



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

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(see note 2 below)

SURNAME: CAUTE

FORENAME(S): JAMES

Examination Answer Books

12 Pages

Instructions to Candidates

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over and seal down (using the label provided) to hide your name.
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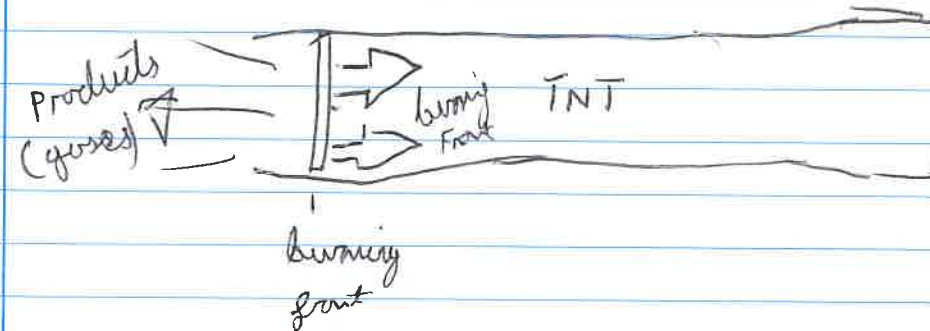
1	Student Number	2313853
2	Title of Examination Paper	PRINCIPLES OF OME
3	Module Code	ACDA 4019
4	Date and Time of Examination	08/01/2025 12:00
5	Examination Venue	IR 310
6	Seat Number	040
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
1	4
2	9
3	10
4	8
5	9
6	7
7	9
8	8
9	5
10	3
Total	72

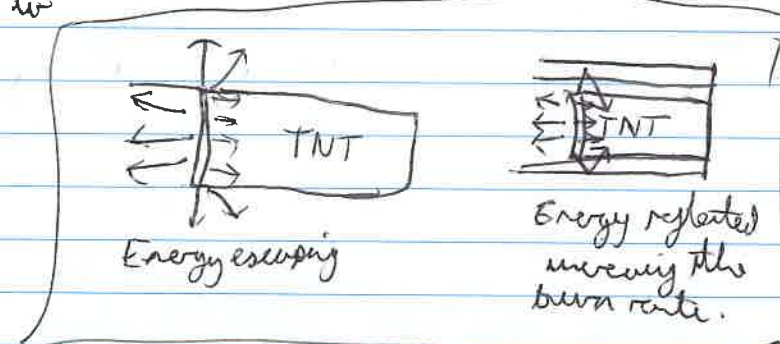
(Gweler yr ochr arall am y fersiwn Cymraeg)

1.

- a) Deflagration is a subsonic decomposition of a material using internal oxygen while the products ~~escape~~ and the burning front moves normal ~~to~~ to the surface in opposite directions.



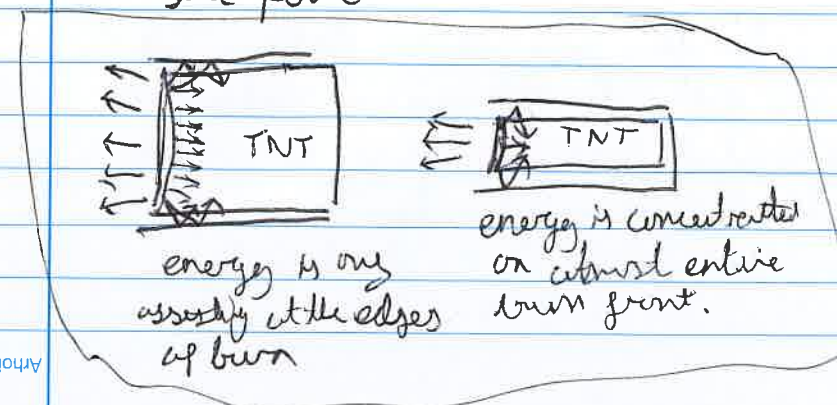
This gives off energy in all directions. If the material is confined then the energy given up is reflected back inwards leading to

