated; Nichols returned to his home in Kansas, and McVeigh drove the truck to Oklahoma City.

Lesson 4

Did You Know?

Five years after the bombing, the Oklahoma City National Museum and memorial were completed. The memorial includes the *Field of Empty Chairs*—symbolic bronze and stone chairs, one for each person lost. The chairs represent the empty chairs at the dinner tables of the victims' families. Smaller chairs represent the 19 children killed.

Timothy McVeigh

(AP/ David Longstreath)

The Explosive Device

Take Notes

Timothy McVeigh and Terry Nichols fashioned their explosive device from large amounts of several chemical compounds, most of which they stole. The chemicals were mixed using plastic buckets and a bathroom scale. They used more than a hundred 22 kg bags of ammonium nitrate, several 208-litre drums of nitromethane, several crates of explosive Tovex sausage, and numerous bags of ANFO (ammonium nitrate-fuel oil).

Ammonium nitrate: a white powder commonly used by farmers as a fertilizer; an oxidizing agent when used in an explosive

Nitromethane: an organic compound used as a solvent, a cleaning solvent, or a highly potent racing fuel

Tovex: sausage-shaped strings of a commercial explosive that has become more popular than dynamite; used in construction, mining, quarrying, tunnelling, etc.

ANFO: *ammonium nitrate-fuel oil*; most widely used explosive in coal mining, quarrying, metal mining, and construction

After the bomb was completed, a fuse was time-delayed and made to detonate using the truck's ignition. The determined bombers included extra explosives near the driver's seat to be ignited by McVeigh's handgun if the main fuse failed.

Did You Know?

ANFO (ammonium nitrate-fuel oil) accounts for an estimated 80% of the 2.7 million metric tons of explosive used annually in North America.


Take Notes

The Explosion

About 9 a.m. April 19, 1995, Timothy McVeigh parked the truck in a drop-off zone on the north side of the *Alfred P. Murrah Federal Building*. This drop-off zone was directly under a children's day-care centre. McVeigh then triggered the time-delayed detonator, locked the vehicle, and walked to his getaway car parked a few blocks away.

The explosion destroyed one-third of the entire building and created a 2.4-metre crater with a diameter of 9 metres. The blast destroyed or damaged 324 buildings in a sixteen-block radius, destroyed 86 cars, and shattered windows in 258 neighbouring buildings. The destruction of the *Alfred P. Murrah Federal Building* left several hundred people homeless and shut many businesses in downtown Oklahoma City.

The Victims

The bombing claimed 168 lives and injured more than 800 people. Of the dead, 160 were from inside the *Alfred P. Murrah Federal Building*, six were from nearby buildings, one woman was across the street in a parking lot, and one rescue worker was struck in the head by debris. The victims ranged in age from three months to 73 years. Tragically, three victims were pregnant women and 19 were children. Family members identified the bodies at a temporary morgue on site. Medical experts determined the identities using X-rays, dental examinations, fingerprints, blood tests, and DNA analysis. The explosion injured 853 people, the majority having various ***abrasions***, severe burns, and fractures.

Lesson 4

The Rescue Effort

Just minutes after the explosion, ambulances, police, and firefighters arrived. They were soon assisted by the Civil Air Patrol, the American Red Cross, and citizens who had witnessed the blast. More than four hundred members of the Oklahoma National Guard arrived within an hour of the explosion to provide security. This immediate action led to the rescue of fifty injured people within the first hour.

About 1.5 hours after the explosion, rescue workers found what appeared to be a second bomb. Many rescue workers initially refused to leave, but police ordered a mandatory evacuation of a four-block area around the site. This evacuation was cancelled when the device was determined to be only an explosive simulation device used in training explosive detection dogs.

Did You Know?

Broken and flying glass from windows in the *Okalahoma City Bombing* accounted for 5% of the death total and 69% of the injuries outside the *Alfred P. Murrah Federal Building*.


Take Notes

In the days that followed, more than 12 000 people helped in the massive rescue and clean-up operation. Twenty-four police service tracking dogs searched for survivors and bodies in the debris. For ten days following the attack, 100 to 350 tons of rubble were removed from the site each day. The rescue and clean-up operation was completed in 35 days and the remains of the *Alfred P. Murrah Federal Building* was demolished.

The Arrests

Just 90 minutes after the explosion, an Oklahoma Highway Patrol officer pulled over 27-year-old Timothy McVeigh as he travelled out of Oklahoma City. He was arrested for driving without a licence plate and carrying a concealed handgun. Later that day, McVeigh was linked to the bombing when investigators found the serial number from the axle of the destroyed rental truck. McVeigh was a 27-year-old decorated U.S. Army veteran of the Persian Gulf War, and he was a ***sympathizer*** of an anti-government militia movement.

Federal agents then searched for Terry Nichols. Two days after the bombing, Nichols learned that investigators were looking for him and he turned himself in. McVeigh and Nichols' motive was to avenge the U.S. government's raid of the Branch Davidian sect in Waco, Texas, in which 80 people died.

A third suspect named Michael Fortier was also eventually arrested. Fortier was a friend of Timothy McVeigh and Terry Nichols. He had an indirect role in the bombing by helping steal some of the bomb supplies and accompanying McVeigh on a previous visit to the *Alfred P. Murrah Federal Building* to plan the bombing

The Criminal Trials

At that time, the *Oklahoma City Bombing* was the largest criminal case in U.S. history. Nearly 28 000 interviews were conducted and evidence weighed more than 3 tonnes. The massive investigation led to separate trials and convictions for Timothy McVeigh and Terry Nichols.

In June 1997, a jury found Timothy McVeigh guilty of eleven counts of murder and conspiracy. McVeigh was sentenced to death and was executed by lethal injection in June 2001. The execution was televised and watched by relatives of the victims.

Did You Know?

The *Oklahoma City Bombing* led the U.S. government to pass legislation to increase protection around federal buildings to prevent future domestic terrorist attacks. This legislation has helped law enforcement to interrupt more than fifty domestic terrorist plots.

Take Notes

Terry Nichols was tried in federal court in 1997 and found guilty of conspiring to build a weapon of mass destruction and of eight counts of involuntary manslaughter. He was sentenced to life without parole. Then in May 2004, he was found guilty of 161 counts of first-degree murder. The jury deadlocked regarding the issue of sentencing him to death, so the presiding judge gave Nichols a sentence of 161 consecutive life terms without the possibility of parole.

Michael Fortier agreed to testify against McVeigh and Nichols in exchange for a modest sentence and immunity for his wife. As a result, Fortier was given only 12 years in prison and a $200 000 fine for failing to warn authorities about the attack. On January 20, 2006, after serving 85% of his prison term, Fortier was released for good behaviour. Michael Fortier and his wife were placed in the Witness Protection Program and given new identities.

Memorial Service at Alfred P. Murrah Federal Building, May 1995

(AP/ Bill Waugh)

Assignment

When you are ready, please complete the assignment for Lesson 4 in the Assignment Booklet.

Did You Know?

The leader of the *Branch Davidian* religious sect in Waco, Texas, was accused of practising polygamy with underage brides, physically abusing children, and stockpiling illegal weapons. Federal law enforcement agents conducted a raid on their compound in February 1993. This initial raid resulted in the deaths of four law enforcement officers and six Davidians. Fifty-one days later, during which time 24-hour surveillance was being conducted, CS tear gas was released into the compound. In an act of defiance, the Davidians set fire to their compound, killing 79 people, 21 of whom were children.

Forensic Studies 35

LDC 3569

Module 4

Forensic Ballistics

Module 4: Forensic Ballistics

Various Types of Firearm Ammunition

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Overview

Forensic ballistics involves the scientific analysis and interpretation of evidence and phenomena related to the illegal use of firearms. For more than a century, the collection of evidence related to the use of firearms in the commission of criminal offences has been a standard investigative tool. Information critical to the successful investigation of firearm-related crimes is obtained from various sources, including matching a bullet to the gun from which it was fired, analyzing traces of gun residue found on a suspect, and tracing shell casings left at a crime scene to a particular firearm.

- Lesson 1 of this module outlines the basic types of firearms and the unique velocity, kinetic energy, and trajectory capabilities of each type. This lesson also outlines the main components of bullet cartridges and firearms.
- Lesson 2 examines the distinct properties within gun barrels and the ways these properties help law enforcement in criminal investigations involving firearms. This lesson also addresses the concept of ballistic fingerprinting.
- Lesson 3 describes five types of testing for gunpowder residue.
- Lesson 4 explores one historical crime case and one fictional crime, both relating to forensic ballistics.

Module Learner Objectives

By the end of Module 4, you should be able to…

- understand that forensic ballistics involves the scientific analysis of evidence from crime scenes in which a firearm was used (such as *firearms, bullets, bullet holes, bullet trajectories, cartridges cases, and gunshot wounds*)
- appreciate that forensic ballistics involves internal ballistics, external ballistics, and terminal ballistics
- outline the major components of a handgun cartridge, a rifle cartridge, and a shotgun shell)
- describe how the structure, function, velocity, kinetic energy, and trajectory of the three main types of firearms (handguns, rifles, and shotguns) differ
- graph and analyze data to compare the average velocity, kinetic energy, and trajectory of handgun, rifle, and shotgun rounds
- recognize that gun barrels have unique lands and grooves and that these markings leave unique marks or *ballistic fingerprints* upon fired casings
- discuss the possible value of a comprehensive national or global *ballistic fingerprint* data bank and propose the positive and negative implications of having such a data bank
- understand that forensic ballistic experts use various gunpowder and/or primer residue chemical test techniques to determine if a suspect has fired a gun
- describe how forensic experts test for gunpowder residue and primer residue using various scientific techniques and technologies (such as *Paraffin Test, Modified Greiss Test, Sodium Rhodizonate Test, Harrison-Gilroy Test, Neutron Activation Analysis and/or Flameless Atomic Absorption System, and X-ray analysis using a scanning electron microscope*)
- discuss one historical crime case (such as *Washington sniper shootings* and *John F. Kennedy assassination*) and one fictional crime case that involve forensic ballistics

Did You Know?

The first court case involving firearms evidence occurred in 1902 when a specific gun was proven as the murder weapon. The expert in the case, Oliver Wendell Holmes, had read about firearm identification and had a gunsmith test-fire the alleged murder weapon into a wad of cotton wool. Then, a magnifying glass was used to match the bullet from the victim with the test bullet

Lesson 1: Firearm Basics

Lesson Objectives: ***The student will...***

Objective

- understand that forensic ballistics involves the scientific analysis of evidence from crime scenes in which firearms were used (for example, *firearms, bullets, bullet holes, bullet trajectories, cartridges cases, gunshot wounds*)
- appreciate that forensic ballistics involves internal ballistics, external ballistics, and terminal ballistics
- outline the major components of a handgun cartridge, a rifle cartridge, and a shotgun shell
- describe how the structure, function, velocity, kinetic energy, and trajectory of the three main types of firearms differ
- graph and analyze data to compare the average velocity, kinetic energy, and trajectory of handgun, rifle, and shotgun rounds

Revolver

Pistol

Rifle

Shotgun

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Did You Know?

The first forensic firearm identification occurred in England in 1835 when the distinctive markings on a bullet taken from a victim were matched with a bullet mould belonging to the suspect. When confronted with this evidence, the suspect confessed to the crime.

Internal, External, and Terminal Ballistics


Take Notes

Ballistics is a science that deals with the motion, behaviour, and effects of ***projectiles*** (such as bullets, rockets, and missiles). Forensic ballistics involves the science of analyzing the motion, behaviour, and effects of a bullet fired from a gun. The study of forensic ballistics has three sub-categories: internal ballistics, external ballistics, and terminal ballistics.

