



Complete, fold and seal
(see note 2 below)

SURNAME: Tucker

FORENAME(S): George

Examination Answer Books

12 Pages

Instructions to Candidates

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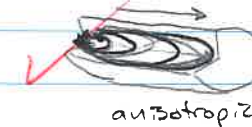
1	Student Number	1906898
2	Title of Examination Paper	Scientific Principles of ONE
3	Module Code	ACDA6008
4	Date and Time of Examination	11/01/2023 12:00
5	Examination Venue	IQ - 310
6	Seat Number	011
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	5
2	5
3	5
4	5
5	4
6	5
7	31
9	33
Total	93

1.) a) 5 principal factors are:

- Propagation ✓
- Attenuation ✓
- Dispersion ✓
- Energy coupling ✓
- Damage volume. ✓

b.) Isotropic propagation is where shock wave front radiates out from the point of ~~det~~ initiation symmetrically and evenly as seen within a centrally-initiated spherical charge. Non-isotropic, or 'anisotropic' propagation is where shock fronts do not propagate out evenly as may be seen in an end initiated ~~charge~~ cylindrical charge.



2.) The effects of blast are negatively affected by increases in altitude. This is because the density of air decreases leading to greater attenuation of shockwaves. At 5000 m altitude the air pressure is roughly 10% that at sea level. In order to counter this effect a warhead designer could:

- ▷ Use a more powerful explosive
- ▷ Use more explosive
- ▷ Reduce case thickness

3.) a.) $L = \frac{t}{\cos \theta}$

$$L = \frac{0.5}{\cos(40^\circ)}$$

$$= 0.6527 \dots$$

$$\approx 0.65 \text{ m.}$$

b.) penetration = $L \sqrt{\frac{P_r}{P_c}}$

$$= 0.535 \times \sqrt{\frac{7000}{7850}}$$

$$= 0.7873 \dots \text{ m}$$

$$0.78 > 0.65$$

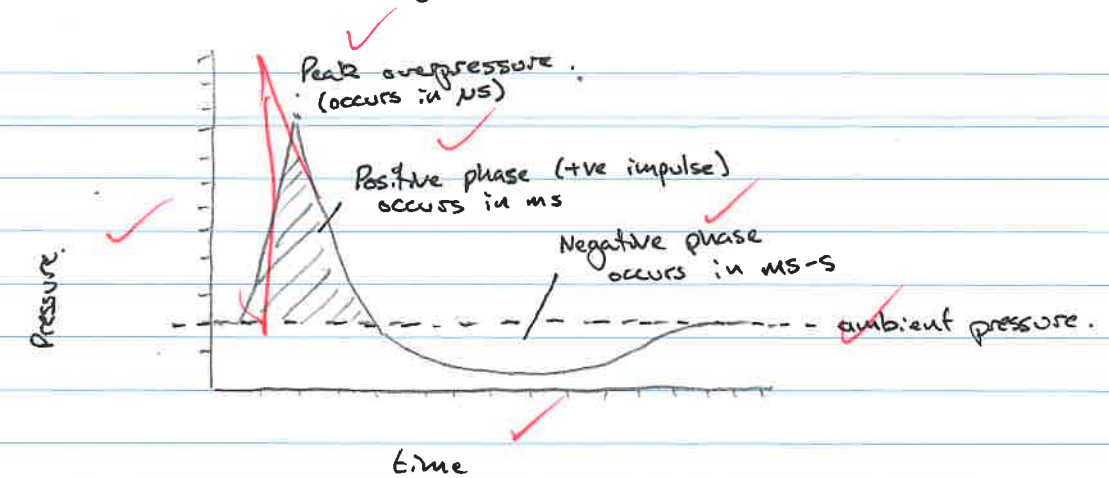
Therefore the penetrator will defeat 0.5m of RHA at 40° angle of attack.

- 4.) a.) A floating vessel can be damaged from the overpressure of the underwater explosion and the successive ~~exp~~ impulse loading which occurs from the bubble-pulse effect.

Additionally, if a bubble makes contact with the vessel's hull, it will collapse and focus the pressure via the Munroe effect. Acting like an 'air shaped-charge' to perforate the hull.

- b.) Aluminium reacts after the initial explosion with detonation reaction products to give off more heat. This will increase the heat of explosion (Q). It will decrease the peak overpressure of the explosion but will increase the duration pressure is exerted (impulse). A larger impulse will exert force onto targets for longer making it more likely for damage to occur. The addition of too much aluminium however, will reduce performance. (Optimum for TNT mix is 18% wt)

Pressure/Time graph for air blast.



Impulse is defined as force multiplied by time. It is represented by the area under the curve in a pressure/time graph as pressure is F/m^2 . The longer the duration of the positive phase the larger the impulse. This means that target structures are under ~~pressure~~ load for longer which causes more damage.

- 6.) a.) The ballistic life of a propellant is the period of time over which it will operate within its designed parameters (Producing correct F and t_o values). It is usually the life determining factor compared to chemical safe life. It is tested using closed vessel testing to ensure propellant performance has not changed.

- b.) Ballistic life is affected by:
- Rate of decomposition of NC and NG in storage and the consumption of stabilizer additives.
 - The migration of components such as surface moderants over time.
 - Storage and environmental conditions, unwanted water ingress etc.

7.)

Due to the nature of the target HESH rounds and their effects are not likely to be considered as there are several layers to the armour which will have different levels of acoustic impedance. Additionally there is a spall liner present which would catch any scabbing to prevent damage to the crew/turret compartment. HESH could be useful in attempting to destroy/disrupt the ERA, however is at risk of not achieving this due to the presence of an active protection system. This method would also require a second shot which would negate any element of surprise attack.

Shaped charge munitions and their effects could potentially be used. The penetration should be enough to overcome the armour system. The only issue would be the ERA which is an effective counter to shaped charges as it can force a flyer plate up into the path of a jet to disrupt it and reduce the amount that is available to penetrate the actual hull armour. The ERA could be overcome by the use of a tandem shaped charge warhead, which would use a smaller precursor charge to pre-emptively set off the ERA allowing the main charge to deal with the hull armour. A munition such as this would also be vulnerable to an active protection system. This could however be countered by adequate velocities or the use of decoys. ~~At this~~ The firing situation would also play a role, gun-launched rounds from tanks may be affected by rifling and the amount of spin imparted to them. Additionally large forces experienced during firing ~~may~~ may cause hot-spotting in the warhead. Other options to offset this would be to use a missile with a rocket motor which accelerates more gradually.

In summary, shaped charges could be used but would need to be tandem and have a method to overcome the active protection system.

EFPs could be a good alternative as they could be made very large (assuming favourable engagement scenario) and triggered to fire from a static design. Penetration can be increased by increasing the diameter of the ballistic disc. ~~At this~~ Due to the 'smashing effect' of an EFP vs SC, it may not initiate the ERA allowing for penetration of hull armour. However, any back-face spalling will still be countered by the liner if the slug does not penetrate. Alternatively, a smaller ~~of~~ ~~the~~ EFP mine could be used to attack the belly armour which is usually the weakest place. This requires pre-set up however and so has no ability to engage targets.

Blast would largely be ineffective against such a hard target but could do damage from beneath due to the weak belly armour. However, as with the EFP this would require a mine to achieve.

Finally, a long rod penetrator could be used. This would work by hydrodynamically penetrating the armour causing adiabatic shearing to enter the vehicle and damage the crew/initiate ammunition. ERA is usually not an issue for long-rods, however it should still be considered as potentially slightly destabilising the flight of the rod. The general parameters would be high KE density achieved through high mass, high velocity and small diameter. An adequate nose shape (perhaps sacrificial tip) and to be self-sharpening will aid in penetration. The density and hardness of some of the target layers (ceramics etc.) means a dense material is required for the rod.

The rod would need to be gun-launched which requires an MBT, and the high velocities mean that barrel wear could be an issue and cost. Finally due to projectile slow-down max engagement ranges will exist, over which penetration will not occur. (Hydrodynamic strike velocities being $>1200 \text{ ms}^{-1}$, otherwise transition zone causes decreased performance). Flight would also need to be fin stabilised ~~and~~ to reduce yaw (1% max).