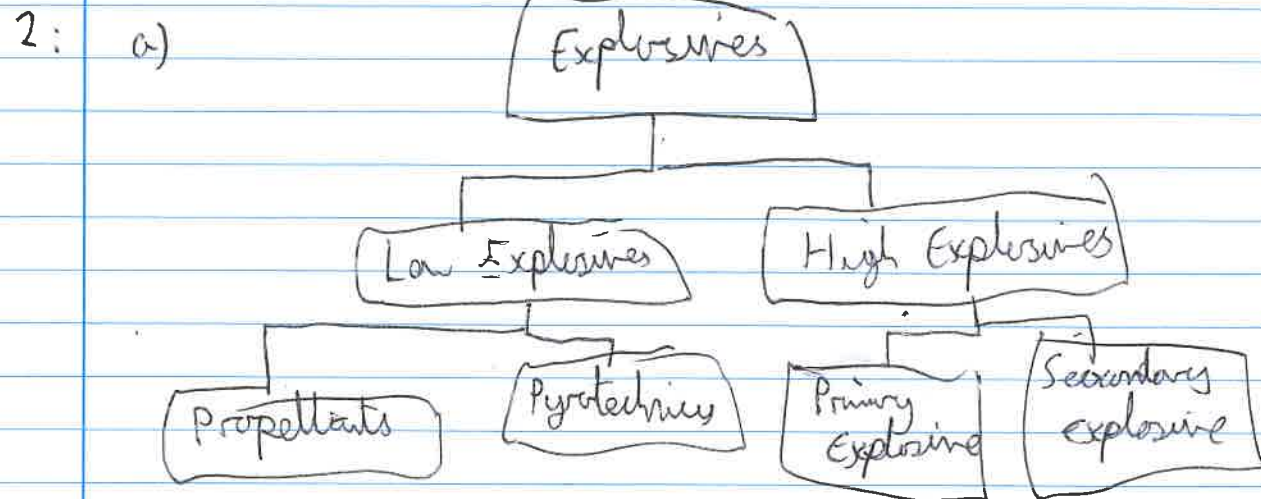


If this increases the burn rate sufficiently then the front may move ~~at same~~ ~~than the~~ at a higher velocity

than the speed of sound at this point the reaction is a detonation.

The narrower the diameter the higher the velocity of ~~xx~~ detonation unless the diameter is below the critical diameter. (in which case no detonation will occur). This is due to more energy being reflected onto the same point





b) Primary explosive - Very sensitive and easily initiated. (Lead azide, silver azide and Lead fulminate are examples)

Secondary explosive - Require more energy to initiate but detonate reliably. (TNT and RDX are examples)

Propellants - Degradate releasing large amounts of heat and gas. (Nitrocellulose and nitroglycerine are examples)

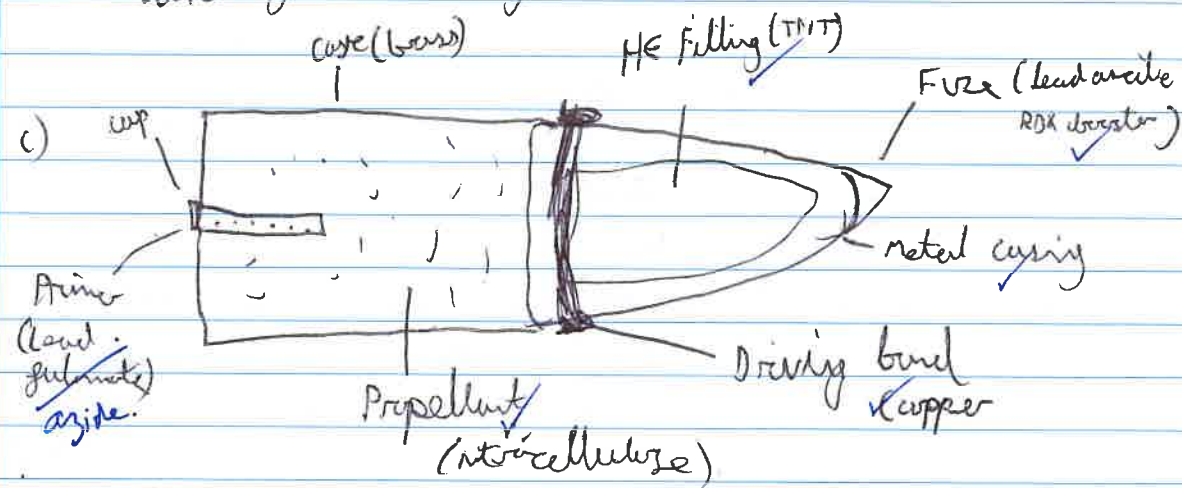
Pyrotechnics - Designed to produce effects such as illumination, sound or smoke. examples include magnesium and Potassium Perchlorate ($KClO_4$)

c) likely failed due to the poor oxygen balance of ammonium nitrate and fuel oil. The commercial detonator would not have provided sufficient energy to initiate insensitive materials. There may have been an insufficient quantity leading to not meeting critical diameter.