1. ***Internal ballistics*** is the study of the evidence produced inside a firearm when a bullet or round is fired. This includes the study of firearm mechanisms, ***gun barrel*** manufacturing techniques, factors influencing the internal gas pressure within a particular firearm, and firearm ***recoil***. The most common types of internal ballistics involve
   - examining the working mechanisms of firearms to determine the cause of accidental discharges
   - examining homemade devices (sometimes called zip guns) to determine whether they are capable of discharging ***ammunition*** effectively
   - comparing fired bullets and cartridge cases to determine whether a particular firearm was used
2. ***External ballistics*** is the study of the bullet's flight from the moment it leaves the ***muzzle*** of the firearm's barrel until it strikes a target. The two most common types of external ballistics forensic examinations involve
   - calculating and reconstructing of bullet ***trajectories***
   - determining the maximum range of a given bullet
3. ***Terminal ballistics*** is the study of a bullet's effect on the target or the counter effect of the target on the bullet. *Wound ballistics* is a form of terminal ballistics in which the target is a human or an animal. Common types of terminal ballistics forensic examinations include
   - determining the distance between firing point and target
   - establishing whether a particular bullet caused the wound in question
   - determining the ***calibre*** and type of bullet that caused damage or, in the case of a human victim, a gunshot wound
   - identifying the entry and exit points of a bullet in a static target or human body
   - examining ***ricochet*** possibilities of targets and fired bullets

Basic Type of Firearms

Take Notes

In most criminal investigations involving the use of firearms, forensic experts typically examine three types of firearms:

1. handguns (referred to as either ***semi-automatic*** pistols or revolvers)
2. rifles (centrefire or rimfire)
3. shotguns (pump action or semiautomatic)

Each type of firearm is unique in structure, function, and ballistic properties as defined by ***velocity***, ***kinetic energy***, and ***trajectory***.

Handguns: The Revolver

© *photos.com*

The term *revolver* is derived from the fact that individual bullet cartridges (bullets or *rounds* as they are commonly known) are loaded into a cylinder that revolves slightly with each pull of the trigger. The cylinder advances so that the next bullet is brought into line with the opening of the barrel.

As the ***firing pin*** strikes the bullet's primer (located at the centre of the base of the cartridge), the gunpowder in the cartridge casing explodes, forcing the bullet out of the cylinder, into the opening of the barrel, down the length of the barrel, and out the muzzle.

Did You Know?

If a gun is fired into the air, the bullet may travel as much as two kilometres high depending on the angle of the shot and the power of the gun. When a bullet reaches its highest point, it begins to fall. Bullets are aerodynamic; therefore, a bullet falling back to earth can be quite lethal if it hits someone.

In an open rural area with few people, the chance of a bullet that has been fired into the air hitting someone is remote. In crowded cities, however, the probability of being hit by a stray bullet that has been shot into the air rises dramatically.

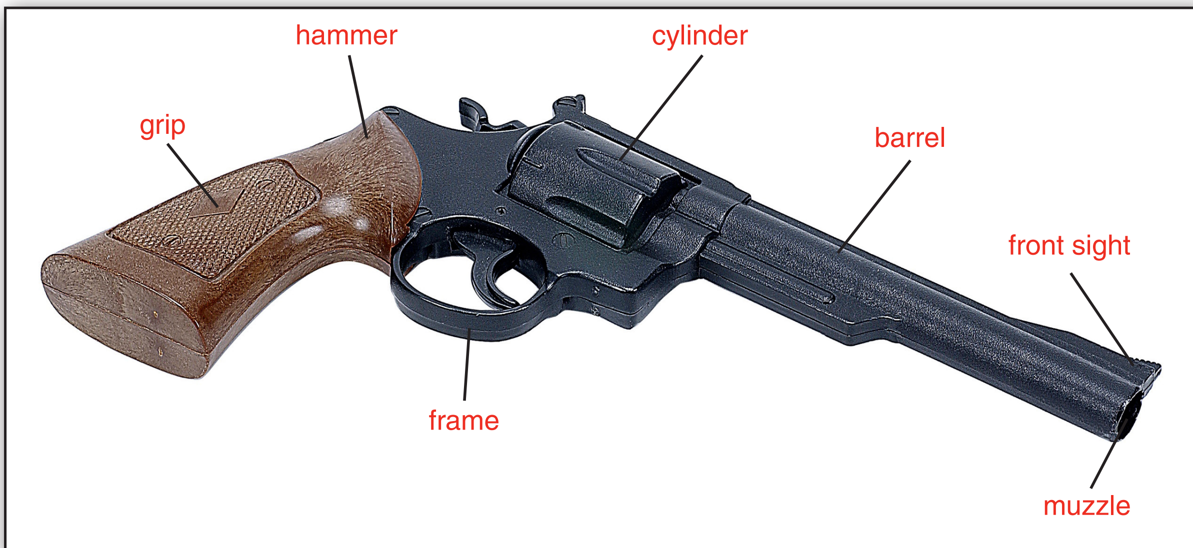
Take Notes

A muzzle *blast* can be quite substantial in revolvers, especially where the cylinder lines up with the opening of the barrel. A revolver typically holds six cartridges in one of various ***calibres*** such as .22, .38, .357, and .44 (spoken as *twenty-two, thirty-eight, three fifty-seven,* and *forty-four*). The calibre of a firearm refers to the diameter of the bullet, usually measured in tenths of an inch. Therefore, a .38 calibre revolver fires a bullet that is 0.38 inch in diameter. Rather than refer to this diameter in metric units, the firearms industry has retained these commonly understood terms.

The ballistic property of revolver ammunition varies by calibre. Typically, .22 and .38 calibre ammunition have low muzzle velocities and limited amounts of kinetic energy. The structure and design of revolvers, specifically because of the use of a cylinder, result in significant loss of kinetic energy and muzzle velocity due to the escape of gases around the cylinder and barrel opening when the gun is fired.

Revolvers remain popular among collectors and people who like to target shoot as a hobby. Law enforcement agencies have generally discontinued their use of revolvers because of low ammunition capacity, lengthy reloading time, and inadequate muzzle velocity.

The Main Parts of a Firearm - Revolver



© *photos.com*

Did You Know?

The enduring popularity of revolvers is due to their simple design. Individual parts fit together in such a way that they rarely jam. In addition, because they are made with a small number of parts, they are relatively inexpensive.

Handguns: The Pistol

© *photos.com*

A pistol is characterized by semi-automatic features in which a slide sits on top of the frame. Bullet cartridges are loaded into a holding device called a magazine that is inserted into the handle of the pistol. The barrel sits inside the slide. Each pull of the trigger and discharge of a cartridge produces a recoil force that moves the slide back drawing a new bullet into the opening of the barrel. The slide then returns to its forward position, locking the bullet into the barrel. When the trigger is pulled again, the process repeats. Pistol bullet velocity can be considerably higher than a revolver's velocity because the hot gases emerging from the bullet casing are contained within the barrel of the pistol, thereby increasing the pressure acting against the bullet as it moves down the barrel and out the muzzle.

The unique design of semi-automatic pistols allows for faster reloading times, higher firing rates, and higher magazine capacities (typically 10 to 16 bullets per magazine). The trigger can be pulled in rapid succession while keeping the pistol on target. For example, a person using the .40 Glock pistol is able to fire fifteen rounds of ammunition continuously before loading a new magazine.

Pistol ammunition varies in calibre, with 9 mm, .40, and .45 being the most common. Law enforcement agencies across North America typically use 9 mm or .40 calibre pistols although .45-calibre pistols are sometimes used.

While occasionally prone to jamming if not properly maintained, automatic weapons have increased among criminals in recent decades. Therefore, law enforcement agencies have adopted semi-automatic pistols because of their large magazine capacity. In addition, police are now using hollow point bullets. Recent trends include the use of semi-automatic rifles (***carbines***) by patrol officers in response to the increased firepower of some criminals. The public became aware of this increased firepower because of such high profile incidents as the 1994 North Hollywood shootout in Los Angeles.

The Main Parts of a Semi-Automatic Pistol

© *photos.com*

Semi-Automatic Pistol Cartridges

© *photos.com*

Did You Know?

Semi-automatic pistols have largely replaced .38 revolvers in police agencies across North America. This transition was stimulated in part by the tragic outcome of a FBI shootout in Miami-Dade County in 1986 when two FBI agents were killed and four others wounded by one of two gunmen armed with a semi-automatic .223 rifle.

The Bolt-Action Rifle

© *photos.com*

Take Notes

Bolt-action rifles are reliable and easy to maintain. These rifles vary widely in calibre and purpose. They are characterized by a handle (bolt) on the side that allows the user to extract a spent cartridge and place a new one into the barrel from the magazine by sliding the bolt back and then forward.

Bolt-action rifles typically hold up to five cartridges and must be reloaded after each round is fired. Telescopic sights help bring targets into focus over long distances. Depending on its calibre, the use of a telescope mounted along the barrel above the *action* of the rifle increases the effective range of a bolt-action rifle to between 200 metres and 1000 metres (1 kilometre).

Because of the longer shell casings, bolt-action rifle bullets possess extremely high muzzle velocities and kinetic energies. For example, while a standard .40 calibre pistol round commonly used by police agencies has a muzzle velocity of 305 metres/second and 542 Joules of kinetic energy, a .308 round from a police sniper's bolt-action rifle has a muzzle velocity of over 792 m/s and almost 3660 J of kinetic energy! In other words, a rifle bullet is smaller in diameter, travels faster, and has much more kinetic energy than a bullet fired by either a revolver or a pistol.

Just as muzzle velocity, kinetic energy, and trajectory vary with revolver and pistol ammunition, they also vary widely depending on the calibre of the rifle bullet. However, the trajectory of rifle bullets can in most cases be much flatter than that of handgun ammunition. For example, a handgun round fired parallel to the ground might fall into the dirt after it has travelled the length of two football fields. A rifle bullet used in big game rifles might travel more than 3 kilometres before doing so.

Did You Know?

Bolt-action rifles have existed since the late 1800s, serving as the principal type of weaponry for soldiers until World War II in 1939. They remain popular with big-game hunters, farmers, and shooting enthusiasts.

The Automatic Rifle

© *photos.com*

Take Notes

Typically referred to as *assault rifles*, an automatic rifle is characterized by its ability to fire a continuous stream of bullets with each pull of the trigger. The rifle pictured above is a version of the standard weapon used by the US military and increasingly by police agencies across North America.

Assault rifles are highly accurate up to approximately 200 metres. They are designed for combat scenarios in which a large number of bullets are directed at a target in a brief time. Automatic weapons such as the AR-15 have been modified for law enforcement use and are valued for their accuracy and stopping power.

Automatic weapons, whether machine guns, assault rifles, or submachine guns, are available for various sizes of ammunition, including .223, 9 mm, and 7.62 mm. Most of these ammunition rounds have relatively flat trajectories. This means that a bullet can travel a great distance without falling into the ground. For example, the .223 round commonly used in the AR-15 rifle might drop only 1 to 2 cm as it travels the length of two football fields. Consequently, automatic weapons are highly accurate under controlled conditions.

Rifle Cartridges

© *Thinkstock*

Did You Know?

With high rates of fire and tremendous muzzle velocities, automatic rifles can be extremely dangerous in the wrong hands. These weapons are illegal in Canada without successfully completing a rigorous screening process.

The Shotgun

© *photos.com*

Take Notes

Shotguns were designed to spray lead ***pellets*** over a large area. They are ideal for hunting birds or small animals that move quickly. Shotguns are very popular due to their versatility and durability. The 12-gauge Remington 870 shotgun has been issued in law enforcement agencies for decades.