In summary:

HESH effects unlikely to be used but could potentially weaken target by removing ERA.

Shaped charges could be effective but would have to be either tandem or large enough to overcome ERA.

EFPs would be a good option if large enough charge can be set-up to provide adequate pen.

Blast is unlikely to be utilized.

High-velocity long-rod penetrators are a good option. Should provide adequate penetration against the target and also not be affected as much by the ERA or active protection system.

$$a.) \quad v_0 = \sqrt{2E \left(\frac{M}{C} + \frac{1}{2} \right)^{-\frac{1}{2}}}$$

$$v_0 = 2700 \left(\frac{8}{12} + \frac{1}{2} \right)^{-\frac{1}{2}}$$

$$= 2499.71 \text{ ms}^{-1}$$

$$\approx 2500 \text{ ms}^{-1}$$

$$b.) \quad 10 \text{ mm} = 0.01 \text{ m}$$

$$\text{Area of frag} = 1 \times 10^{-4} \text{ m}^2$$

$$\text{Volume} = 1 \times 10^{-6} \text{ m}^3$$

$$\text{Mass} = 1 \times 10^{-6} \times 7850 = 7.85 \times 10^{-3}$$

$$V_s = V_0 e^{\left(\frac{-Cd \rho A v A S}{2m} \right)}$$

$$V_s = 2500 \times e^{\left(\frac{-1.6 \times 1.225 \times 1 \times 10^{-4} \times 100}{7.85 \times 10^{-3} \times 2} \right)}$$

$$= 717.403 \text{ ms}^{-1}$$

$$= 717 \text{ ms}^{-1}$$

If a sphere was used the drag coefficient would be smaller. That means the exponent term would be smaller resulting in V_s being larger. I.e. the fragment would be travelling faster at a distance of 100 m.

$$c.) \quad \text{KE density} = \frac{\frac{1}{2} m v^2}{\text{Area}}$$

$$\therefore \frac{\frac{1}{2} \times 7.85 \times 10^{-3} \times (717)^2}{100}$$

$$= 20.177 \text{ J mm}^{-2}$$

$$\approx 20 \text{ J mm}^{-2}$$

$20 > 6$ $\therefore$ fragment will enter the car passenger area.

d.) The five goals of IM are:

- Reduce operational risk.
- Reduce the risk of accidents.
- Increase life (shelf life of munitions)
- Reduce/remove defects (cracking or powdering, for example)
- Increase the tolerance of munitions to the environment when deployed on expeditionary operations.

For a warhead such as this several things could be done:

- Packaging could be altered to protect munition from heat - also it could include features such as ~~venting~~ venting.
- The munition could also have design features that allow for venting when exposed to a fire. This prevents pressure build-up which can lead to a deflagration-to-detonation transition.
- A less sensitive RDX could be used to replace the TNT/RDX fuze (DNAN)*. However it should be borne in mind that this may reduce ~~the~~ performance against targets.
- Warhead could be made modular and stored in separate components for storage and transport. E.g. a removable sleeve containing preformed frag to reduce the risk of lethal fragmentation in an accident.
- New techniques such as RAM mixing and better scanning methods (CT scanning) could help reduce the amount of defects, such as cracks and voids, in finished munitions. RAM mixing providing more homogeneous mixtures, and CT scanning revealing details that x-rays do not.

12

33



Examination Answer Books

12 Pages

SURNAME: Harwood

FORENAME(S): Thomas

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2	Title of Examination Paper	Scientific principles of OM & Design
3	Module Code	ACA6008
4	Date and Time of Examination	12:00 11/01/23
5	Examination Venue	1Q 310
6	Seat Number	010

7	Number of Answer Books handed in	
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List the numbers of the questions you have attempted	Office Use
1	4
2	4
3	2
4	3
5	3
6	3
7	25
9	31
Total	75

Q1 A) Factors affecting warhead Performance

- ① Energy Coupling ✓
- ② Attenuation ✓
- ③ Propagation ✓
- ④ dispersion ✓
- ⑤ Spin ✓

so close!

④

B) Isotropic propagation
is when the fragments from a warhead ~~can~~ are of uniform size and travel away from the initiation point in all directions

Non-isotropic propagation
is when the fragments from a detonated warhead travel in only one direction

Q2

When blast occurs at altitude its performance is significantly reduced a blast at 15,000 metres has the equivalent performance of 10% of its charge mass at sea level. meaning that if you wish to have the same performance at 15,000 metres ~~then~~ as you do at sea level you would need a 10 times bigger charge. ~~that~~

④

if the warhead designer ~~requires~~ wishes to have a similar performance at 15,000 metres ~~that~~ they did at 100 metres they will need a significantly bigger charge.

Q3 1a) ~~$V = \frac{L}{\cos \theta}$~~ $L = \frac{t}{\cos \theta}$
 $t = 0.5 \text{ metres}$ * ~~500 mm~~ $\theta = 40$

$$L = \frac{0.5}{\cos 40}$$

$$L = 0.65 \text{ metres}$$

the actual thickness the penetrator must defeat is 0.65 metres

2)

(2)

Q4 a) Two principle methods of damage.

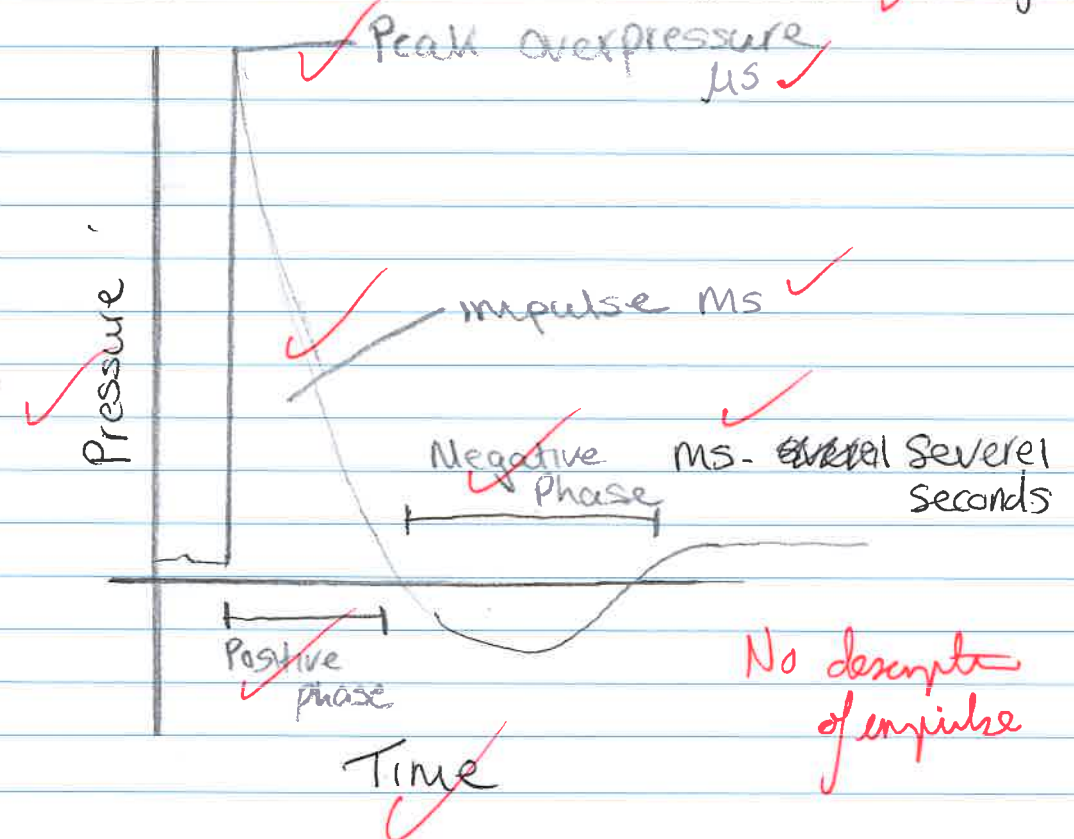
1) direct damage from the ~~the~~ initial detonation blast damage ~~for the~~ from the initial shock wave

2) damage from the bubble pulses which migrate to the rigid surface after the initial detonates. the bubbles utilise the monroe effect when they contact the rigid body creating jet like formations similar to that of a shaped charge.

b) Adding aluminium to an explosive will decrease the heat of detonation but will increase the duration of the ~~negative phase~~ positive phase increasing the impulse and thus increasing the magnitude of the bubbles about 18%. Aluminium is a good ratio

(3)

Q5.