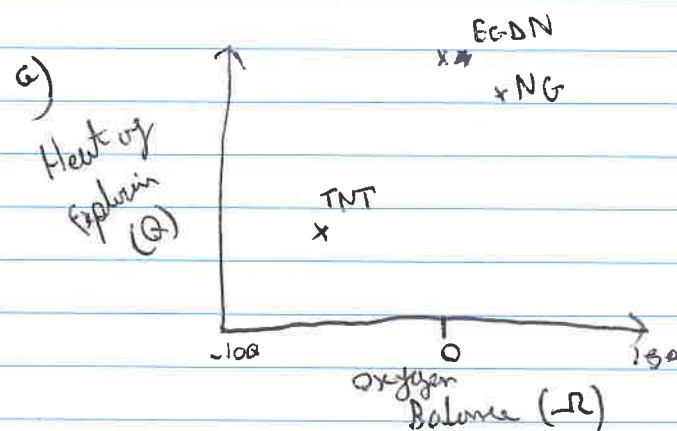
3: a) critical diameter - the minimum diameter of a charge required for the detonation to sustain due to the corner shock front.

critical density - minimum density of particles needed to allow a detonation to take place.

b) if either are below the threshold, then the detonation will at best only use some of the material and at worst fail entirely.



Q4:



b) because it has a low oxygen balance leading to incomplete combustion resulting in excess carbon left over.

c) H_2O , CO_2 , N_2

energy

d) It would produce Al_2O_3 (Aluminum oxide) and $AlCl_3$ (Aluminum chloride). Adding aluminum would increase the heat of reaction and increase the volume of gas V due to the extra products.

Q5:

a) hot spots - These are formed in the ~~filling~~ high explosive filling of any explosive. Some examples can be caused by crystals ☒ snapping, explosive being shocked/compressed, bubbles in the structure collapsing.

These can trigger unwanted detonation as the energy becomes sufficient to initiate a DDT. Each explosive material has its own unique ignition temperature ☒ (where it will begin burning therefore in the case of internal oxygen depletion). If a hot spot reaches this temperature then it will degenerate to detonation boundary. They act as stores of energy. If many long thin crystals form and all snap at the same time then it could lead to unwanted detonation.

b) The ~~low~~ shock front of a detonation wave reaches hot spots which ignite throughout the material.

b) Long term storage in these conditions will lead to repeated exposure to temperature changes. This has the possibility (especially with TNT and its relatively low melting temperatures of $\approx 60-70^\circ C$) to soften the filling allowing it to flow freely and then re-solidify ☒ this process could lead to formation of bubbles and crystals. The crystals formed are long and brittle. The settling of the propellant giving the gun would likely cause many of them to snap creating hot-spots. These would have sufficient energy to ~~be~~ initiate the main fill at the moment of firing. Alternatively, the repeated heating and cooling through storage could have created hot spots with expansion and contraction of the casing. Then, as before, the initiation of the primer adds enough energy to detonate.

Q6:

- a) Single - Nitrocellulose
 Double - Nitrocellulose, Nitroglycerine
 Triple - Nitrocellulose, Nitroglycerine, Nitroguanidine

1 1/2

- b) highest the oxidant percentage ~~is~~ is 60% ^{13.4%}
 the more nitrogen content, the more Force Constant
 due to a higher volume of gas being produced.
 The flame temperature will increase due to the
 more bonds breaking which release their energy.

2

- c) a high explosive such as RDX. The large increase
 in force constant this would result in would wear
 down the barrel much faster, possibly reducing
 capability as barrels will need changing more regularly.
 This is due to the propellant moving much faster
 through the barrel and a much higher heat
 produced when fired.

3

- d) Introducing a coolant into the mixture ~~to~~ is order
 to reduce heat wearing the barrel down.

1/2

Q7:

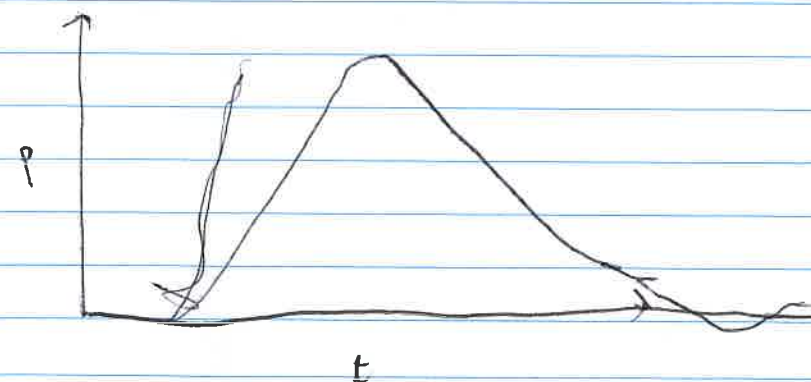
- a) A ~~gas~~ Fuel Air Explosion (FAE) utilises a gaseous
 or vapour fuel which combusts using atmospheric
 oxygen.