Shotgun Shells

© *photos.com*

Shotguns fire *shells* rather than cartridges from a magazine holding three or four rounds. They can fire a wide variety of shells in various calibres. *Birdshot* typically consists of a large number of small lead pellets packed within the shell, which sits above a brass casing and primer. *Buckshot* consists of a smaller number of lead pellets, each of which is larger in diameter than birdshot. Typical buckshot rounds used by police agencies contain approximately nine lead pellets, each the size of a small pea. Its effective range is limited to 20 to 30 metres. *Rifle slugs* are also used in shotguns, increasing the effective range of a shotgun to approximately 100 metres (the length of a football field). Slugs are lead bullets about the size of a man's thumb. They have substantial amounts of kinetic energy over short distances. However, they lose height rapidly after approximately 100 metres. Therefore, shotgun slugs are inaccurate past that distance.

Did You Know?

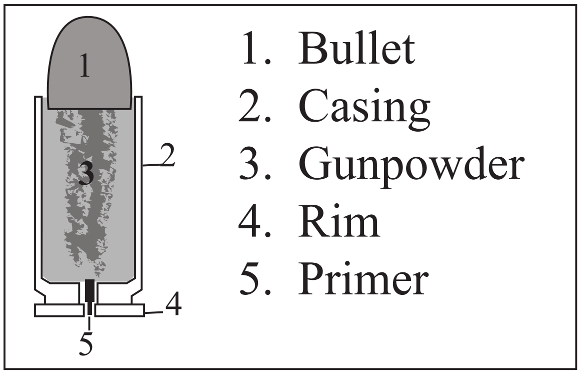
Shotguns have existed since the mid-1800s and have undergone very few modifications since World War II. They are widely owned in both Canada and the United States and are typically used for hunting and sports such as skeet shooting.

Firearm Cartridges and Components

Take Notes

To gain a better understanding of the science behind forensics ballistics, one must understand the basic parts of a firearm and the assembly of rifle and pistol cartridges.

The Main Parts of a Firearm Cartridge



© ADLC

Cartridges are often referred to as *bullets* although this is technically an inaccurate term. A bullet is just one component of the various parts of a cartridge. A cartridge consists of a casing (2) made from brass with a primer (5) at its base (4); the casing is filled with a particular amount of gunpowder (3) on top of which sits a ***projectile*** called a bullet (1).

A Handgun Cartridge

© photos.com

The photograph above displays two .357 handgun cartridges. The primer mounted in the base of each bullet is displayed in the upper right photograph. The silver-coloured casing contains a hollow point bullet designed to increase stopping power. The bullet in the brass-coloured casing is the wadcutter design intended for target practice.

A Rifle Cartridge

© *photos.com*

Take Notes

Rifle (or long-gun) cartridges utilize the same basic designs as handgun cartridges and can carry the same calibre bullet as a pistol cartridge, but they contain larger amounts of gunpowder in the elongated casings. As a result, muzzle velocities of bullets leaving a rifle barrel are often much higher than the muzzle velocities of handgun rounds.

The mechanics of loading and firing a cartridge are essentially the same in both types of firearms. A cartridge is initially loaded into the cylinder or magazine of the firearm. Then, it is manually loaded into the breech by *cocking* the weapon. This places the firing pin in a position immediately behind the primer. When the person using the firearm pulls the trigger, the firing pin is released, and it strikes the primer. When the primer is detonated, it ignites the gunpowder in the casing, causing a controlled explosion in which a high-pressure pulse of hot-gas is released to force the bullet out of the casing and down the length of the gun's barrel. The longer the barrel, the greater the muzzle velocity because the exploding gases have more time to exert pressure on the bullet. As the bullet leaves the muzzle of the gun, a brief flash may be evident followed by smoke and the scent of gunpowder as gases escape. The empty casing usually remains in the cylinder of a revolver or rifle.

With a semi-automatic weapon, the recoil results in the used casing being ejected and a new cartridge chambered. This happens once per trigger pull. Revolvers are structured in a fundamentally different way—each pull of the trigger causes the cylinder to turn slightly. This movement lines up another chamber with the barrel of the gun.

Did You Know?

A gun silencer screws onto the end of a handgun barrel and has a volume 20 or 30 times greater than the barrel. Because the silencer has a larger volume than the barrel, the pressurized gas behind the bullet has a large space in which to expand. Therefore, the pressure decreases. When the bullet exits the silencer, the pressure released is much lower and the sound of the gun firing is much softer.

Source: http://people.howstuffworks.com/question112.htm

Bullet Velocity, Kinetic Energy, and Trajectory

Take Notes

Two essential objectives in forensic ballistics involve determining what type of firearm was used in a crime and the position of the suspect using the firearm in relation to the victim. The velocity, kinetic energy, and trajectory of the bullet(s) fired from the suspect's firearm must be determined to answer these questions. Therefore, understanding these concepts and their relationship to the application of forensic ballistics is important.

Velocity *(v)* is a measurement of both the speed and direction of a bullet once it leaves the barrel of a firearm. Velocity differs according to cartridge specification and barrel length. The mathematical equation used to determine velocity is distance (*d*) divided by time (*t*) or $v = d/t$. In forensic ballistics, the velocity of a bullet is measured in metres per second (m/s).

Kinetic energy (E_k) is the energy possessed by the bullet after it leaves the barrel of a firearm. The kinetic energy of a bullet is determined by the type of gun and the amount of gunpowder in the bullet cartridge. If the amount of gunpowder in the cartridge is held constant, the amount of kinetic energy produced by the gun is also constant. The speed of the bullet when it exits the gun is determined by the equation $E_k = 1/2mv^2$ (one half the mass times the square of the velocity) and so, if you have a lighter bullet being fired from the gun, that bullet will travel more quickly (or have a higher velocity) than a heavier bullet fired from the same gun. In forensic ballistics, the kinetic energy of a bullet is measured in joules *(J)*.

Trajectory is the flight path (arc) of a bullet after it leaves the barrel of a firearm and travels towards the intended target. The arc of a bullet's flight path depends upon its muzzle velocity and mass. All bullets have a parabolic trajectory. However, lighter bullets possessing higher muzzle velocity tend to have a flatter trajectory, and heavier bullets with lower muzzle velocity tend to drop more dramatically in a shorter time. The trajectory of a bullet is determined by the effect of gravity on the bullet in relation to the change in its kinetic energy over time. In forensic ballistics, the trajectory of a bullet is measured by the loss of vertical distance per metre travelled.

Hollow Point Bullets

© *Thinkstock*

GRAPHING ACTIVITY: Velocity, Kinetic Energy, and Trajectory of Ammunition Fired from Various Types of Firearms

Take Notes

Forensic ballistic experts can accurately reconstruct the events that occurred at a crime scene when a firearm is involved because each type of firearm has unique characteristics of velocity, kinetic energy, and trajectory. For example, after the Washington sniper shootings in the fall of 2002, ballistic experts linked the suspect's firearm to almost all the shootings by examining the bullet fragments found in each victim. The location of each shooting victim enabled forensic experts to determine approximately where each suspect had been hiding when the shot was fired.

In this activity, the creation of three graphs comparing the velocity, kinetic energy, and trajectory of three basic types of firearms (handguns, rifles, and shotguns) will help you see the unique ballistic properties exhibited by each. After you have completed each graph, answer the related questions.

Graph #1: Comparison of the VELOCITY of Ammunition Fired from Various Firearms

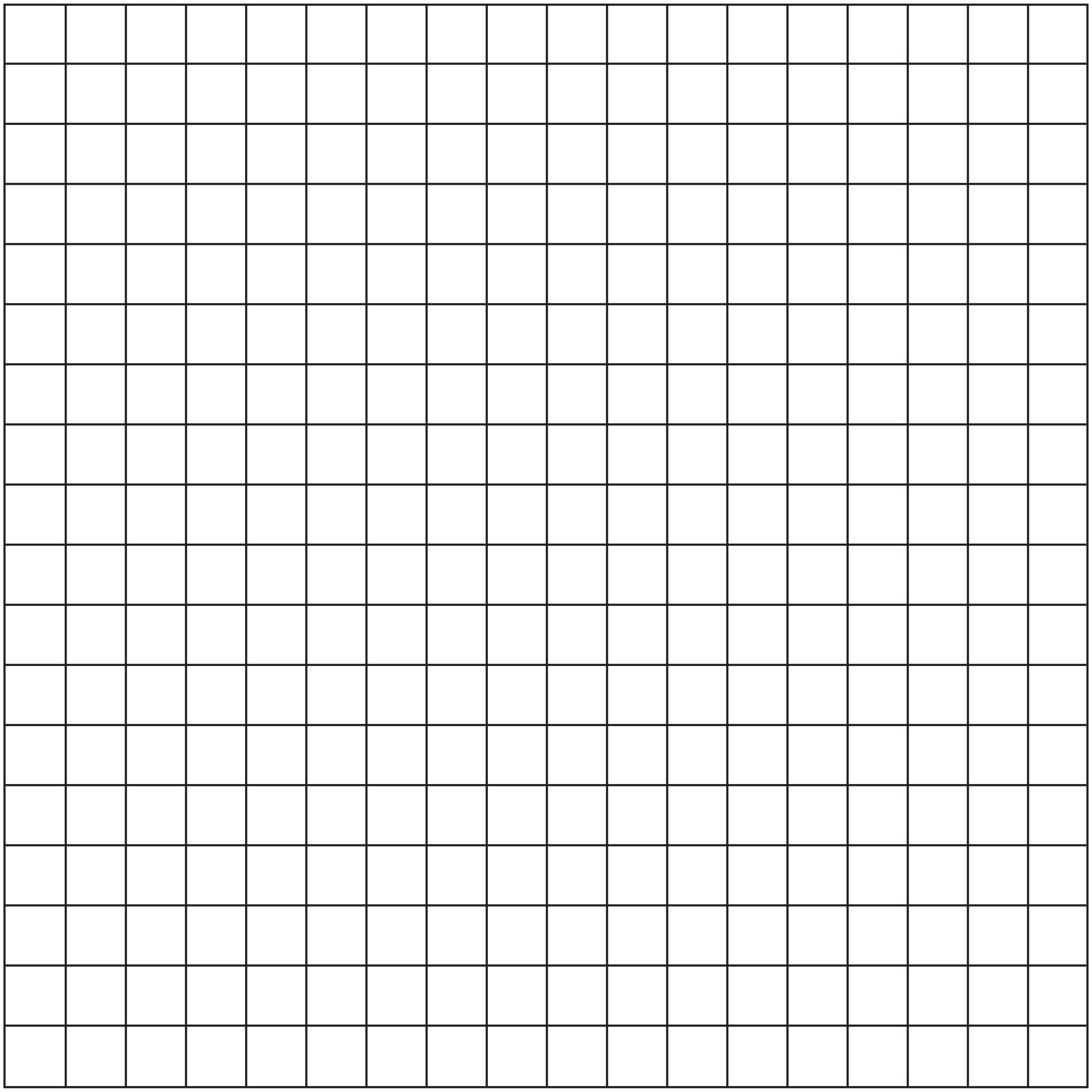
Problem: How do the average velocities of handgun, rifle, and shotgun rounds differ?

Procedure:

- Use the data below to plot three lines on one graph.
- Use the x-axis to represent the three distances: 0 m (muzzle), 50 m, and 100 m.
- Use the y-axis to represent bullet velocity (in metres/second).
- Provide a legend for your graph; a title is given.