(3)

Q6 a) the Ballistic life of a gun propellant is the length of time to which a gun propellant ~~keeps its performance~~ maintains its desired performance and is deemed as safe to use. this length of time is shorter than its chemical life

b) Factors affecting its ballistic life are the storage conditions of the gun propellant, whether the gun propellant has been stored at the correct temperature and in the correct container, whether its been handled, dropped or crushed.

Q9 a)

$$V_0 = \sqrt{2E \left(\frac{m}{C} + \frac{1}{2} \right)^{-\frac{1}{2}}}$$

$$V_0 = 2700 \left(\frac{12.8}{12} + \frac{1}{2} \right)^{-\frac{1}{2}}$$

$$V_0 = 2700 \left(\frac{7}{6} \right)^{-\frac{1}{2}} \quad \left(\frac{7}{6} \right)^{-\frac{1}{2}} = 0.92582$$

$$V_0 = 2700 \times 0.926$$

$$V_0 = 2500.2 \text{ ms}^{-1}$$

(3)

Q9

$$V_s = V_0 \exp \left[\frac{-C_d \times \rho_{\text{air}} \times A \times s}{2m} \right]$$

$$A = \text{area of frag} = 0.01 \text{ m} \times 0.01 \text{ m} = 1 \times 10^{-4} \text{ m}^2$$

$$\text{mass of frag} = \rho \times V = m = \rho \times V$$

$$m = 7850 \times (1 \times 10^{-6})$$

$$\text{mass} = 7.85 \times 10^{-3} \text{ kg}$$

$$V_s = 2500.2 \times e^{\left[\frac{1.6 \times 1.225 \times 100 \times 1 \times 10^{-4}}{2 \times 7.85 \times 10^{-3}} \right]}$$

$$V_s = 2500.2 \times e^{[1.25]}$$

$$V_s = 716.319 \text{ ms}^{-1}$$

(8)

B) i) If the frag was a sphere rather than a cube it would alter the area and volume values for the equation thus altering the changing the slow down. The spherical fragment wouldn't slow down as much as the cube fragment.

(2)

$$c) \text{ Kinetic energy density} = \frac{\frac{1}{2} m v^2}{\text{area}}$$

$$= \frac{\frac{1}{2} \times 7.85 \times 10^{-3} \times (716.39)^2}{\text{area}}$$

$$\text{area of cube in mm} = 10 \times 10 = 100 \text{ mm}^2$$

$$= 20.14 \text{ J mm}^{-2}$$

(6)

Yes, the frag fragment will enter the passenger area as 20.14 (the kinetic energy) of the fragment is higher than 6 J mm⁻² required to enter the vehicle.

Q9

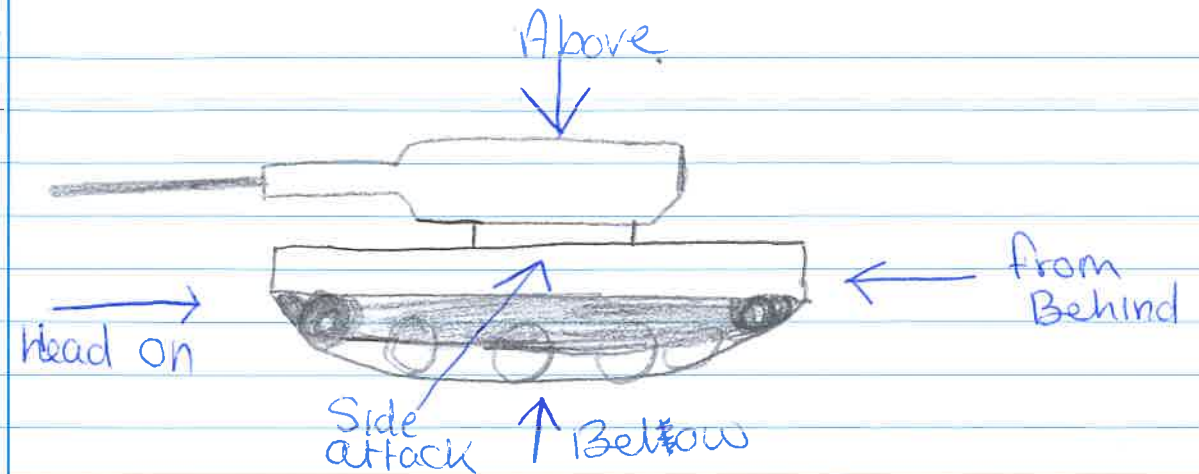
d) five goals of IM Compliance

- ① Reduce Operational Risk
- ② Reduce risk of accidents
- ③ longer life span of munitions
- ④ Fewer defects i.e. (cracking of powder)
- ⑤ less harmful to its environment

a warhead as described in the could become compliant to the five IM goals if the storage container contains the blast if a warhead goes off detonates inside it, or if the storage container could protect the warhead from an external fire. If the explosive fill chosen was ~~an~~ ^{an} ~~complaint~~ ^{considered} to be insensitive and IM compliant then there would be less defects in the fill and would reduce the chance of a burn to detonation and more chance of a burn cook off of the explosive fill.

(10)

Q7



In order to defeat this Tank there are 5 main points of ~~ent~~ ^{attack} to defeat the platform Above, below, head on, from behind or a side attack

Head on

From the brief, it states the tank is thought to be composite, comprising of unknown RHA, Composite and Spall liners.

Two methods of attack for a head on ~~two~~ ^{two} weapon system are ~~evident~~ ^{evident} Kinetic energy ~~long~~ ^{long} Rod Penetrator or Shaped Charge.

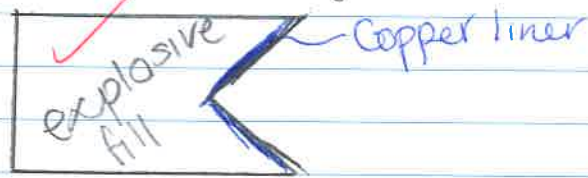
Kinetic energy long-Rod ~~penetator~~ ^{penetrator}



These weapon system use their Kinetic energy to ~~drive~~ ^{drive} through the armour creating a hole the same diameter ~~of~~ ^{as} itself ~~got~~ ^{good} weapon to penetrate armour due to its high velocity and small hole penetration. One main down is if the long-rod isn't ~~a~~ ^{self} sharpening it will form a mushroom style head which will cause the long rod to slow down

details etc of speed/length/dia.

Q7 the shaped charge.



this type of weapon utilises the ~~manoe~~ affect to form a thin jet which penetrates the armour at high velocity.

A shaped charge is usually made up of explosive fill and a copper liner which is cone shaped and a thick wall case.



Copper is used as it is a ductile metal which will form the jet and penetrate the armour.

The main downside to a shaped charge is that if you get uniform detonation then the jet may not form correctly. A wave shaper can be used to ensure ~~uniform~~ the waves hit the copper liner in the correct location and time.

From behind, above and side attack

From the brief it describes the glassis plate, turret and side of the tank to have ERA. ~~As~~ there are two methods to defeat these locations EFP and Shaped Charge.

Q7

As shaped charge has been described in the head on section. this section will evaluate the EFP.

EFP or Explosively Formed Projectile uses a similar concept to a shaped charge but they have clear differences.



An EFP uses an explosive fill with a dish shape liner which will create a slug when detonated.



this slug will punch a hole in the target at high speeds velocities to ~~create~~ and bounce around the cab of the tank.

When look at the EFP and shaped charge side by side and EFP is not as accurate as a shaped charge but can be fired up to ~~1000~~ cone diameters away.

Whereas a shaped charge is very accurate but ~~can~~ to achieve the best effect must only be 2-8 cone diameters from the target.