First, the fuel needs to be released by some mechanism.
 This could be an air dropped device or a manually planted
 bomb. The fuel (propane gas, butane gas etc) is ejected
 and dispersed into the air. Time must be taken to
 ensure that the concentration of fuel is correct. If
 it is too dense it will just explode (or to sparse). Once
 the correct density is reached a separate initiator
 needs to go off. This can be a conventional fuse
 or a small bomb, as long as it achieves ignition
 of the fuel. The fuse will trigger the primary which
 will initiate the booster to then initiate the
 fuel in the air. Once this occurs the fuel
 will use atmospheric oxygen and rapidly combust.

Advantages - Covers a very large area with high
 casualty rate against individuals.

Disadvantages - Requires 2 separate devices, one to release
 fuel and another timed just right to set
 it off.

b)



not as steep.
 or a constant
 detonation

8

1

Q8: a) Projectile b will penetrate further ✓

This is because a smaller diameter sphere of the same mass will be denser, meaning it will deform less than the larger sphere ($\therefore$ kinetic energy is maintained). Also it will have a smaller point of impact, concentrating all the force on a smaller area.

b) The long rod penetrator ✓

- It is made out of a denser material ^{penetrator} resulting in less deformation so kinetic energy will be preserved for deforming target instead.
- It has a smaller profile so will not have to deform as much of the armor to pass through (more of the kinetic energy can be focused on smaller area of armor)
- Its smaller more aerodynamic form will also allow it to retain more ~~so~~ if its mass ^{velocity} by time of impact. A higher impact velocity will lead to more kinetic energy being transferred into the armor $\therefore$ a deeper penetration.

3

Q9: a) gasless will produce solid products which do not expand
gassy will produce gas products (CO_2 , N_2 , etc)

b) gassy will only be used in situations it is vented to allow gases to escape
gasless will be used in unvented spaces where expansion of gases could lead to damage or undesired effects.

c) The more porous a delay the faster it will be as there is less material to burn in the same volume. If the is too ~~to~~ tight it will be unable to conduct the burn through itself and may ~~lose~~ fail.

2

2

1

- Q10: a) The blue flame burns hotter than the red. ✓
- Both are producing wavelengths not visible to human eye (ultra violet for blue and infrared for red)
- potassium and copper burn to create a blue flame and potassium and strontium burn to produce red. ✓

2

- b) Some materials burn very differently and give off different products. Different combustion requires different materials to be safely used for different effects to be produced using the same materials.

1



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(see note 2 below)

SURNAME: BIGGS

FORENAME(S): EMMA ALICE

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3	Module Code	ACDA 4019
4	Date and Time of Examination	08/01/25 12:00
5	Examination Venue	1Q 310
6	Seat Number	42
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	10
2	10
3	10
4	9
5	8
6	9
7	9
8	5
9	4
10	5
Total	79

(Gweler yr ochr arall am y fersiwn Cymraeg)

- 1 Deflagration to detonation transition is where an explosive begins ~~undergo~~ ^{undergoing} rapid burning (where conduction plays a large role in the transfer of heat) upon initiation from an external stimulus or hot spot. The velocity of the burning front accelerates from subsonic speeds above 100 m/s to supersonic speeds due to the increasing temperature caused by the generation of heat ~~gas~~ and gaseous products which increase pressure within the material. When the burning front exceeds the velocity of sound within the material, it transitions to a detonation.

Direction
of burning



Direction of
burning

Deflagration is a surface level phenomena where direction of products is opposite to direction of burning front. When burning rate exceeds velocity of sound, a shock wave is generated causing transition to detonation.

products
of detonation

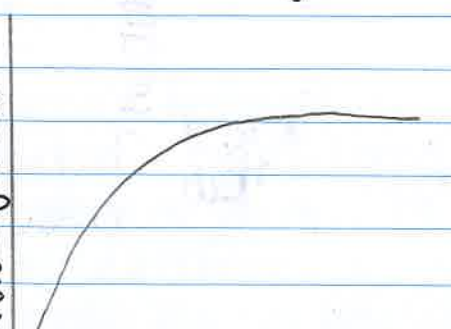
shock
wave front

Detonation expands ^{radially} from point of initiation. products travel in the same direction

unreacted material

Detonation is only able to occur if the ^{charge has} ~~material~~ a diameter larger than the critical diameter. Increasing the diameter of the charge will increase the velocity of the reaction until the point where it is ~~no longer the limiting factor~~ ^{no longer the limiting factor}.