			VELOCITY (metres/second) at a distance of		
Type of Firearm	Type of Ammunition	Type of Bullet	0 m (muzzle)	50 m	100 m
Pistol	9 mm Luger	Jacketed hollow point	352	329	296
Rifle	.223 Remington	Metal jacket	988	930	841
Shotgun	12-gauge Slug	3 inch / 1 oz. slug	536	454	328

The Velocity of Ammunition Fired from Three Firearms



Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

1. Which type of firearm shoots bullets with the highest initial velocity?

2. What happens to the velocity of each type of bullet as it moves away from where it was shot?

3. Which type of ammunition loses speed at the quickest rate?

Graph #2: Comparison of the KINETIC ENERGY of Ammunition Fired from Various Firearms

Problem: How do the kinetic energy levels of a handgun, a rifle, and a shotgun differ?

Procedure:

- Use the data below to plot three lines on one graph.
- Use the x-axis to represent the three distances: 0 m (muzzle), 50 m, and 100 m.
- Use the y-axis to represent kinetic energy (in Joules).

			KINETIC ENERGY (Joules) at a distance of		
Type of Firearm	Type of Ammunition	Type of Bullet	0 m (muzzle)	50 m	100 m
Pistol	9 mm Luger	Jacketed hollow point	462	380	327
Rifle	.223 Remington	Metal jacket	1738	1410	1260
Shotgun	12-gauge Slug	3 inch / 1 oz. slug	4070	2380	1520

9 mm Bullets

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Kinetic Energy of Ammunition Fired from Three Firearms

- Provide a legend for your graph; a title is given.

Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

1. Which firearm projects its bullet with the most kinetic energy? Explain.

2. Why does the kinetic energy of each bullet decline as it moves away from where it was shot?

3. Which type of ammunition loses kinetic energy at the slowest rate?

Graph #2: Comparison of the TRAJECTORY of Ammunition Fired from Various Firearms

Trajectory is the path of a moving object through space. Flying objects have trajectories that are shaped like a parabola because the force of gravity pulls moving objects downward. The arc of a bullet's flight towards its target varies widely according to such variables as calibre, muzzle velocity, and bullet mass.

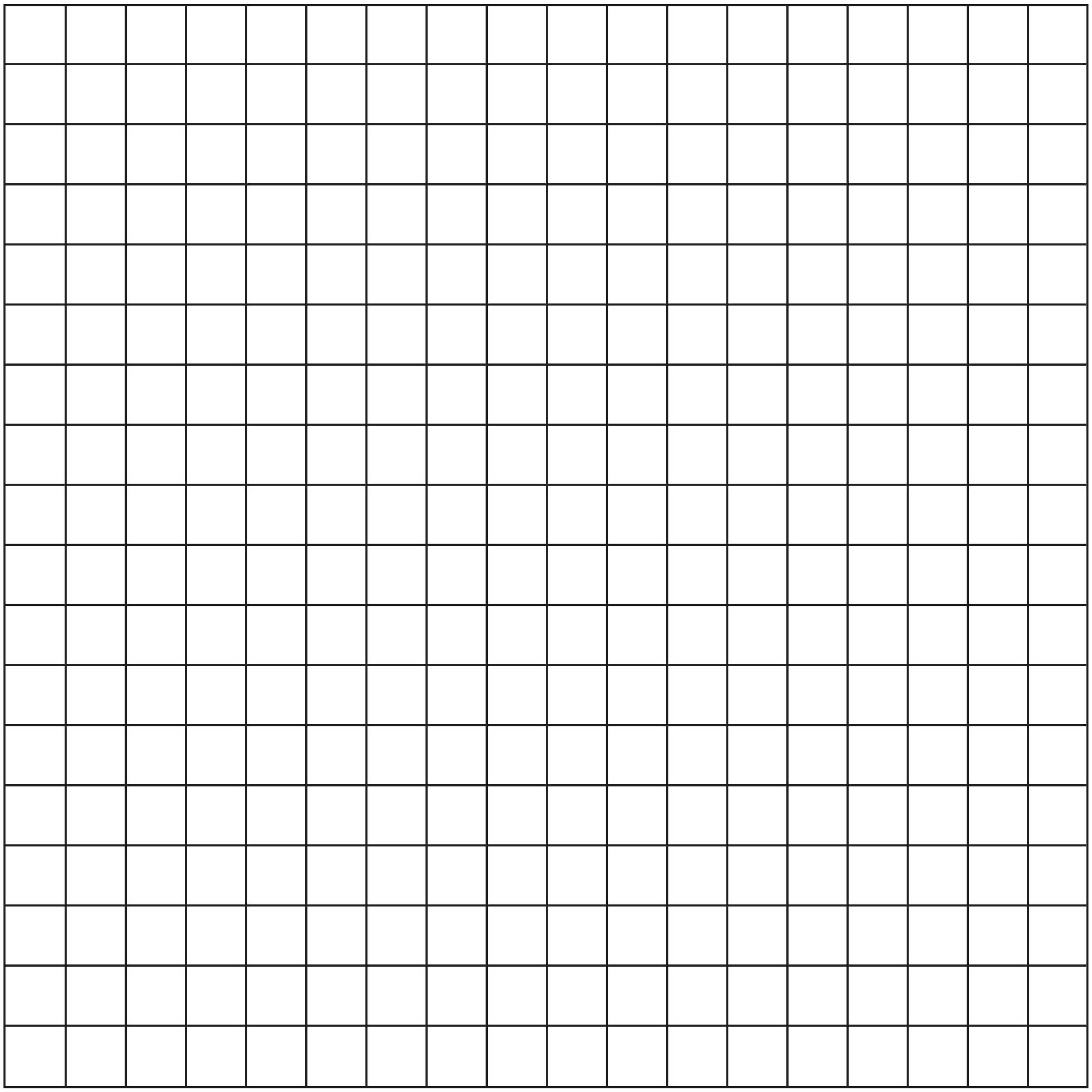
Problem: How does the trajectory of a projectile differ when fired by a handgun, a rifle, or a shotgun?

Procedure:

- Use the data below to plot three lines on one graph.
- Use the x-axis to represent the three distances: 0 m (muzzle), 50 m, and 100 m.
- Use the y-axis to represent the change in height in centimetres.

			CHANGE IN HEIGHT (centimetres)			
Type of Firearm	Type of Ammunition	Type of Bullet	Distance from Firearm (m)			
			50 m	100 m	150 m	200 m
Pistol	9 mm Luger	Jacketed hollow point	-2.1	-7.9	-14.5	-21.9
Rifle	.223 Remington	Metal jacket	-2.9	-4.8	-7.2	-14.0
Shotgun	12-gauge Slug	3 inch / 1 oz. slug	-3.8	-9.4	-18.9	-31.8

Change in Height of Ammunition Fired from Three Firearms



- Provide a legend for your graph; a title is given.

Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

Assignment

1. Explain which type of firearm ammunition is the most accurate at hitting its target at short range (50 m).

2. Explain which type of firearm ammunition is the most accurate at hitting its target at longer ranges.

Check your answers in the Module 2 Appendix in the back of this book.

When you are ready, please complete the assignment for Lesson 1 in the Assignment

Booklet.

Lesson 2: Ballistic Fingerprinting and Wound Ballistics

Lesson Objectives: ***The student will...***

- recognize that gun barrels have unique lands and grooves and that these features produce unique marks or *ballistic fingerprints* upon the fired casings
- discuss the possible value of a comprehensive national or global *ballistic fingerprint* data bank and propose the positive and negative effects of having such a data bank
- discuss one historical crime case that involves the use of forensic ballistics (the assassination of John F. Kennedy)

Lesson 2

In any criminal investigation where a firearm has been used, evidence may be analyzed, which includes the weapon, a bullet, a piece of the bullet (fragment), a cartridge casing, bullet holes, the injury caused by the bullet, or even gunpowder residue. All these clues can be used to match a suspect weapon to a crime.

The Interior of a Gun Barrel

Image courtesy of Flickr user Steven Sanchez

Did You Know?

The country with the highest rate of homicides caused by firearms is South Africa. Columbia and Thailand follow at a distant second and third.

Source: The Seventh United Nations Survey on Crime Trends and the Operations of Criminal Justice Systems: 1998 – 2000. (http://www.unodc.org/unodc/crime_cicp_survey_seventh.html)

Ballistic Fingerprinting


Take Notes

Ballistic fingerprinting involves the identification of unique markings on bullets and cartridge casings that have been located at crime scenes. By comparing the striations and marks left on a bullet or shell casing recovered at a crime scene to those left on a bullet or shell casing by a gun that has been test fired in a laboratory, police can determine whether that specific firearm was involved.

Land and Groove Impressions

The interior of the barrel in every gun contains unique striations called *lands* and *grooves*. The lands are raised ridges, and the grooves are recessed portions between each of the ridges. Known as *rifling*, these lands and grooves are cut into the barrel during production to increase the accuracy of that firearm. When the gun is discharged, these lands and grooves cause the bullet to spin as it travels the length of the barrel. This stabilizes the bullet during flight. At the same time, the expansion of the fired cartridge and the high pressure propelling the bullet through the barrel press and scrape the bullet against the rifling as it moves toward the muzzle. As a result, the fired bullet has unique microscopic striations left upon its exterior from the lands and grooves. These striations are called land and groove impressions by forensic firearm investigators.

Because rifling is randomly generated during manufacture or due to wear, no two gun barrels leave the same land and groove impressions upon a bullet. This uniqueness enables the identification of bullets as having originated from a particular gun.

To link a bullet to a particular firearm, forensic ballistics experts typically fire a crime scene weapon into a tank of water and then retrieve the test bullet. The test bullet is then compared to the bullet in question using a comparison microscope. If the land and groove impressions match, a photograph is taken for use as evidence in court. However, if a weapon is not left at the crime scene and the crime scene investigators are able to retrieve an intact bullet from the victim or from the scene, they can only make an assumption of the type and model of firearm used based upon the calibre of the bullet and the wound ballistics. Simply based on the rifling impressions on a particular bullet, it would be impossible for investigators to deduce the type and model of firearm because rifling impressions are unique to a particular gun and not to a type of gun (for example, all .44 magnum pistols will not have the same rifling impressions). The only exception would be if the same gun had been used in a previous crime and the bullet and gun had been entered into the ballistic database.

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Cartridge Identification Methods

The microscopic land and groove impressions found on the surface of fired bullets are routinely used to match bullets with a suspects' weapons. Impressions can be found on cartridge cases as well, and these can be used to match a cartridge case to a specific firearm. Firing pin impressions, extractor marks, ejector marks, chamber marks, and ammunition stamps on the cartridge casing are all features analyzed by forensic firearm experts.

Firing pin impressions are left during the discharge of a firearm. The firing pin creates microscopic features of the indentation left when it strikes the primer of a cartridge.

Extractor and ejector marks are produced when the cartridge case is mechanically extracted from the chamber. Visible fine striations and impressions are left on the rim and head of the casing.

Chamber marks are parallel striations on the cartridge case caused by contact with the walls of the chamber of the firearm.

Ammunition stamps consist of information about the type of ammunition stamped by the manufacturer onto the base of the cartridge casing.

Ballistic Databases

Forensic Technology Inc., a Canadian company located in Montreal, Quebec, has developed a computerized ballistic fingerprinting system called *Integrated Ballistic Identification System* (IBIS). IBIS creates digital images of the markings left on bullets and shell casings. This allows them to be compared easily to a database of images. When the system finds a bullet or cartridge casing that has similar markings, firearms experts compare these markings to the original evidence to determine whether a match has been made. IBIS minimizes the amount of time firearms experts spend viewing non-matching evidence. Consequently, law enforcement agencies are able to discover links between crimes more efficiently.

Did You Know?

Ballistic fingerprinting works poorly with firearms such as shotguns because the cartridge rides inside a plastic sleeve that prevents it from ever touching the barrel.