Q7 From Below

The Brief describes the underneath of the tank as flat and to be tracked not wheeled. Two main attack methods for this location are EFP and or Blast.

As EFP has been described in the previous section, this section will look at blast.

Blast is probably the most simple method as it only requires an explosive fill and a casing.

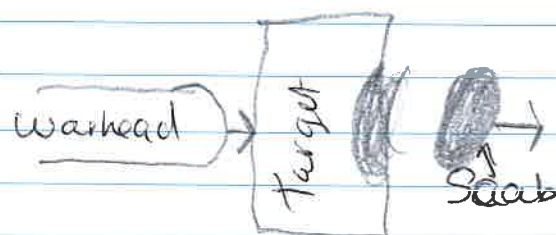


there are a lot of disadvantages to blast as its not very accurate timing is key but it can be very effective if done correctly.

Especially with the flat underbelly of this tank a blast weapon could work very well.

Another attack option could be Hesh.

Hesh or High Explosive Squash head could be used to defeat the tank.



a Hesh round impacts the target and creates a scab on the opposite side of the target which travels at high velocity on the inside of the tank but with the design of the tank having ERA, I would not recommend a Hesh as they are easily defeated by explosively reactive armour. Spall/spacing

With the Design of the Tank in mind in my opinion I would design an EFP or blast warhead to attack the tank from the underbelly to this would either fully defeat the tank or topple the tank rendering it useless.

25



SURNAME: Graham

FORENAME(S): Frazier

12 Pages

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3	Module Code	ALDA6008
4	Date and Time of Examination	11 Jan 2023 12:00 - 14:00
5	Examination Venue	IQ 310
6	Seat Number	009
7	Number of Answer Books handed in	1

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

Q1

a) Propagation ✓

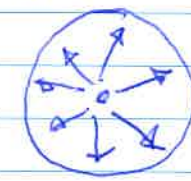
Attenuation ✓

Dispersion ✓

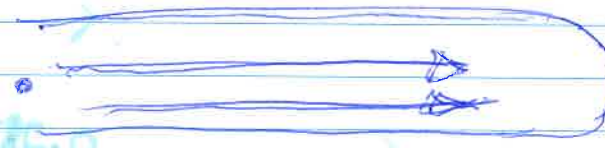
Energy coupling ✓

Damage volume ✓

b) Isotropic propagation is the method of initiation where it ~~travels~~ radiates from the point it propagates ✓



Non-isotropic allows designs for propagation in a desired pathway. ✓



(2)

(2)

Q2)

As altitude increases the density of air decreases therefore reducing the pressure of the shock & blastwave & therefore the transfer of energy. To achieve the same function at 15,000m as 100m you would need to use more explosives, mass. This can be determined using graphs.

Q.3)

$$0.5 \frac{t}{\cos \phi} = 1 \quad \frac{0.5m}{\cos(40)} = 0.65m$$

⑥ $\rho = L \sqrt{\frac{\rho_p}{\rho_T}}$ ✓ $\frac{0.535}{53.5} \sqrt{\frac{17000}{7850}} = 1.16m$ ✗ $0.787m$

$$53.5 \text{ cm} = 0.535$$

The penetrator is suitable, overmatching the targets by roughly double.

3

②

②

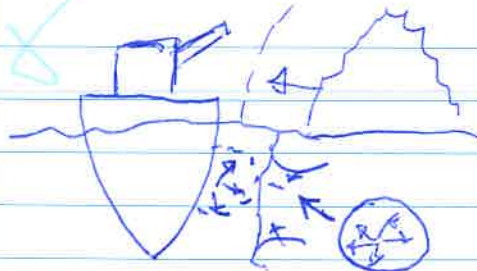
Q4)

Q

Q5

1

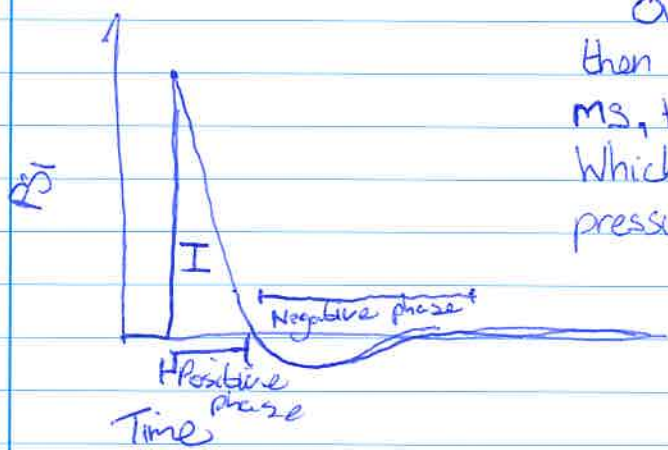
Arholwr yn yr



When an explosion occurs underwater damage can be applied from the shock front & the bubble pulse. However the bubble itself will move towards the rigid body. This will then adiabatically compress & release another shockwave next to the target. There will also be above surface effects which can create a blast wave & plume. Depending on the size the ship can sink into. The bubble will break ^{disintegrate} ~~disintegrate~~ ships from the ~~explosion~~ ^{expansion} & contraction apply stress to the ship!.

⑥ By adding aluminium more energy is released (Q is increased) while ~~the~~ less gas is produced from complete combustion. Additionally the ~~shock wave~~ impulse is also increased ~~thereby~~ generating more damage to structures. ✓

Q5



Overpressure occurs in the PS then this rapidly dissipates in the MS, with into a negative phase. Which then equalises from atmospheric pressure in the MS-S time domain

I: Impulse is the explosive loading/energy which can be dumped into targets. A greater impulse ~~will result~~ over a longer period of time will result ~~out~~ into greater damage on structures & targets due to the force applied. However a negative phase can also deal damage as the pressure in an opposite force will damage targets.

Timing?

Language

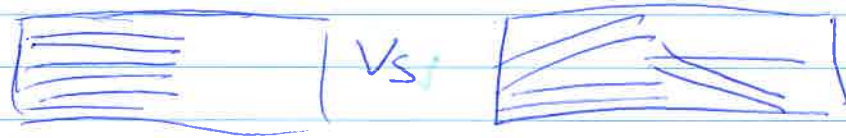
③ Not quite

Q6) Ballistic life is the performance of a propellant within the cartridge ~~within before~~ & during the loading & firing.

b) Factors which effects ballistic life are

- Age
- Impurities
- Distribution

• Distribution & mix: This is if any additives or propellants are no longer neatly distributed within the shell. ✓



• Impurities, cracks, hot spots or contaminants which will affect the transfer of the shock wave or burn propellant will change the performance of.

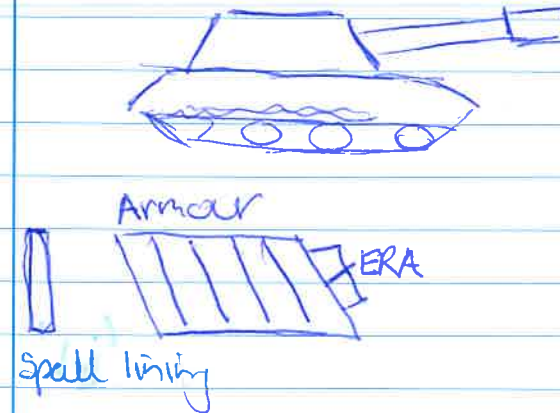
• Age: Stabilizers & nitrogen oxygen will reduce the chemical performance over time by changing the oxygen balance affecting performance & affecting mechanical life.

2
r
f
T, Q

①
composition
degradation -
migrate

①

7



① High Explosive squash Head could be used to remove defensive aids side & explosive reactive armour. HESH will not be able to defeat the target alone due to the following:

- Spaced armour preventing spalling killing the personnel
- Composite armour which will reduce the acoustic impedance
- ERA could prevent hitting & finally
- Shell moves slowly compared to alternative choices < 700 therefore the defensive aid suite. ✓

② EFP → Explosively formed projectiles

However their advantages are easy to manufacture & does not lose performance from sloped armour but can still ricochet > 65° ✓

② EFP

This could penetrate armour roughly 1-2 CD from up to 1000 CD away! They use the Munro-Schardin effect. They are also easier to manufacture compared to shape charges & SABOT long rod penetrators

→ where? side/belly/top.