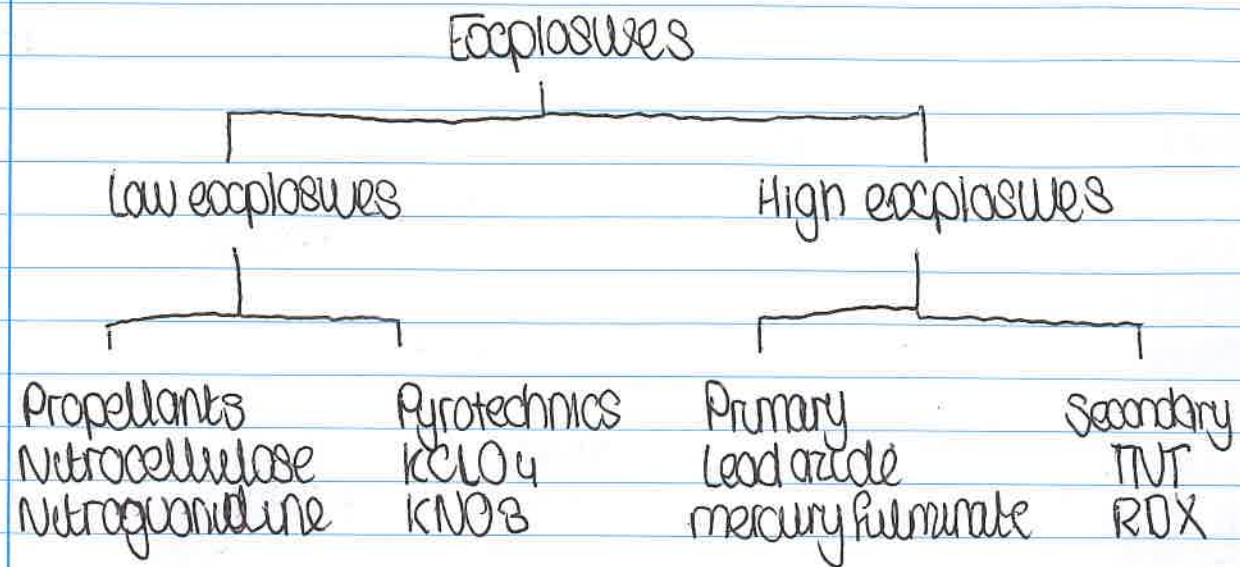
velocity of detonation



charge diameter

A graph showing increasing charge diameter increases velocity of detonation until it plateaus

2a



2b

Low explosives → undergo deflagration
 Propellants → burn without external sources of oxygen to produce high temperature gases used to generate thrust
 Pyrotechnics → when initiated correctly burn to produce a desired effect such as light, heat, smoke and sound

~~Primary explosives~~

High explosives → undergo detonation

Primary explosives → readily initiated by external stimuli, creating shock wave which is commonly used to initiate less sensitive energetic material

Secondary explosives → less sensitive, more powerful explosives compared to primary which require impingement of a shock wave in order to cause detonation

Propellants → nitrocellulose, nitroguanidine

Pyrotechnics → $KClO_4$, KNO_3

Primary → Lead azide, mercury fulminate

Secondary → TNT, RDX

2c

Ammonium nitrate and fuel oil is a tertiary explosive meaning it is relatively stable and requires a boost from a secondary, more powerful explosive to initiate detonation. As commercial detonators only contain primary explosives, the shock wave generated by the detonator was insufficient to cause detonation of the ANFO.