Take Notes

In November 2006, the *Royal Canadian Mounted Police* (RCMP) and the ATF began sharing their ballistic information in an attempt to improve success in solving crimes involving gun violence.

The US Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) utilizes IBIS in coordinating one of the largest ballistic fingerprinting programs in the world. The ATF's National Integrated Ballistic Information Network (NIBIN) contains detailed ballistic information about firearms that have been seized from crime scenes across the United States. Since ATF began using IBIS and NISBIN, more than 926 000 pieces of crime scene evidence have been entered into the database resulting in more than 12 500 positive identifications (hits).

Wound Ballistics

The nature of a wound caused by a particular bullet can provide clues to help identify the type of firearm used by the suspect. Numerous factors related to the ballistic properties of a bullet can influence wound characteristics.

Kinetic Energy, Mass, Velocity, and Tumbling: As a bullet travels towards its target, it spirals through the air similar to a football thrown by a quarterback. This is due to the influence of lands and grooves in the gun barrel causing the bullet to spin as it exits the barrel. A bullet is said to *tumble* if it flips end over end as it approaches its target. A bullet that tumbles has more kinetic energy; therefore, it can cause a more serious injury. A light, high velocity bullet (such as a .223 rifle round) begins tumbling rapidly in tissue. This causes a pronounced ***cavitation*** or large wound resulting from the relatively large amount of kinetic energy that is transferred from the bullet to the target.

Did You Know?

In December 2006, police in Detroit, Michigan, responded to a report of shots being fired. When officers arrived, they learned that a suspect had approached two people in a vehicle and fired several shots at them. Key characteristics associated with several cartridge casings and bullets recovered from the crime scene were entered into NIBIN. A month later, a suspect was arrested for possessing a pistol during an unrelated drug-trafficking investigation. The pistol was submitted for test firing, and subsequent images were entered into IBIS. This resulted in a match to the ballistic evidence recovered at the shooting that had occurred a month earlier.

Take Notes

A bullet's kinetic energy is dependent upon its mass, its velocity, and whether it tumbles as it moves. Recall the formula for Kinetic energy ($E_k = 1/2mv^2$): the faster a bullet is travelling when it strikes the target or the greater the mass of the bullet that strikes the target, the more kinetic energy that bullet will have and the more serious the damage will be. However, if a bullet exits the target, it retains some of its kinetic energy and, therefore, causes less damage.

Bullet Design: As a bullet enters an object, the bullet expands in diameter, a process referred to as the *mushroom* effect. This expansion releases a bullet's kinetic energy within an extremely short period of time and causes significant tissue damage. *Hollow point* bullets expand upon impact, especially when travelling at over 305 m/s.

Distance to Target: The distance between the muzzle of a firearm and the intended target has a large role in the kinetic energy a bullet loses during its flight. The kinetic energy lost by the bullet also depends on the type of firearm and the type of cartridge used. For example, most bullets fired from handguns lose significant amounts of kinetic energy after 100 metres; high-velocity military rifle rounds still possess considerable kinetic energy at distances of 500 metres or more. Compared to a handgun round, a rifle bullet possesses more kinetic energy over long distances because its cartridge contains more gunpowder which increases the amount of energy transferred to the bullet and therefore, increases the bullet velocity.

A Mushroomed Bullet

Image courtesy of Pyramydair.com

Did You Know?

The Geneva Convention, a series of treaties outlining international laws during warfare, forbids the use of expanding bullets during military combat. Therefore, military bullets must have full metal jackets of copper around the lead core. In fact, military assault rifles that fire multiple rounds at high velocity (>610 m/s) must use this type of cartridge to avoid having a soft-nose lead bullet melt in the chamber, resulting in a misfeed.

Law enforcement agencies are exempt from these treaties and typically use hollowpoint cartridges in their firearms.

Take Notes

Type of Tissue: The severity of a bullet wound depends on factors such as tissue density and elasticity. Tissues that are more dense (such as bone) tend to sustain more tissue damage. This is because the bullet may fragment and/or cause fragmentation of the bone. Organs such as the liver, spleen, and kidney are relatively inelastic and are easily injured. Fluid-filled organs such as bladder, heart, large blood vessels, and intestines may rupture when struck by a bullet because of the cavitation produced by accompanying shock waves. Conversely, highly elastic tissue suffers less damage. For example, lung tissue, which is more elastic than other internal organs, usually fares better than other tissues when struck by a bullet.

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Did You Know?

The transfer of a bullet's kinetic energy varies depending on the target. For example, a bullet must possess a high level of kinetic energy and be durable enough to withstand fragmentation to penetrate a large, heavy target such as a vehicle or brick wall. However, if this bullet were to penetrate human tissue, it acts like a spear retaining sufficient kinetic energy to exit the body and does little more damage than a knife wound unless it strikes bone.

CRIME CASE STUDY 4.1: The JFK Assassination

Funeral of U.S. President John F. Kennedy, 1963

Consolidated News Service/ Rex Features

Example

The assassination of John F. Kennedy, the thirty-fifth President of the United States of America (USA), occurred on Friday, November 22, 1963. Because he was fatally wounded by two gunshots, ballistic evidence was important in the forensic investigation.

The Assassination

Take Notes

President Kennedy was riding in an open-top limousine in a presidential motorcade through Dallas, Texas. The President's wife (Jacqueline), Texas Governor John Connally, Governor Connally's wife, and a driver were also in the vehicle. After Kennedy's limousine slowly passed a building called the Texas School Book Depository, three shots were fired at the limosine from a distance of approximately 60 metres.

As President Kennedy waved to the crowd on his right, the first bullet entered his upper back, exited through his throat, and entered Texas Governor John Connally, penetrating his back, chest, and right wrist. The second bullet missed the vehicle, but the third bullet struck the President in the back of the head. After the three shots, the driver of the President's limousine sped to a local hospital in a desperate attempt to get emergency medical treatment for the President and the Texas Governor. The President died before arriving at the hospital, and the Governor survived after receiving emergency surgery.

The Investigation

The Dallas Police immediately began searching the area for signs of the assassin. Witnesses claimed the shots came from a nearby building called the Texas Book Depository. Subsequently, police officers found an Italian bolt-action rifle on the sixth floor of the Texas Book Depository. A witness who saw the male assassin fire the last shot from the building gave police a physical description. Police determined that the person that matched the description might be an employee of the Texas Book Depository named Lee Harvey Oswald.

Take Notes

A few hours after the assassination, Dallas Police Officer J. D. Tippit, after hearing the assassin's description, stopped Oswald on a street corner. When Officer Tippit tried to question Oswald, Oswald shot Tippit four times with a revolver. Oswald fled the scene on foot, and Tippit died from his gunshot wounds. Oswald went into the nearby Texas Theater without paying. The police quickly arrived and arrested Oswald after being notified by theatre staff.

Oswald was questioned for twelve hours about both the Tippit shooting and the assassination of the President. He denied any involvement with the murders. Paraffin tests were performed on Oswald's hands and right cheek for gunpowder residue. The results were positive for the hands and negative for the right cheek.

Two days later as Lee Harvey Oswald was being taken to the Dallas County Jail, he was shot and killed by Jack Ruby before live TV cameras in the basement of Dallas police headquarters.

An official investigation by the Warren Commission conducted in September 1964 concluded that Lee Harvey Oswald was solely responsible for the assassination of President Kennedy.

Italian bolt-action rifle like the one that killed President Kennedy

© *photos.com*

Did You Know?

In October of 1981, Lee Harvey Oswald's body was exhumed after British novelist, Micheal Eddowes, proposed that the body buried was not Oswald but a look-alike KGB assassin. Eddowes claimed that, when Oswald visited the Soviet Union, he was replaced with a Soviet KGB agent. The novelist's theory was proved wrong when examination of the remains through dental records positively identified the body as Lee Harvey Oswald.

Take Notes

Internal Ballistic Evidence

The bullet that hit President Kennedy in the head imploded upon impact. As a result, the bullet could not be analyzed for rifling impressions.

However, the bullet that hit Kennedy and Governor Connally was found at the hospital. The bullet was a 6.5 mm round-nose military-style full-metal jacket design specifically meant to pass through the human body. Important pieces of ballistic evidence related to this bullet found by the FBI include the following:

- Neutron Activation Analysis (NAA) of the bullet fragments in Governor Connally's wrist matched the bullet found.
- The mass of the bullet found was 10.28 g. The average mass of a single, unfired bullet of this type is 10.42 g. The lead fragments retrieved from Connally's wounds in the wrist weighed about 0.13g.
- Rifling impressions found on this bullet matched the lands and grooves in the rifle found at the Texas Book Depository.

Type of Bullet that Hit President Kennedy and Governor Connally

© *photos.com*

Did You Know?

Five years after John F. Kennedy's death, former FBI agent and New Orleans District Attorney, Jim Garrison, attempted (unsuccessfully) to prove legally that Lee Harvey Oswald was not solely responsible for the assassination, but rather that it had been a government conspiracy involving numerous people.

Take Notes

External Ballistic Evidence

The muzzle velocities of the bullets that hit President Kennedy were calculated to be between 560 and 610 m/s. Each bullet arced downward while travelling and hit President Kennedy at an angle of 25 degrees from the horizontal.

Terminal Ballistic Evidence

The first bullet that hit the President entered his upper back above the shoulder blade, passed through the base of his neck, bruised the upper tip of his right lung without puncturing it, and exited the front of his neck. The entry point of the bullet was 4 mm by 7 mm in size, and the exit wound was 3 mm by 5 mm. The bullet fractured one of the President's vertebrae.

Upon leaving the President's neck, the bullet's velocity had slowed to about 457 m/s and it had started to tumble. It then hit Governor Connally who was sitting in front of Kennedy. The bullet entered Connally's back creating an 8 mm by 15 mm entry wound. This large entry wound indicates that the bullet was tumbling greatly, which often happens after hitting a target, which was President Kennedy in this case. The bullet destroyed part of one of Connally's ribs as it smashed through his chest leaving an exit wound with a diameter of 50 mm. Slowed to 274 m/s, the bullet entered Connally's upper right wrist depositing metal fragments and exited his palm.

The autopsy of President Kennedy concluded the wound from the second bullet that hit his head was fatal. A small entry wound was visible in the rear right-hand side of the President's head. The bullet imploded upon impact causing a large portion of the right side of Kennedy's brain and skull to detach.

Lee Harvey Oswald

Photo courtesy of AP images

Did You Know?

In the 1970s, an investigation by the *House Select Committee on Assassinations* concluded that Lee Harvey Oswald was the assassin of John F. Kennedy, but it also suggested that likely others were involved in the planning of the assassination in a "probable conspiracy".

Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

1. Of the two bullets that hit President Kennedy and Governor Connally, why was only one analyzed for ballistic fingerprints?

2. What three pieces of ballistic evidence linked the Connally bullet to the rifle from the Texas Book Depository?

3. a) How much did the bullet's velocity change between when it hit Governor Connally in the back to when it entered his wrist?

   b) Explain why this change occurred.

4. When the second bullet hit President Kennedy, it created a 4 mm x 7 mm entry wound. After it left the President's body, this same bullet hit Governor Connally creating an 8 mm x 15 mm entry wound.

   Explain why Governor Connally's entry wound was so much larger than the President's entry wound.


Assignment

Check your answers in the Module 2 Appendix in the back of this book.

When you are ready, please complete the assignment for Lesson 2 in the Assignment Booklet.