The disadvantages of EFPs are that they cannot penetrate deep armour, therefore ~~to~~ would need to be aimed at weak points. The belly/crook. Additionally, they have manufacturing requirements based on

- The size of disks ✓
- Density ✓
- Explosive brisance power → not too much else you 'ish'
- ~~Shape~~ shape may fold the disks
- Cone angle → 140°-160° ✓

Overall, the larger the penetration requirements the larger the system. Which can cause supply, manufacture & operational problems. As a larger disc increase weight, increase explosive quantity ✓ Logistics then.

③ Shape Charges.

These can penetrate armour 2-6 times their CD & use the Munroe effect. They are smaller compared to EFPs however have more critical features. ✓

The disadvantage of a SC is that they cannot be used in rifled barrels unlike HESH as this will reduce penetration performance. Additionally SC require a stand-off, & as long as the jet formation can be interrupted this will reduce performance. To defeat SC slope armour & denser materials can be used, as well as composites. ✓

An advantage is it can have better energy coupling & can be design. These will perform better than EFP & yet be a smaller system! ✓

Expense?
Factors?

④ Long rod penetrator

Unlike EFPs SC, & HESH, long rod penetrators & EFP use $K_e = \frac{1}{2}mv^2$ to penetrate. Therefore only the mass & density $P = 1 \sqrt{\frac{\rho_p}{\rho_t}}$ is required to penetrate. The disadvantage is $\frac{1}{\rho_t}$ energy can be loss during transit. h+g

Therefore K_e ~~may~~ will be loss & has the potential to be defeated. A shape charge & HESH can have better energy coupling for a variety of targets.

Unfortunately all systems will have a lower damage volume compared to disks which would be ineffective due to the armour. Unless a ton was placed under it! ie a mine

Long rods may be defeated by ERA by disrupting the rod path. Additionally the rod needs sharp sharpening tips, little-no yaw & must have an optimal L/D ratio. However it will be able to ~~penetrate~~ ^{penetrate} the armour & spill later. Unfortunately if the rod is too stiff it can shatter & also misalign! ✓

8

a

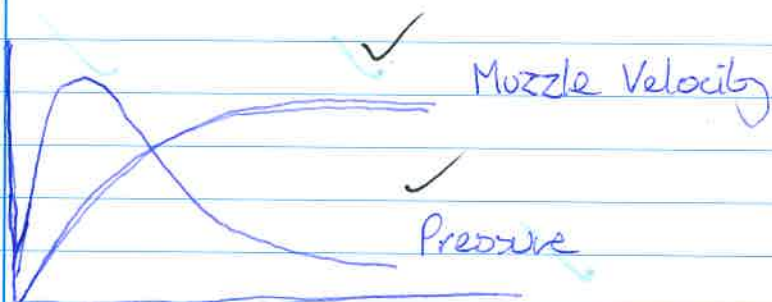


Ballistics have four stages, internal, external, terminal, & penetration (when the bullet interacts with the target).

Internal is the performance within the breech to the muzzle.

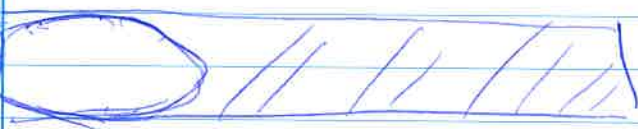
External is the area just outside the muzzle, looking at how gases behave.

Terminal is the performance of the ballistic flight & the last stage penetration/lethality is looking at how the interaction between target & ballistic.



Units?

$$F_v = nRT$$



An peak pressure from the propellant is created, & as the gases expand will move the projectile. This will increase volume & decrease pressure. However as more gases are created a greater force is applied increasing muzzle velocity.

Overall a high temperature, bulk F & constant pressure is desirable.

For spin-stabilisation use a rifled bore!

intermediate

6

c

Storage life: Carbanite or diphenylamine
To absorb nitrogen oxides, & neutralise acids. Must be inert to ~~compound~~ propellant & must be able to mix in propellant matrix
Depends on base gas NG & NE can sometimes not mix with above additives

Barrel wear: talc or titanium oxide
Added as a separate component to create a cool layer of air across the barrel.

Muzzle flash: Metal salts: Potassium nitrate or potassium sulphate
Added to improve oxygen balance to zero to reduce hydro incomplete combustion of hydrogen & nitrogen.

b

Single: Nitrocellulose

Double: Nitroglycerine

Triple: Nitroglycerine

Lowest F value & Q
grain: grain/sticks

Highest F & Q value
Wax based & granular

Intermediate single & double
sticks/wax base

13.5% nitrogen

12.9% - 13.6%

O₂Nitrogen % changes
Carbon nitrogen

single double & triple
oxygen & hydrogen
however all have

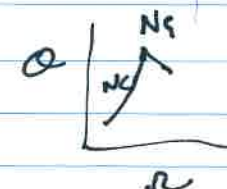
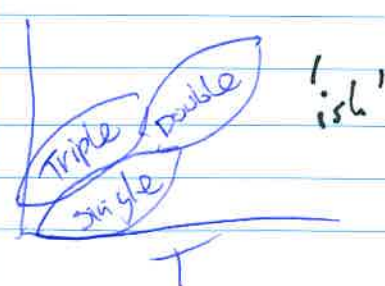
or

Often used in
small arms due to
easy manufacture all
the way to artillery

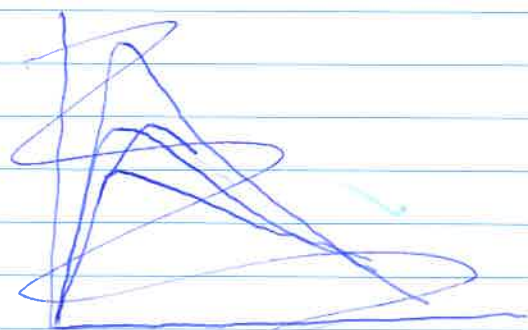
Precision rifles &
SA for high accuracy
& kinetic weapons for
high velocity.

Because these are
flashless & reduce lower
Q & F best for
armor & heavy
platforms to reduce
barrel wear while
achieving performance

Q/F



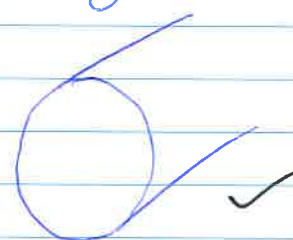
Progressive



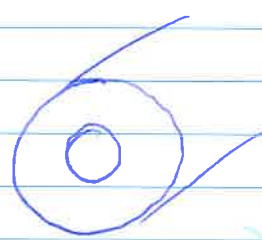
Progressive burn rate increases over time. The surface area increases to increase the burn rate to create greater pressures.

Neutral the surface area remains neutral to produce a constant pressure.

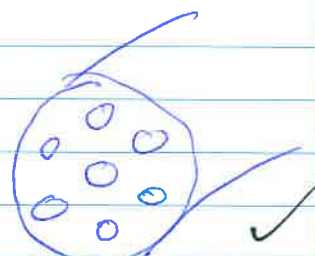
Regressive the surface area decreases as the propellant is burnt. Resulting in a large spike followed by rapid decay!



Regressive



Neutral



Progressive



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

Complete, fold and seal
(see note 2 below)

Examination Answer Books

12 Pages

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SURNAME: PECK

FORENAME(S): MICHAEL

1	Student Number	1907404
2	Title of Examination Paper	Scientific Principles of OME Design
3	Module Code	ACDA 6008
4	Date and Time of Examination	11/01/2023 12 pm
5	Examination Venue	301C
6	Seat Number	
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	1
2	2
3	2
4	5
5	4
6	3
7	15
9	18
Total	50

(Gweler yr ochr arall am y fersiwn Cymraeg)



Section A

Question 1

The 5 principal factors that affect the performance of a warhead are:

Length to diameter ratio, for optimum performance the ratio should be between 23 and 27.