3a

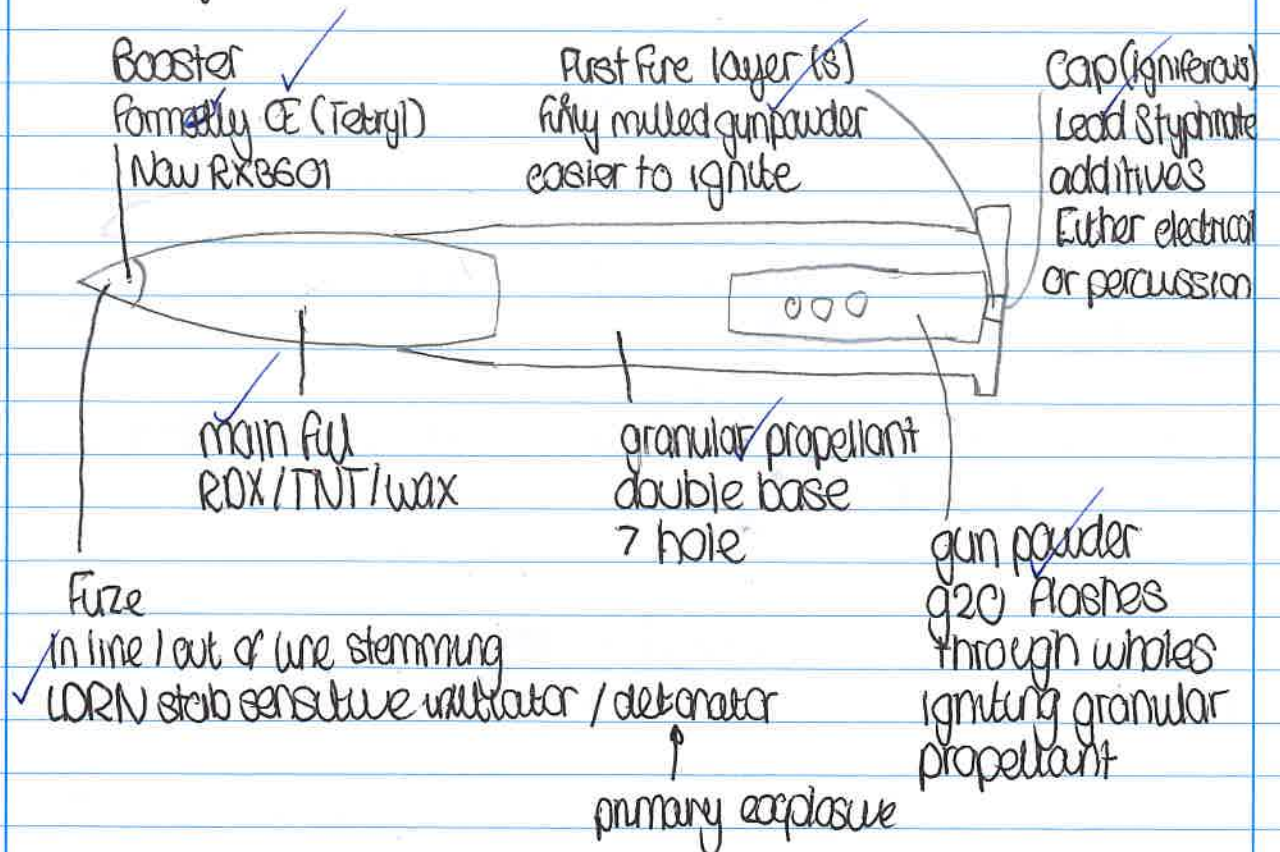
Critical diameter → the minimum diameter of a charge required to sustain a stable detonation wave / prolonged complete propagation of detonation
 Critical density → the minimum density of a charge required to sustain a detonation wave / complete propagation of detonation

3b

If critical diameter of a charge is not met (the charge has a smaller diameter than the critical diameter) detonation will fail to propagate causing the charge to fail.

If critical density of a charge is not met (the charge is less dense than critical density) particles within the charge may be too far apart for detonation to propagate, causing the charge to fail