Lesson 3: Testing for Gunshot Residue

Lesson Objectives: ***The student will...***

Objective

- understand that forensic ballistic experts use various gunshot residue chemical test techniques to determine if a suspect has fired a gun
- describe how forensic experts test for gunshot residue using various scientific techniques (such as *Paraffin Test, Modified Greiss Test, Sodium Rhodizonate Test, Harrison-Gilroy Test*, and X-ray analysis with a scanning electron microscope)

The Evolution of Firearms and Gunpowder

Firearm effectiveness has increased dramatically since the first firearms were developed more than 600 years ago. Fixed ammunition, which consisted of a primer, gunpowder, and projectile contained within a shell casing, made its first appearance in the American Civil War in the 1860s. These early firearms utilized a *single action* firing mechanism that produced a relatively slow rate of fire because the weapon had to be reloaded after each round was fired. However, their increased muzzle velocity and higher degree of accuracy over long distances resulted in a tremendous increase in the destructive capabilities of rifles and handguns.

Take Notes

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Did You Know?

In the 1880s, Alfred Nobel made his fortune by developing dynamite and a smokeless gunpowder called *ballistite*. When Nobel died in the late 1800s, he left the majority of his estate to establish the Nobel Prizes to be awarded annually to individuals who helped to better mankind. Apparently Nobel did this after reading an article in a French newspaper that condemned him for inventing dynamite and gunpowder by stating that he *"···became rich by finding ways to kill more people faster than ever before"*.

A Gunpowder Horn

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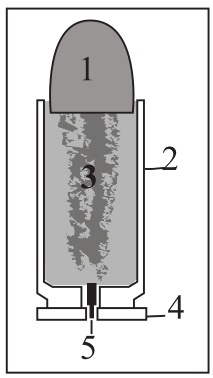
Take Notes

Traditional varieties of gunpowder led to rapid residue build-up in the interior components, causing a weapon to jam after short periods. Semi-automatic rifles and automatic weapons (machine guns) became prominent with the advent of higher grades of gunpowder. Further refinements were made during both World Wars, which led to the development of reliable ammunition with smokeless gunpowder and precision weapons with high rates of fire. This has translated into the mass adoption of semi-automatic handguns by law enforcement agencies as the use of revolvers was phased out in recent years.

Lesson 3

Gunpowder is of two types: black powder and smokeless powder. Both burn very rapidly and release large amounts of gas in the process. The pressure from the gases generated inside the gun barrel is sufficient to propel a bullet, but it does not destroy the gun barrel.

The Main Parts of a Firearm Cartridge



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Gunshot Residue

When the trigger of a gun is pressed, the firing pin strikes the primer (5) at the base (4) of the cartridge. This causes a ***combustion*** reaction that produces flames. These ignite the gunpowder or ***propellant*** (3). The burning gunpowder produces a large amount of gas that propels the bullet (1) from the gun barrel, leaving the casing (2) behind.

Did You Know?

In 9th century China, the oldest known explosive consisting of sulphur, charcoal, and saltpetre (nitre, potassium nitrate) was developed.

Take Notes

Gunshot residue is composed of two substances: a propellant and a primer. Each of these is a solid mixture made of various chemical compounds. The two types of propellants are black powder and smokeless powder.

Black powder consists of charcoal (15%), sulphur (10%), and potassium nitrate (75%). When black powder is ignited, about 55% of its products are solids (soot). The remaining 45% is a gaseous thick black smoke. The soot left behind ***corrodes*** the interior of the gun, and the thick smoke reduces accuracy because the target may be obscured.

Smokeless powder is the name given to a number of gunpowder-like propellants that do not produce smoke when fired because their product is mainly gas. All modern ammunition uses smokeless powder. Various types of smokeless powder contain either nitrocellulose (single-based powder) or nitrocellulose mixed with nitro-glycerine (double-based powder).

A ***primer*** is a mixture of chemical compounds located in the base of a cartridge. It ignites when subjected to great pressure such as when struck by the firearm's ***firing pin***.

Several types of primers are available, but the most common are lead(II) azide, lead(II) styphnate, mercury(II) fulminate, barium nitrate, potassium chlorate, and antimony(III) sulphide.

Gunshot Residue Analysis

Whenever a gun is fired, the shooter gets sprayed with an invisible blast of chemical residue that consists of the by-products of the incomplete combustion of gunpowder and primer. These products of combustion are deposited on areas of the exposed hand, arm, face, and clothing—right or left side, depending on how the gun was held. The deposited material is known as gunshot residue (GSR), detectable on a person's skin and clothing to determine if that person has fired a gun.

Because many different types of chemical compounds are in both gunshot residue and primer residue, many testing techniques can be used to detect them. Each of the GSR chemical tests identify unique elements, ions, or compounds. Gunpowder consists of charcoal, sulphur, potassium nitrate, nitrocellulose, nitro-glycerine; primers consist of lead(II) azide, lead(II) styphnate, mercury(II) fulminate, barium nitrate, potassium chlorate, and antimony(III) sulphide.

Did You Know?

Originally, bullets were spherical metallic or stone balls placed in front of a charge of black gunpowder at the end of a closed tube.

Take Notes

Paraffin Test

This chemical test is also known as the *dermal nitrate test* or *diphenylamine test*. In this procedure, the hands of the suspect are coated with a layer of paraffin. After cooling, the paraffin casts are removed and treated with an acidic solution of diphenylamine. This solution detects two ***polyatomic ions*** (nitrites and nitrates) that originate from gunpowder or primer. A positive test produces blue flecks in the paraffin in response to deposits on the hands of the shooter.

Sodium Rhodizonate Test

The sodium rhodizonate test is designed to determine if barium or lead residue are present on the hands. In this test, the hands of the suspect are swabbed with gauze moistened with dilute hydrochloric acid. Then, the gauze is cut into small pieces and drops of sodium rhodizonate, distilled water, and a buffer solution are added to each piece.

A colour change indicates that a salt has formed from rhodizonate and either barium or lead. If the gauze turns a brown-pink, barium was present on the hand. If the gauze turns a scarlet red, then lead was present. A mixture of both these colours indicates that both elements were present.

Harrison-Gilroy Test

The Harrison-Gilroy Test checks for the presence of barium, antimony, and lead on the hands. In this chemical test, the hands of the suspect are swabbed with gauze moistened with dilute hydrochloric acid. The gauze is allowed to dry and then treated with the chemical ***reagent*** triphenylmethylarsonium iodide. If antimony is present, the triphenylmethylarsonium iodide turns an orange colour.

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Did You Know?

Black gunpowder is used to blast granite and marble from the earth because it causes fewer fractures than other explosives.

The granules that make up smokeless gunpowder are coated with graphite to prevent static electricity from causing undesired ignitions.

Take Notes

Modified Greiss Test

The Modified Greiss Test detects the presence of nitrite residues near suspected bullet holes on a surface such as wood, metal, furniture, clothing, belt, hat, shoes, or purse. Nitrite residues are a common by-product of the combustion of smokeless gunpowder.

In this test, a piece of photographic paper is treated with a chemical mixture of sulfanilic acid and alpha-naphthol in methanol. As a result, the photographic paper is no longer light-sensitive, but it is reactive to the presence of nitrite residues. Then, the paper is placed face down against a suspected bullet hole. The back of the photographic paper is steam ironed with vinegar instead of water in the iron. Vapours from the vinegar penetrate the paper, and a reaction occurs between any nitrite residues on the suspected bullet hole and the chemicals in the treated paper. One of the products of the resulting reaction appears as red and/or orange specks on the photographic paper.

X-ray Analysis with a Scanning Electron Microscope (SEM)

The scanning electron microscope method using X-ray analysis is considered the most reliable and useful way to test for gunshot residue because it can detect any type of element, ion, or compound. This testing procedure is especially helpful when used to confirm the results of one of the other GSR chemical tests. The false negative rate is only 10% for pistols, but it is 50% for long guns.

Samples taken from the hands are analyzed with a scanning electron microscope. X-rays within the microscope are capable of identifying individual particles. Because the scanning electron microscope is an expensive piece of equipment requiring highly specialized experts, not all police departments are able to use X-ray analysis. However, using this method to analyze a sample is possible up to twelve hours after the shooting.

Gunpowder Exploding

© Thinkstock

Did You Know?

Gunpowder is used to make fireworks by mixing it with other chemical compounds, each of which produces a specific colour.

Validity of Gunshot Residue Analysis


Take Notes

Positive GSR test results alone never prove the guilt of a suspect in a court of law. However, when these results are combined with other valid pieces of evidence, gunshot residue test results are powerful.

The strongest conclusion that can be made using only gunshot residue test results is that a suspect recently fired a gun, handled a recently discharged gun, or was close to a gun when it was fired. If the suspect's fingerprints are also found on a gun, a positive GSR test is compelling evidence that the suspect fired that gun. However, a negative GSR test does not necessarily prove that a suspect did <u>not</u> fire a weapon.

The elements, ions, and compounds such as nitrate, nitrite, or lead that GSR tests identify are not unique to guns and cartridges. Although it is unusual, these substances can also be found in the environment. A person who has not fired a gun but has been near the shooter or the gun after it has been fired can become contaminated with gunshot residue. This is known as *secondary transfer*. Based on these issues, defence lawyers debate the reliability of GSR evidence in court.

Forensic experts conducting GSR testing are aware of potential contamination problems. Therefore, a positive test for GSR is typically not seen as conclusive unless three or more unique elements or compounds have been detected.

Lesson 3

Fireworks
the most common use of gunpowder

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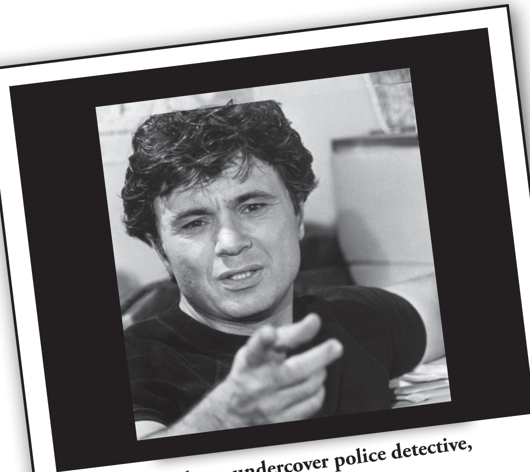
CRIME CASE STUDY 4.2: The Mysterious Murder of a Hollywood Star's Wife



Robert Blake as undercover police detective, Tony Baretta

Everett Collection

Example

Robert Blake is an American actor who was famous for his starring role in the popular 1970's television series *Baretta*.

The Murder

Take Notes

In 1999, Robert Blake had an intimate relationship with Bonnie Lee Bakley, a woman with a history of exploiting wealthy older men for money. When Bakley became pregnant and told Blake that he was the father, he ordered a DNA test to determine his paternity. After DNA tests proved that he was the biological father, Blake married Bakley in November 2000. This was Blake's second marriage and Bonnie Lee Bakley's tenth marriage.

Five months later on May 4, 2001, Blake took Bakley to a restaurant for dinner. Later, Bakley was murdered by a gunshot to the head while sitting in Blake's car, which was parked on a side street around the corner from the restaurant. Bakley was shot once in the right cheek and once in the shoulder. Blake told the police that he had walked his wife to his car and then returned to the restaurant because he had left his revolver (which he carried for protection) under a booth. He said that, when he returned to the car, he found Bakley dead.

The Investigation

No witnesses of the shooting were available. No one at the restaurant remembered seeing Robert Blake return to get his gun.

Detectives swabbed Blake for gunshot residue about two and a half hours after the murder. Five particles of gunshot residue were found on his hands, and more residue was found on his black T-shirt, blue jeans, belt, and boots.

Take Notes

The murder weapon was found the next morning in a garbage dumpster about 6 m from Blake's car. It was an antique 9 mm Walther P-38 double-action, semi-automatic pistol that had been standard issue for the German army in World War II. The gun had no registered owner, and no fingerprints were found on it.