The type of warhead ^{energy coupling} should be matched to the target, i.e. continuous rod/blast fragmentation are better suited to fast moving aircraft than long rod penetrator

①

Must be able to be initiated at the right distance to achieve the desired effect, i.e. air blast used to make use of reflected pressure wave to x8.

①

Should have a well-designed safety and arming unit, so that it functions when required, but doesn't function unintentionally.

energy coupling, dispersion, damage volume, attenuation and propagation

Examiner technique and knowing how much to write in an answer for the marks is lacking here.

agreed

Question 2

Blast is dramatically affected by altitude as the air gets less dense as altitude increases. This means that a much greater mass of explosive would be required at a greater altitude to achieve the same effect. ✓

The greater mass of explosive is required as the explosive will have to do more work to exert the same pressure due to the air being less dense there are less air molecules per unit volume to compress and pass on the pressure wave and as such would affect how well fragmentation is spread in the vicinity of the target. ✓

As this is a fast-moving air target at either altitude it would be unreliable to target with a long rod penetrator and as such a fragmenting blast warhead such as continuous rod would be much more effective.

2

2

Question 3

1. To calculate the actual thickness of the armour (l) you would need the equation as follows:

(See booklet) $l = \frac{t}{\cos(40^\circ)} = \frac{0.5}{\cos(40^\circ)} = 0.65\text{m to 2d.p.}$

2. Assuming the L:D ratio is around 23 to 27 then yes, the penetrator will defeat the target.

Question 4

When an explosion occurs underwater, there is a high peak overpressure produced in a shockwave which can cause damage to a near by vessel, but this does not last very long and despite the high peak pressure will have a low impulse at distance to the target.

3

One of the more significant effects is the bubble pulse which is caused by shrinking or compression of the explosive gases caused by hydrostatic pressure, this compression causes adiabatic heating, which causes expansion. The bubble pulse will migrate towards a hard boundary which can act like a shaped charge against the hull of the vessel, causing defeat.

The other method of defeat is where the explosive gases from the bubble cause the water density to decrease causing the vessel's back to break or the vessel to sink.

Adding aluminium to an underwater explosive increases it's Heat of Explosion (Q), while decreasing the volume of products, largely due to converting CO and H₂O to aluminium oxide which is a solid therefore taking up less volume, a much higher QxV gives a much higher power of explosion compared to TNT, with the optimum being at 18% aluminium. Overall this leads to a greater power of explosion and a much larger pressure wave and bubble pulse as described above.

2

5

Question 5

See booklet for pressure-time curve.

The impulse is the area under the graph for the period of the positive pressure phase (as seen on graph), the impulse is the stage in which the pressure wave pushes outward i.e. doing work, this means the greater the impulse or area, the greater the destructive force produced by the explosive. ✓

4

There is also an impulse in the negative phase of the curve which causes a vacuum effect, pulling people from behind buildings etc.

4

Handwritten notes in red ink, possibly a signature or additional notes.

5

Question 6

✓ Ballistic life of a gun propellant is the life for which the propellant will still be able to project the projectile as desired, this is different to the chemical life which gives a better indication of how long the chemicals in the propellant can continued to be safely stored without risk of incident, say due to acid build up due to water ingress.

Factors which influence the ballistic life are aspects such as: whether stabilisers or plasticizers are contained within the fill allowing the composition to remain effective and not contain voids which could cause shear planes, which in turn could cause detonation on set-back, when firing.

degradation and mechanical
relaxation

3

Section B

Question 7

The thickest armour on a tank is at the front, as it is slope which then increases the distance needed for the penetrator to perforate the armour. The armour on the belly of the tank is flat and generally thinner than the armour at the front and top. High Explosive Squash Head (HESH) could be used, but may not be effective against ERA, which may blast it away as it impacts, pushing the pool of explosive back as it forms thus not allowing a shock to progress through the armour and a scab or spall to form in the inside of the tank, which will cause injury, but not necessarily with lethal effect. A better form of attack would be a shaped charge as the jet formation would be a lot faster (in the region of $10\text{km}^{-1}\text{s}$) and this would not be stopped by a spall lining. These would be most effective at a stand-off, of 4-8 cone diameters, so may be dependant on the thickness/size of ERA, so may be best used on the front armour.

Another lethal mechanism may be use of a buried Explosively Formed Projectile (EFP), this could quite easily penetrate the thinner flat under belly armour of the tank and could be as simple as a buried metal dustbin filled with explosive and the lid inverted to form the shallow dish to form the slug. This kind of device is effective up to 1000 cone diameters away but would not be as effective against the more substantial armour of the front and top. So would only really be effective on a common tank patrol or known route.

A long rod penetrator could also be used as the high length to density ratio (23-27) with a self-sharpening and work hardening tip would make it ideal, though for frontal attack it is likely to ricochet due to the angle of obliquity, though due to its high density and velocity maybe able to penetrate the ERA.

Much more detail required for
35 marks.

SC
EFP
LRP
HESH

15

15

Question 9

- a) Where, $v_0 = \sqrt{2E} \left(\left(\frac{M}{C} \right) + \left(\frac{1}{2} \right) \right)^{-\frac{1}{2}}$, $M=8\text{kg}$, $C=12\text{kg}$ and the Gurney constant = 2700ms^{-1}

Substitution of the above values gives:

$$V_0 = 2499.7 \text{ ms}^{-1}$$

- b) Fragment slow down, $V_s = V_0 e^{\left[\frac{-C_d \rho_{air} A S}{2m} \right]}$,

Where $C_d=1.6$, $\rho_{air}=1.225 \text{ kgm}^{-3}$, $S=100\text{m}$, $m = ((10 \times 10^{-3}\text{m})^3 \times \rho_{steel} = (1 \times 10^{-6}\text{m}^3) \times 7850 \text{ kgm}^{-3} = 7.85 \times 10^{-3}\text{kg}$, $A = (10 \times 10^{-3}\text{m})^2 = (1 \times 10^{-4}\text{m}^2)$, and $V_0 = 2499.7 \text{ ms}^{-1}$

$$V_s = 2450.27 \text{ ms}^{-1} \text{ to 2.d.p.}$$

If the fragment geometry were to change to a sphere of diameter 10mm the volume would decrease and the surface area would increase (assuming you'd use the hemispherical surface), most likely the drag coefficient would decrease. So, without running the numbers I would think the slowdown would be less.

- c) Kinetic Energy Density, KED

$$\text{KED} = \frac{\frac{1}{2}mv^2}{A} = \frac{0.5 \times 7.85 \times 10^{-3}\text{kg} \times (2450.27 \text{ ms}^{-1})^2}{10\text{mm} \times 10\text{mm}} = 235.65 \text{ Jmm}^{-2}$$

As the KED of the fragment is much higher than that required to penetrate the car it would enter the passenger compartment.

- d) The five goals of IM compliance are as follows:

Reduced operational risk – Make the case more impervious to round impact or fragmentation

Reduced storage risk – improved ballistic, but more importantly chemical life

Reduced risk in transport – Better mitigations to fire and impact, as well as better packaging

Safe disposal – ensure the warhead has additives to ensure no off-gassing or acid release which cause detonation in storage etc



Complete, fold and seal
(see note 2 below)

Examination Answer Books

12 Pages

SURNAME: KENRICK

FORENAME(S): PETER

ROBERT

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1	Student Number	1410613
2	Title of Examination Paper	Scientific Principles of HOME Design
3	Module Code	ACDA6008
4	Date and Time of Examination	11/01/2023 12:00
5	Examination Venue	1Q310
6	Seat Number	012
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	2
2	2
3	2
4	3
5	3
6	3
7	10
9.	17
Total	42

1

- 1.) Mass of charge
- 2.) Altitude
- 3.) Shape of charge
- 4.) Temperature
- 5.) Composition of charge.

Isotropic means the propagation is equal in all directions
eg. a sphere



Non isotropic means the propagation is in a single direction



②

②

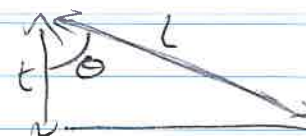
2. Blast waves propagated through air, at higher altitudes the air is thinner and won't conduct the ~~force~~ pressure as well as at ground level.

The designer would need to increase the payload of the explosive to account for the lower air pressure.