3c



3

2

2

5

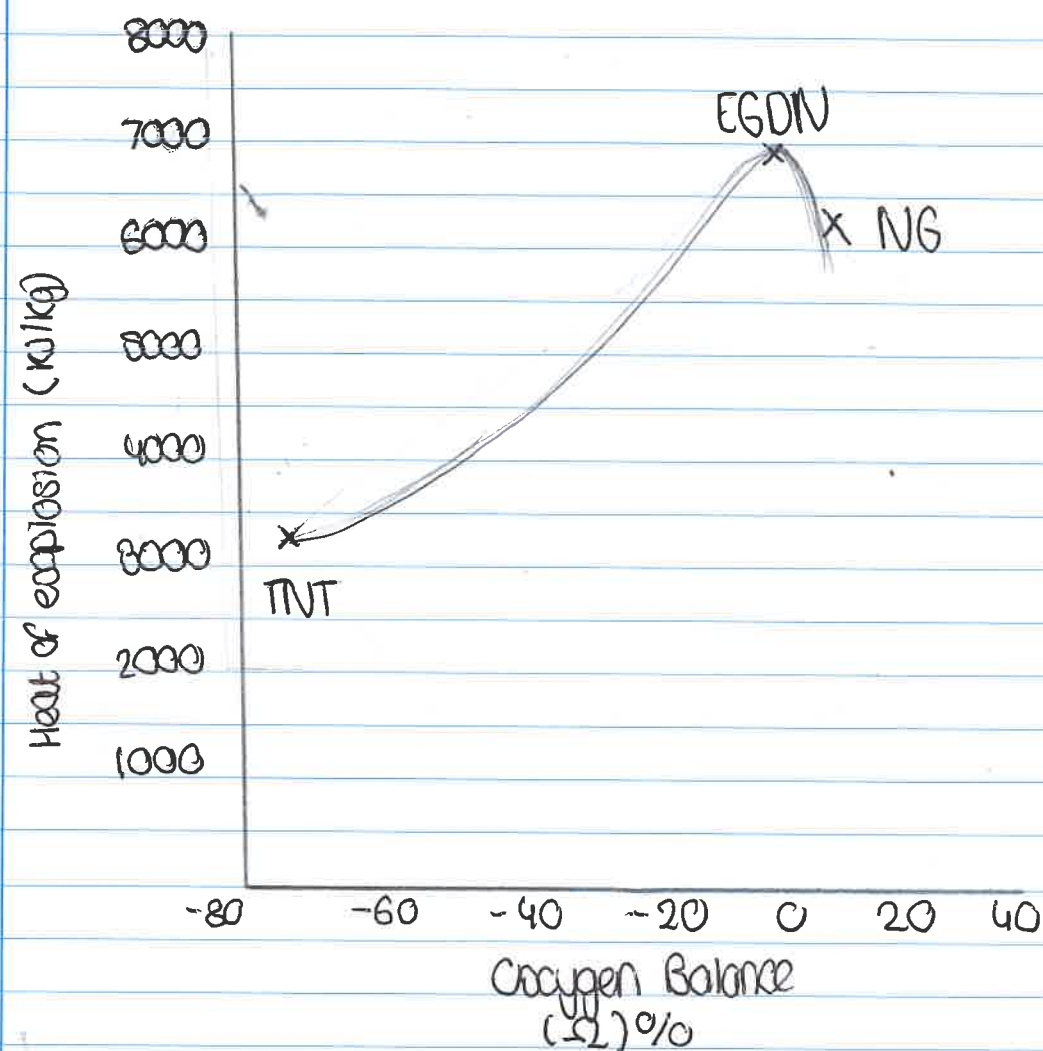
6

2

10

10

4a



- 4b) Due to low oxygen balance of TNT, solid carbon is produced during combustion
- 4c) Carbon dioxide (CO_2), water (H_2O) and nitrogen gas (N_2) energy
- 4d) Adding aluminium to an explosive would produce aluminium oxide (solid white powder). Adding aluminium increases the heat of explosion but reduces the volume of gas produced

5a

Hot spots are areas within an energetic material that exceed the activation energy of the material. Ignition temperature is the temperature at which the material has enough energy to exceed activation energy. Primary explosives are most commonly initiated by intercrystalline friction. This is where the ~~and~~ rubbing together of crystal structures within the material generates enough heat (energy) to overcome activation energy. The intercrystalline friction generated a hot spot of sufficient energy to detonate the material. Secondary explosives are most commonly initiated through adiabatic compression of air spaces between particles. This compression generates a hot spot of enough energy to cause initiation of the material. If the energy within the hot spot fails to reach activation energy or is not prolonged, the hot spot will die out, no detonation will occur and the material will remain chemically unchanged

5b

Thermal cycling causes thermal expansion and contraction of the TNT. Because TNT is crystalline in its structure this can cause fractures in crystals to form. These fractures can lead to the generation of hot spots, increasing the likelihood of premature detonation. Thermal cycling causes condensation to form leading to the ingress of water into the TNT. Water increases the rate of degradation of the material, ~~more~~ decreasing its stability and increasing likelihood of premature detonation. Thermal cycling also puts stress on crystal structure increasing the likelihood of material fatigue leading to crystal breakages, hotspot formation and premature detonation melting + recrystallization

6a Single base propellant → nitrocellulose
typically used in small arms ammunition and small calibre artillery shells / mortars
Double base propellant → nitrocellulose + nitroglycerin
used in medium calibre artillery shells and as solid rocket propellant in missiles
Triple base propellant → nitrocellulose + nitroglycerin + nitroguanidine
used in large calibre artillery shells and rocket propellant