Months into the investigation, police interviewed two retired stuntmen. Both claimed that Blake tried to hire them to kill his wife.

After nearly a year of investigation, Robert Blake was arrested and charged with the murder of his wife. His long-time bodyguard, Earle Caldwell, was also arrested and charged with conspiracy to commit murder.

Lesson 3

The Criminal Trial

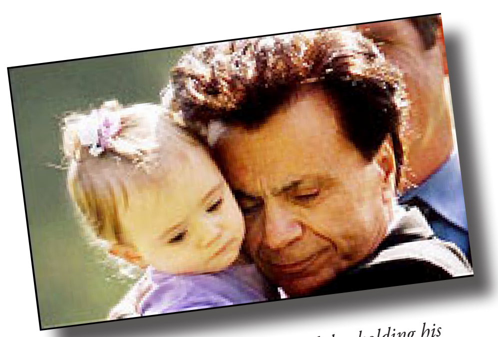
After spending almost a year in jail, Robert Blake was granted $1.5 million bail and allowed to go free while awaiting trial.

One key piece of physical evidence at the trial was the gunshot residue found on Blake. Defence lawyers argued that this gunshot residue could have come from the gun he picked up from the restaurant. They also argued that the source of the gunshot residue could have been any surface upon which there was gunpowder. Ultimately, the jurors agreed that the presence of gunshot residue on Blake did not necessarily prove that the murder weapon was ever in his hands.

On March 16, 2005, Blake was found not guilty of the murder of Bonnie Lee Bakley and not guilty of soliciting a former stuntman to murder her.

After the Trial

In late 2005, Bonnie Lee Bakley's four children filed a civil suit against Robert Blake stating that he was responsible for their mother's death. A jury found Blake liable for the wrongful death of his wife and ordered him to pay $30 million. This lead Blake to file for bankruptcy in early 2006. Blake's and Bakley's young daughter, Rosie, was adopted by Blake's eldest daughter.



Hollywood Actor, Robert Blake, holding his 11-month-old daughter at the funeral of his wife, Bonnie Bakley (AP / Damian Dovarganes)

Related Questions: (Note that the answers to these questions do not have to be submitted for marks.)

1. During the investigation of Robert Blake, where did detectives locate the gunshot residue?

2. Where did Robert Blake's attorneys claim the gunshot residue found on him could have come from?

3. *"How valid gunshot residue test results are seen by a jury depends a lot upon on how convincing the other evidence in the case is."*

   Explain how this statement applies to the Robert Blake case.

4. Why did Robert Blake file for bankruptcy in 2006?

Check your answers in the Module 2 Appendix in the back of this book.

Assignment

When you are ready, please complete the assignment for Lesson 3 in the Assignment Booklet.

Lesson 4: Crime Case Studies Involving Forensic Ballistics

Lesson Objectives: ***The student will...***


Objective

- discuss one historical crime case and one fictional crime case that involve the use of forensic ballistics (such as *Beltway sniper shootings*)

The *Duke Projectile Recovery System* (below) allows forensic ballistic experts to test fire a gun and retrieve the bullet intact for ballistics forensic firearm identification.

Ballistics Research Inc. (www.ballisticsresearch.com)

Did You Know?

"You only get one opportunity to process the crime scene."

- Captain R.T. Colgan, Prince William County Police Department

Source: Gerard R. Murphy, Chuck Wexler, Heather Davies, Martha Plotkin. Managing a Multijurisdictional Case: Identifying the Lessons Learned from the Sniper Investigation. Police Executive Research Forum, US Department of Justice, October 2004, p.56.

CRIME CASE STUDY 4.3: The Beltway Snipers

A firearms identification expert with the U.S. Bureau of Alcohol, Tobacco, and Firearms holds the Bushmaster rifle used in the Beltway Sniper shootings.
(Tracy Woodward / AP)

Example

Take Notes

During September and October 2002, a series of random shootings terrorized the public along the east coast of the United States. The murders were coined the *Beltway sniper killings* because the majority of the shootings occurred near a freeway called the Capital Beltway in Maryland, Virginia, and Washington, D.C. The shooter used a high-powered rifle from a concealed location approximately 100 m or less away from each victim. Thirteen people were killed, and three people were critically injured while in various outdoor public places. Ballistic evidence played a critical role in the capture and conviction of the two males responsible for the shootings. It was later discovered that the pair was also responsible for sniper attacks in California, Arizona, and Texas.

Identity of the Snipers

The older of the two men responsible for the Beltway sniper killings was John Allen Williams. After converting to Islam, he changed his name to John Allen Muhammad in 2002. A 41-year-old ex-member of the United States National Guard and the United States Army, he had earned medals for expert marksmanship while serving in the army.

The younger of the two Beltway snipers was 17-year-old Lee Boyd Malvo who also used the name John Lee Malvo. He had posed as John Allen Muhammad's son, but he was the son of a woman with whom Muhammad had a friendship. Malvo shoplifted the rifle used in the sniper shootings from a gun dealer in Tacoma, Washington.

The Shootings

On September 5, 2002, a pizzeria owner died after being shot six times at close range while closing his restaurant in Maryland. His laptop computer was found in the suspect's car when they were arrested later.

Take Notes

On September 21, a liquor store clerk in Alabama was shot and killed during a robbery, and a co-worker was injured.

On October 2, a 55-year-old program analyst was shot and killed in a grocery store parking lot in Maryland.

October 3 was the deadliest day. Within a 15-hour period, four people in Maryland and one in Washington, D.C., were shot and killed. The first victim was a 34-year-old man shot while mowing a lawn. Then, a 54-year-old taxi driver was killed while pumping gas into his taxi. The third victim was a 34-year-old woman shot while reading a book on a bench. The fourth victim was a 25-year-old woman shot while vacuuming her van. The fifth victim was a 72-year-old retired man shot while walking down a street in Washington, D.C.

On October 4, a 43-year-old woman was shot in a shopping centre parking lot; fortunately, she survived.

On October 7, the public was shocked when the Beltway sniper shot a 13-year-old boy walking into his school in Maryland. The boy lost 25 to 30% of his blood. One of his lungs, his diaphragm, part of his liver, stomach, pancreas, and spleen were damaged. Incredibly, after emergency surgery, the boy survived after spending eight weeks in hospital.

The next two shootings, October 9 and 11, were strangely similar despite happening two days apart. In both instances, 53-year-old males were shot and killed while pumping gas at a gas station in Virginia.

On October 14, a 47-year-old FBI intelligence analyst from Virginia was shot dead outside a Home Depot store.

Five days later, a 37-year-old man was shot in a parking lot outside a restaurant in Virginia.

A bus driver was shot and killed while standing outside his bus on October 22—making thirteen dead and three injured.

The Investigation

After each shooting, roadblocks were set up near the crime scene. Cars and drivers were inspected as they passed through each roadblock, resulting in massive traffic jams. Despite these efforts, police discovered later that the suspects had gone through these roadblocks several times and had not been caught.

At several crime scenes, ***Tarot cards*** and handwritten notes were left by the suspects. One tarot card was the Death card upon which was written, *"Dear Policeman, I am God. Do not tell the media about this."* The handwritten notes were several pages long and carefully sealed inside plastic bags. One of the notes demanded $10 000 000. It stated, "Your children are not safe, anywhere, at any time."

On October 21, a fingerprint from the September 21 Alabama shooting was found and identified. The print belonged to 17-year-old Lee Boyd Malvo. Investigators learned that Malvo was in the company of John Allen Muhammad. Police issued a description of Muhammad's dark blue Chevrolet Caprice sedan to the media.

Investigators then discovered that Malvo and Muhammad had recently been staying at a home in Tacoma, Washington. A tree stump from the yard of this home, believed to have been used for target practice by the suspects, was seized. Metal detectors were used to search for bullet and cartridge casings in the yard to try to link the suspects to the shootings.

On October 24, two separate citizens reported a blue Chevrolet Caprice sedan parked at a rest area in Maryland. John Allen Muhammad and Lee Boyd Malvo were sleeping inside the vehicle and were arrested without incident. A search of the vehicle revealed that the suspects had created a firing port in the trunk of the car. The firing port allowed them to remain hidden while they shot at their unsuspecting victims. After these arrests, the Beltway sniper shootings stopped.

Ballistic Evidence

A Bushmaster .223 semi-automatic rifle and ***bipod*** were found in a bag in John Allen Muhammad's car. Bullets fired from this rifle had an average muzzle velocity of 960 m/s. A bullet fired at this high velocity disintegrates when it hits bone or tissue leaving behind hundreds of bullet fragments (see photo below). In an X-ray, these numerous bullet fragments form a pattern known as the *snowstorm effect*. The snowstorm effect was visible on X-rays of each of the Beltway sniper's victims.

Ballistics Research Inc. (www.ballisticsresearch.com)

The recovered bullet fragments and cartridge casings were compared to 150 different guns. Ballistic experts were unable to link any of those weapons to the crime scene evidence. The bullet fragments and cartridge casings from the shootings were then compared to test bullets fired from the rifle recovered from Muhammad's car. Ballistic experts concluded that 11 of the 14 bullet fragments recovered from the shootings matched the rifling impressions from the rifle seized from the suspect's car.

Take Notes

A forensic chemist found both gunpowder residue and primer residue in the trunk of Muhammad's car. The presence of these chemicals indicated that a gun was likely fired from inside the trunk.

Although not considered ballistic evidence, numerous amounts of DNA matching both Malvo and Muhammad were identified on several areas of the rifle found in the suspects' car.

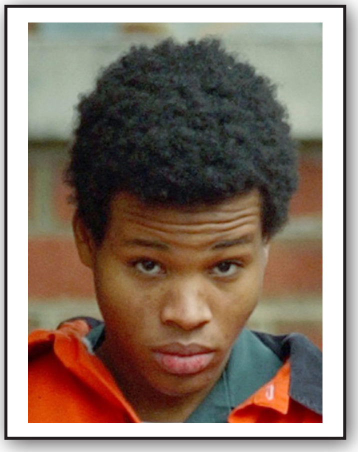
Conclusion

John Allen Muhammad and Lee Boyd Malvo were tried separately in both Maryland and Virginia.

In 2003, after more than 130 witnesses and 400 pieces of evidence, Muhammad and Malvo were each found guilty for the shootings that occurred in Virginia. Muhammad was sentenced to death, and Malvo's jury gave him a life sentence without parole.

In 2006, Muhammad was extradited to Maryland and found guilty of six counts of first-degree murder. He was sentenced to six consecutive life terms without the possibility of parole. Malvo pleaded guilty to these six murders and was also given six consecutive life terms without parole.

17-year-old Lee Boyd Malvo at his first court hearing after his 2002 arrest



AP / Susan Walsh

Did You Know?

Legal action was taken by the families of the Beltway sniper victims against the store from which Malvo stole the rifle and the company that manufactured the rifle. Before the case went to court, an out-of-court settlement of US $2.5 million was paid. The settlement was the largest ever paid by a gun dealer. It was also the first time a gun manufacturer has ever paid damages for negligence leading to criminal violence.

CRIME CASE STUDY 4.4: Distance, Shielding, and Movement: Critical Incident Response

Example

Take Notes

Distance, Shielding and Movement

When police officers encounter an armed suspect, they must focus on three factors to ensure the safety of themselves and the public:

- maintaining a safe *distance*
- seeking cover (*shielding*)
- *movement* to a safe area from which to contain the suspect.

Ideally, a police officer will seek cover (rather than ***concealment***) behind which he or she can maintain visual contact with a suspect. This way, if the officer is fired upon, he or she is not an easy target. Moving to cover or gaining distance from the suspect is also effective if the officer is not in a position to seek immediate cover.