2

2

3 1.)



Sata Lath Lou

$$\cos(40) = \frac{t}{L}$$

$$\frac{t}{\cos(40)} = L$$

$$\frac{0.5}{\cos(40)} = L = 0.65 \text{ m}$$

$$2.) \quad L_t = 0.65 \text{ m} \quad \partial_p = 17000 \quad \partial_f = 7850$$

$$L_p = 0.535 \text{ m}$$

$$P = \sqrt{\frac{P_t}{P_f}}$$

2

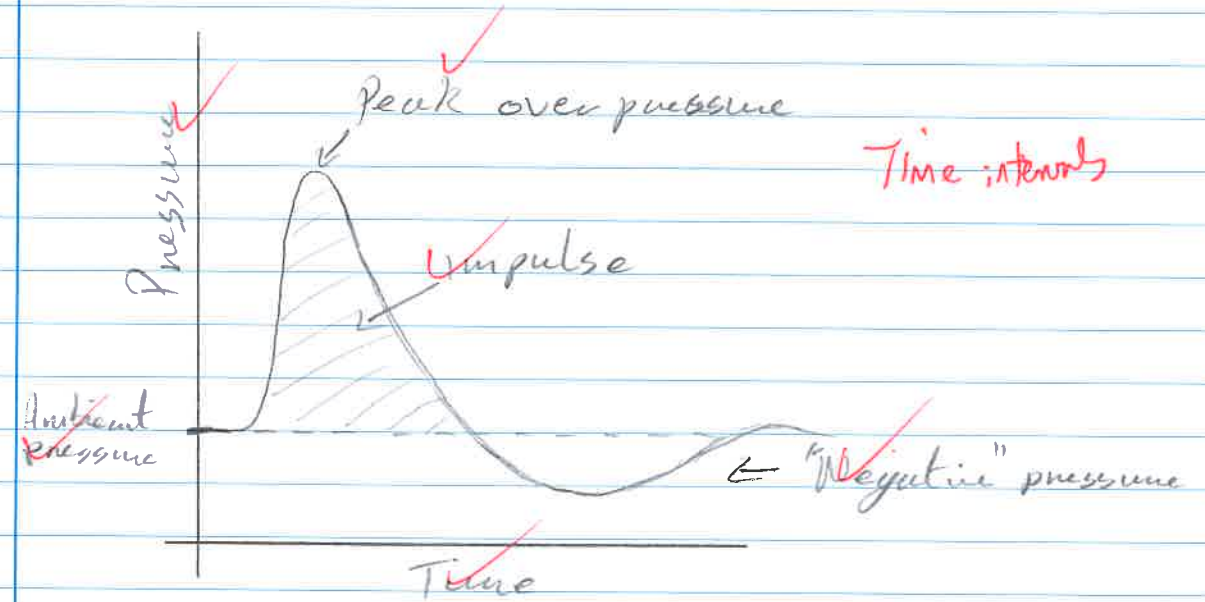
2

4. 1. i) Bubble pulse - a bubble formed by the explosion which expands and contracts, and will rise towards the surface of the ship

1. ii) Fracturing - The ship will be lifted in the middle then experience negative pressure ~~as~~ as it comes down ~~to~~ causing it to fracture in the middle

2. Bubble pulse requires high heat of explosion to cause more powerful explosive expansions in the gas bubble. Adding AL to the explosive increases the H of E substantially.

5)



Impulse is time over which the pressure acts and is represented as the area under the curve.

A short impulse will not have time to effect a target whereas a longer impulse will.

As a target moves away from the explosion the Peak pressure will drop but the impulse will increase.

6. Ballistic life is the time from manufacturing the propellant to when the propellant ceases to act as intended or unpredictably

- Storage environment - Temperature / Humidity
- Composition - Some chemicals will degrade faster than others.

8
7

Under belly attack

Given that the Belly of the Tank is flat, a Shape Charge pointed directly upwards and detonated at the right time would easily penetrate the belly. TRUE!!
As there is no angling it wouldn't be deflected

- Advantages

- Simple
- Lack of angles means less explosion necessary
- If the belly isn't hit, the trucks would be damaged

- Cons

- Would need to be set up in advance
- Antitank measures could disrupt it
- Could be set off by other vehicle, including civilians

Tandem charge

Hitting the ERA before the main warhead hits the Tank would eliminate the ERA's effectiveness so the second stage of the warhead could focus on penetrating the rest of the armour

- Advantages

- The ERA would be used up uselessly
- Secondary stage can focus on penetrating Armour

- Disadvantages

- If the secondary charge is too close to the ERA it will still be affected
- The charge would need to hit at 90° to get maximum chance of penetration

Continued on next page...

7. Cont...

HESR & Long rod penetrators wouldn't be particularly useful here as the ERA would disrupt them, and even if the ERA was taken out, the composite layers and spall lining would prevent a HESR round from being effective as spalling wouldn't form properly & a LRP would have to hit square on for best performance against unknown number of layers which, being composite, would deflect the LRP more.

9. a) $V_0 = \sqrt{2 \times 2700} \left(\frac{8}{12} + \frac{1}{2} \right)^{-\frac{1}{2}}$
 $= \sqrt{5400} \left(\frac{7}{6} \right)^{-\frac{1}{2}}$

$$= 73.48 \times 0.926$$

$$= 68.05 \text{ m/s} \quad \therefore \text{transpose error to next.}$$

b) $V_s = 68.05 \exp\left(\frac{-1.6 \times 1.225 \times A \times 100}{2 \times m}\right)$

$$A = 10 \text{ mm}^2 = 0.01 \text{ m}^2 = 1 \times 10^{-4} \text{ m}^2$$

$$\text{Volume} = 10^3 \text{ mm} = 0.01^3 = 1 \times 10^{-6} \text{ m}^3$$

$$\text{mass (m)} = \text{Vol} \times \text{density} = 1 \times 10^{-6} \times 7850 = 7.85 \times 10^{-3} \text{ kg}$$

$$\frac{-1.6 \times 1.225 \times 1 \times 10^{-4} \times 100}{2 \times 7.85 \times 10^{-3}} = -1.247$$

$$= 68.05 \exp^{-1.247}$$

$$= 19.555 \text{ m/s} = 19.528 \text{ m/s}^{-1}$$

c) $KE = \frac{1}{2} m v^2$

$$\frac{1}{2} \times 7.85 \times 10^{-3} \text{ kg} \times (19.528 \text{ m/s})^2$$

$$= 1.49 \text{ kJ. Joules}$$

$$\text{Area} = 10 \text{ mm}^2 \quad 100 \text{ mm}^2 \quad \text{error in units.}$$

$$\frac{1.49 \times 10^3}{100} = 14.95 \text{ mm}^2 \quad \text{So there would be penetration.}$$

Continued on next page.

For this calculation based on the transposition of the error

(2)

(6)

(2)

9 Cont

b) Fragment geometry

Aspherical fragment would ~~have~~ less slow down as it is more aerodynamic and wouldn't tumble through the air, i.e. less drag.

(2)

d) Insensitisation aims to improve the safety of explosives when ~~not~~ in use.

Fragmentation - to prevent detonation when pierced
→ Better casing to protect the war head in transit

Fire

~~Fire~~ - To prevent the explosive detonating when heated ~~(cook off)~~ (cook off)

→ Different explosives used.

→ design which melts to prevent detonation from pressure build up

(6)

Electro sensitivity - to prevent the device being set off from electromagnetic radiation.

→ EMI protection / Faraday cage.

Impact - to stop detonation by being impacted eg. in a crash.

→ Better packaging / storage.

A list on questions with, accidents, increase bfe X,

(17)



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(see note 2 below)

SURNAME: SLATTERY

FORENAME(S): JOSEPH
ROBERT

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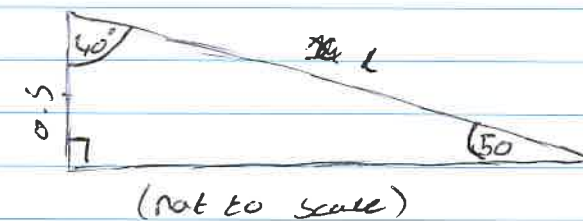
List the numbers of the questions you have attempted	Office Use
1	1
2	3
3	3
4	3
5	3
6	2
7	8
9	7
Total	30

1 a The 5 principle factors that affect warhead performance are: casing thickness, mass of explosive material, Distance to target, type of explosive fill and material of casing.

b Isotropic and non isotropic propagation refers to the blast effect and how it travels through the explosive. ^{But how} Isotropic is through the grain alignment of the material and non isotropic is against it (perpendicular).