6b Maximum theoretical percentage = 14.4%
Increasing nitrogen content increases amount of oxygen available for oxidation reaction, increasing amount of gas produced and temperature of the reaction. This increases the temperature of the flame and the pressure within the barrel, increasing force constant

6c High energy nitramines such as RDX and HMX can be added to double based propellants to increase energy density, creating higher temperatures and more pressure within the barrel by increasing gas production. Increasing temperature and pressure within the barrel would increase muzzle velocity however would put more strain on the barrel reducing its life. Burning rate modifiers and additives such as KNO3 could also be added for the same effect

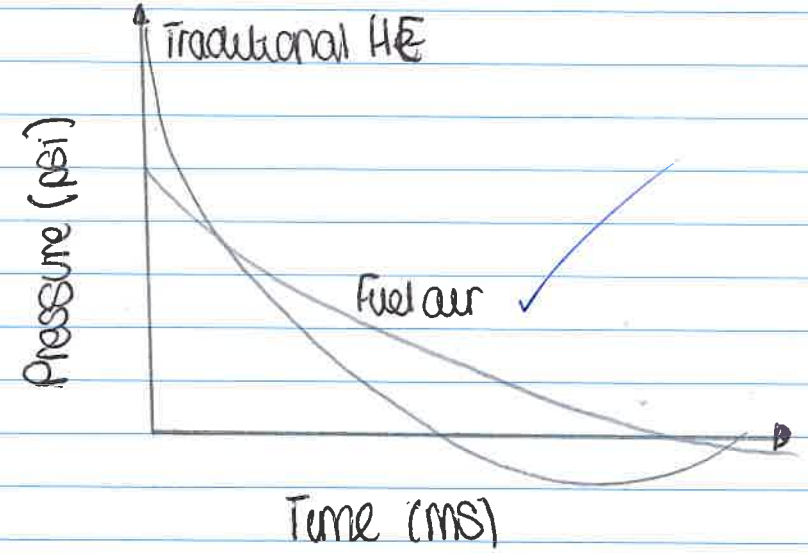
6d Barrel life can be extended by using a ceramic thermal barrier or lining to reduce contact between the barrel and the hot gases produced. Stronger alloys could be used that are less sensitive to thermal increases

7a Primary explosion initiates first secondary explosion detonation to disperse fuel into the air. Second timed detonation of primary then secondary explosion then ignites the fuel air mixture creating high temperatures and prolonged over pressure.

Advantages
Higher overpressure remains high for an extended period of time causing high amounts of damage
High temperatures generated cause damage in addition to blast
High casualty rates

Disadvantages
Lower initial peak pressure compared to HE
Secondary charge is required for detonation
Rapid combustion of fuel + atmospheric oxygen

Rapid combustion of fuel + atmospheric oxygen generates blast wave



3 }

2

3

1 }

7b

7

2

8a The projectile with the smallest diameter (4mm) will penetrate the furthest due to it having a higher density. Objects with higher densities have higher impact energy density meaning their kinetic energy is dissipated over a smaller area of the target than less dense objects which dissipate energy over a larger area. The smaller denser projectile will be able to penetrate further as energy is focused on a smaller area. Same kinetic energy.

8b The APFSDS round (second projectile) will be able to penetrate further into armour due to its smaller size. As it has a smaller diameter, it will be more dense than the first projectile meaning it has a greater impact energy density. Its kinetic energy is dissipated over a smaller area meaning it is more concentrated so will penetrate further.

3

2

and fuel are

9a The oxidiser is selected as one that generates low amounts of gas when undergoing burning.

9b gasless delays are used in confined containers to prevent an increase of pressure generated by the production of gas. Gassy delays are used where there are flame holes for ignition of the next composition and gas is able to vent.

9c Having pores are important to generate hotspots needed for ignition however too large / too frequent pores can prevent conduction of the burn through the compound.

2

1

10a The spectrum of the blue flame tells us that the combustion is of a lower temperature as the predominant peak falls within the visible light spectrum. The combustion of the red flame is hotter as the predominant peak is in the infrared. The more peaks there are, the more carbon based products there are from combustion.

3

10b Different combustion regimes are needed to produce flames that ~~have~~ have different wave lengths. Different wave lengths are required to mimic ~~target~~ the wave lengths produced by the target. Different detectors on threats can operate in different parts of the electromagnetic radiation spectrum such as visible light, ultra violet or infrared meaning flames need to be able to mimic the signatures of targets across a variety of different wave lengths in order to prevent threats damaging the targets. To produce different wave lengths, different compositions of pyrotechnic are required which will require different combustion regimes in order to produce the desired effect.

2