Identifying the type of firearm being used by a suspect is important when considering the principles of distance, shielding, and movement. Often, distinguishing among a revolver, semi-automatic pistol, shotgun, and rifle is possible. Confronting a suspect who has a rifle rather than a small handgun means that officers must be especially careful when choosing cover because rifle bullets can penetrate many materials that handgun bullets cannot.

Early Morning Robbery

At 5:30 on a Sunday morning, a silent alarm is received by police from a local convenience store located in a quiet neighbourhood in a large city. Several violent robberies have occurred in the past month, and this alarm might be related.

Four police officers are available to respond. They travel to the convenience store in two police vehicles. When the patrol units are still about a block away from the store, they receive word that three masked suspects have fled the store and are about to leave in a vehicle. However, police have cut off the only avenue of escape, leaving the suspects with nowhere to go.

The four officers are then notified by radio that one of the suspects shot and killed the lone clerk at the convenience store and may use a firearm to aid in his escape. The officers are in various positions about half a block away. If the suspects decide to escape on foot, police may have to close in on the parking lot to contain the area until additional police units respond.

The suspects step out of their vehicle and begin running across the parking lot. One suspect brandishes a handgun and runs west towards an elementary school. A second suspect, also armed with a handgun, runs north toward a shopping mall. The third suspect runs east into a wooded ravine, carrying what appears to be a shotgun. The officers are still a half block away, but they start to move in on foot to prevent the suspects from escaping.

A police helicopter arrives and is able to track the three suspects, simultaneously broadcasting their locations over the police radio. Another pair of officers, travelling in a marked police cruiser, locates the first suspect hiding in a playground at the nearby school. When officers corner the suspect, he is upset and makes verbal threats that he will shoot if the police close in. Meanwhile, the second suspect runs towards the shopping mall pursued by officers on foot. The officers see the man throw his gun into a dumpster as he enters the building. At the same time, officers on foot follow the third suspect into a ravine.

Assignment

Use the above information from this case study to answer the questions in your Assignment Booklet.

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Forensic Studies 35

LDC 3569

Modules 3 and 4

Appendix, Bibliography, and Glossary

Module 3 Appendix

Related Questions - Graphing Activity: Causes of Fatal Home Fires in Alberta

1. **What were the top three leading causes of fatal home fires in Alberta from 2001 to 2005?**

   1. Smoking
   2. Arson
   3. Cooking and Electrical Wiring (tie)

2. **What percent of the total deaths was the result of arson from 2001 to 2005 in Alberta?**

   9.7%

3. **Arson is a deliberately set fire. Explain what other cause of fire could also be considered to be a deliberately set fire.**

   Child fire play is a fire deliberately set by a youngster. Most often, it is considered an accident or misbehaviour.

Related Questions - Arson Case Study: The Expert Fire Setter

1. **In the deadly 1984 arson fire, was John Orr's assumption correct about the cause of the fire?**

   Orr insisted very early that the cause of the fire was arson. Initial findings did not support Orr's assumption. However, further investigation confirmed this and revealed that the fire was started by someone who was an expert in fire setting.

2. **What piece of individualized evidence linked the culprit directly with the arson fire?**

   A fingerprint on a small piece of paper inside a small time-delay explosive device at one of the fires inked the culprit with the fire.

3. **How did investigators create a short list of arson suspects?**

   Investigators compared a list of attendees from the Fresno arson investigation conference with the list of attendees from the Pacific Grove arson investigation conference.

4. **What finally lead investigators to arrest John Orr?**

   Orr was arrested when he was tracked to the scene of another suspicious fire before dispatchers were made aware of the blaze.

Related Questions - Crime Case Study 3.1: The Lockerbie Air Disaster

1. **Why did investigators reconstruct parts of the airplane involved in this explosion?**

   The airplane was reconstructed to determine the site or origin.

2. **Where was the site of origin of the explosion? How was this determined?**

   - *The explosion originated in the front cargo hold.*
   - *Investigators determined this by examining fragments from the front cargo hold, which showed an area of blackening, pitting, and severe damage*

3. **What type of bomb was used—high or low?**

   A high explosive device was used.

Module 4 Appendix

Related Questions - Graphing Activity: Graph #1 - Velocity of Ammunition Fired

1. **Which type of firearm shoots bullets with the highest initial velocity?**

   Rifle / .223 Remington

2. **What happens to the velocity of each type of bullet as it moves away from where it was shot?**

   They all slow down.

3. **Which type of ammunition loses speed at the quickest rate?**

   Shotgun sling.

Related Questions - Graphing Activity: Graph #2 - Kinetic Energy of Ammunition Fired

1. **Which firearm projects its bullet with the most kinetic energy? Explain.**

   Shotgun / .12-gauge slug. This firearm likely causes the most kinetic energy to be generated because the .12 gauge slug contains more gunpowder than the other rounds.

2. **Why does the kinetic energy of each bullet decline as it moves away from where it was shot?**

   Kinetic energy is a function of mass and velocity (Ek = 1/2mv2). Therefore, as each bullet moves, its kinetic energy decreases because its velocity decreases (as shown in graph #1).

3. **Which type of ammunition loses kinetic energy at the slowest rate?**

   3. 9 mm Luger / jacketed hollow point

Related Questions - Graphing Activity: Graph #3 - Change in Height of Ammunition Fired

1. **Explain which type of firearm ammunition is the most accurate at hitting its target at short range (50 m)?**

   The pistol (9 mm Luger) is the most accurate at hitting its target at short range because its bullet falls only 2.1 cm after travelling 50 metres. The rifle and the shotgun rounds each fall 2.9 cm and 3.8 cm respectively.

2. **Explain which type of firearm ammunition is the most accurate at hitting its target at longer ranges?**

   The rifle (.223 Remington) is the most accurate at hitting its target at long range. Its bullet falls only 14 cm after travelling 200 metres; the pistol and the shotgun rounds each fall 21.9 cm and 31.8 cm respectively.

Related Questions - Crime Case Study 4.1: The JFK Assassination

1. **Of the two bullets that hit President Kennedy and Governor Connally, why was only one analyzed for ballistic fingerprints?**

   The bullet that hit the President in the head imploded into fragments upon impact, and therefore, could not be analyzed.

2. **What three pieces of ballistic evidence linked the bullet from Connally's leg to the rifle from the Texas Book Depository?**

   i. *NAA of the bullet fragments in Governor Connally's wrist matched the bullet found.*

   ii. *The mass of the bullet found was 10.28 g and the mass of lead fragments retrieved from Connally's wrist was 0.13 g. The average mass of a single, unfired bullet of that calibre and type is 10.42 g.*

   iii. *Rifling impressions found on this bullet matched the lands and grooves in the rifle found in the Book Depository*

3. a) **How much did the bullet's velocity change between when it hit Governor Connally in the back to when it entered his wrist?**

   457 m/s – 274 m/s = 183 m/s

   b) **Explain why this change occurred.**

   As the bullet smashed through his flesh and bone (rib), it began losing some of its kinetic energy and slowing.

4. **When the second bullet hit President Kennedy, it created a 4 mm x 7 mm entry wound. After it left the President's body, this same bullet hit Governor Connally creating an 8 mm x 15 mm entry wound.**

   As the bullet moved through the President's neck, it began losing kinetic energy and slowing, causing it to tumble before it hit the Governor. This tumbling caused the Governor's entry wound to be significantly larger than the President's entry wound.

Related Questions - Crime Case Study 4.2: The Robert Blake Case

1. **During the investigation of Robert Blake, where did detectives locate the gunshot residue?**

   Gunshot residue was found on Robert Blake's hands, shirt, pants, belt, and boots.

2. **Where did Robert Blake's attorneys claim the gunshot residue found on him could have come from?**

   Blake's attorneys argued that the gunshot residue found could have come from his revolver or it could have been transferred to him after touching a surface containing gunpowder.

3. "How valid gunshot residue test results are seen by a jury depends a lot upon on how convincing the other evidence in the case is." Explain how this statement applies to the Robert Blake case.

The gunshot residue evidence did not convince the jury that Blake was guilty largely because of a lack of additional evidence.

4. Why did Robert Blake file for bankruptcy in 2006?

In a civil suit, a jury found Blake liable for the wrongful death of his wife and ordered him to pay $30 million to her children.

Modules 3 and 4 Bibliography

Module 3

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Module 3 and 4 Glossary

abscess - abrasion: a scraped area on the skin resulting from an injury or irritation

accelerant - a substance used in spreading an intentionally set fire

alibi - a form of defence whereby a defendant attempts to prove that he or she was elsewhere when the crime in question was committed

ammunition - projectiles, such as bullets, together with their fuses and primers that can be fired from guns or otherwise propelled

bipod - a stand having two legs, as for the support of an instrument or as a weapon

calibre - the diameter of the bore of a firearm, traditionally shown in hundredths or thousandths of an inch, but may be in millimetres

carbine - a lightweight rifle with a short barrel

cavitation - the formation of an empty space within a solid object or body

circumstantial - evidence not based directly on the fact in dispute but on various circumstances from which the judge or jury might infer the occurrence of the fact

combustion - a chemical change accompanied by the producation of heat and light

concealment - hiding or kept from being seen, found or discovered

corrodes - the gradual destruction of a metal or alloy, especially oxidizing or chemical action (rusting)

disassociative - a psychological disorder in which a person exhibits two or more different personalities, each functioning as a distinct entity

extradite - to give up or deliver a fugitive to the legal jurisdiction of another government or authority

firing pin - the part of the bolt or breech of a firearm that strikes the primer and detonates the charge of a projectile (bullet)

flash point - the lowest temperature at which the vapour of a combustible liquid can be made to ignite momentarily in air

grievance - an actual or supposed situation regarded as the cause of a complaint

gun barrel - the tube through which a bullet travels when a gun is fired

incendiary - capable of causing fire; containing chemicals that produce intensely hot fire when exploded (such as an incendiary bomb)

interpersonal - relating to the interactions between individuals

ion - an atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons

ionization chamber - a gas-filled enclosure containing positive and negative electrodes to measure the amount of radiation passing through an ion

IQ - (intelligence quotient) the ratio of tested mental age to chronological age, usually expressed as a number multiplied by 100; a number intended to represent a measure of relative intelligence as determined by the subject's responses to a series of test problems

kinetic energy - the energy possessed by a body because of its motion

meticulous - extremely careful and precise; concerned with details

muzzle - the forward, discharging end of the barrel of a firearm

navigates - directing the way to go by determining position, course, and distance travelled

non-porous - does not have pores; does not allow substances to be absorbed

pellets - small, metal balls found within certain types of shotgun cartridges

photons - the particles composing light

point of entry - location of entry into an enclosed object, as a bullet entering an object or a burglar entering a house

polyatomic ions - an ion of two or three atoms that has a charge and acts as a single unit (for example, hydroxide ion = oh-)

porous - full of pores that absorb most gases or liquids

projectile - a fired or propelled object, such as a bullet, that with no capacity for self-propulsion

propellant - something that propels or provides thrust; especially gunpowder

pyromaniac - a person with an obsessive desire to set fires

reagent - a substance used in a chemical reaction to detect, measure, examine, or produce other substances

remorse - regret; anguish arising from sorrow for past misdeeds

ricochet - to rebound or bounce at least once from a surface

sanctions - a coercive measure adopted usually by several nations acting together against a nation violating international law

semi-automatic - a firearm that requires a squeeze of the trigger for each shot, but it ejects the cartridge casing and loads the next round of ammunition automatically

subservient - excessively eager to serve or obey

sympathizer - to share or understand the feelings or ideas of another person or group

trajectory - the path through space of a projectile or other moving body

velocity - the speed and direction of a body in motion

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