2 Assuming no changes to the fuse distance the same warhead would function much better at 100m compared to 15,000m. This is due to the lower air density at 15,000m resulting in you needing more explosive mass to achieve the same effect for a given distance to target.

3 a



$$\sin(50) = \frac{0.5}{L}$$

$$L = \frac{0.5}{\sin(50)} = 0.6527036447 \approx 0.65 \text{ m of armour}$$

b maximum penetration = $\sqrt{\frac{p_{\text{penetration}}}{p_{\text{armour}}}} \times \text{length of penetrator}$

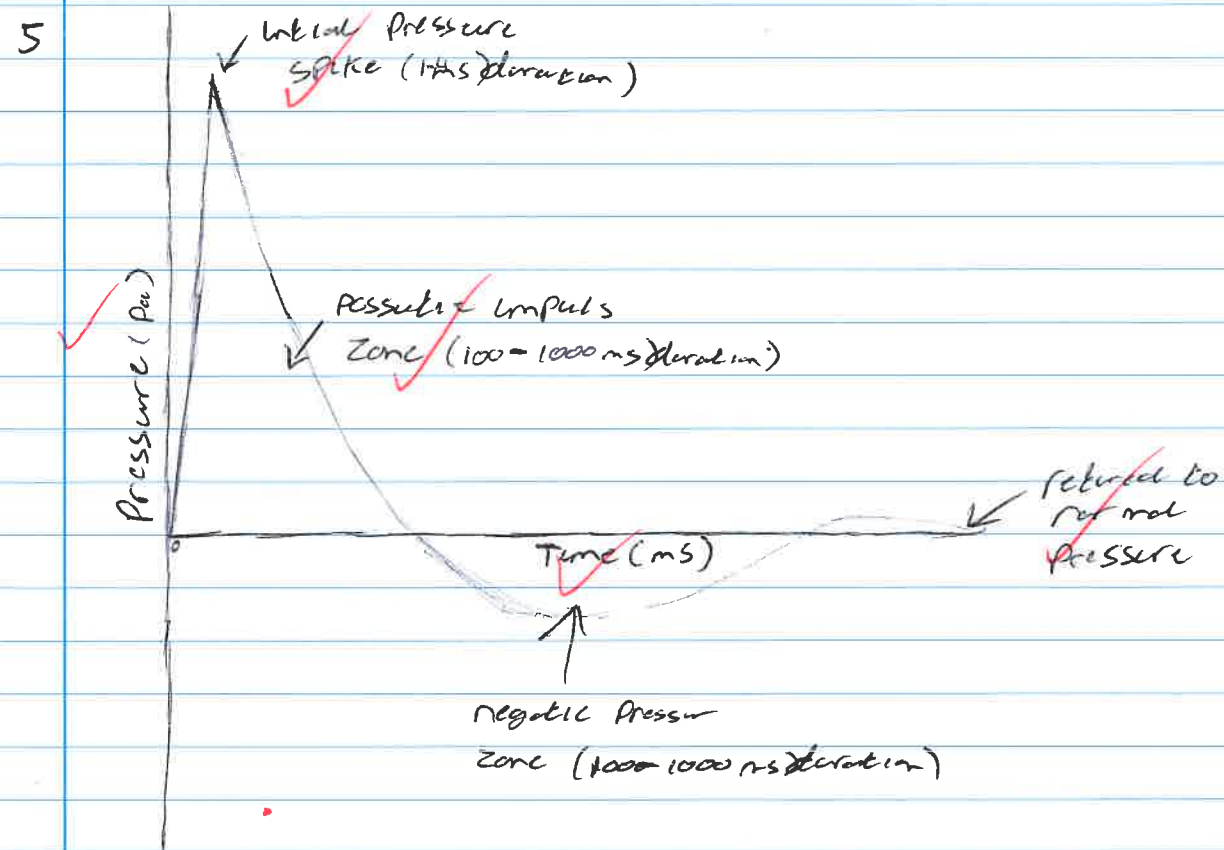
$$\text{max}_p = \frac{17000}{7850} \times 53.5 = 115.86 \text{ cm}$$

$p = \sqrt{\frac{p_i}{p_o}}$

∴ It would be able to penetrate the armour.

4a The two principal methods of damage to a floating ship from underwater explosions are hull penetration caused by the pulsing of the cavitation bubble close to the hull passing through it to create a rupture. The second would be a larger deformation further out the partially displaced part of the ship and on the water causing major structural damage typically referred to as breaking the back of a ship.

b Adding aluminium to an explosive improves its performance by increasing the impulse. This is particularly useful underwater as it increases the lifetime of the bubble pulse allowing it to do more damage.



The impulse is what causes damage therefore the longer the impulse the greater the damage caused.

6a The ballistic life of a gun propellant is its life from the point of being used rather than its whole expected shelf life. This is typically in the order of milliseconds during the standard operation of a gun.

b factors affecting ballistic life are; water or moisture content, material being used, temperature at operation and confinement within the chamber.

7 The first part of designing a defeat mechanism is to identify any possible weak points which could be exploited. ~~targeted~~ with the tank in question targeting the front back or sides would prove ineffective due to ERA the same can be said for the top by the turret. This leads to two possible paths of attack, the tracks and the under carriage.

First is the tracks, as it is known as to ~~whether~~ whether or not the tracks are protected with armour we will assume that only the top half is covered as this is most commonly seen. This is advantageous as without armour tracks are easily destroyed with either a lump of explosive on its own or a ~~explosive~~ explosively formed projectile (EFP). Due to how tracks work if a single section is destroyed the track will no longer function this leaves the tank either spinning on the spot or immobile either way mobility is now zero. This does have the down side of leaving the turret operational so could still fire at you.

7 Cont The under side would be the best point of attack. Although hard to fire at a weapon system planted in the ground ahead of an ~~advance~~ advance could disable the tank when it passes overhead. The reason the underside is a good target is the lack of ERA leaves it more vulnerable, this combined with the fact it is flat ~~the~~ mean any weapon deployed can make perfect 90 degree contact for optimal penetration.

The two weapons systems you would use are an EFP ~~and~~ a shaped charge. The advantage of an EFP is its greater penetration depth meaning it could go through more armour and its larger size would cause greater internal damage to the tank. The down sides are the required stand off distance is greater than a shaped charge so would need to be barraged deeper to get full penetration effect. Its larger size also requires more resources to manufacture ~~the~~ resulting in you possibly being able to make less.

The advantages of a shaped charge are its shorter stand off so doesn't need to be barraged as deep making for quicker deployment and therefore lower material cost. The disadvantages are the smaller size leads to less penetration and lower internal damage so would need to be more strategically placed to target key systems.

aka

$$V_0 = \sqrt{2E \left(\frac{m}{2} + \frac{1}{2} \right)^{-\frac{1}{2}}}$$

$\sqrt{2E}$ is already given.

$$V_0 = \sqrt{2 \times 2700 \left(\frac{4}{12} + \frac{1}{2} \right)^{-\frac{1}{2}}}$$

$$V_0 = 68 \text{ ms}^{-1}$$

b $V_s = V_0 e^{\left(\frac{-\text{Cd} \rho A V_0^2}{2m} \right)}$

$$V_s = 68 \times e^{\left(\frac{-1.6 \times 1.225 \times 10^{-4} \times 100}{2 \times (8 \times 10^{-6}) \times 7850} \right)}$$

$$V_s = 19.5 \text{ ms}^{-1}$$

$$\text{Area of fragment} = 0.01 \times 0.01 = 0.0001 = 1 \times 10^{-4} \text{ m}^2$$

$$\text{mass of fragment} = \text{volume} \times \text{density} = 1 \times 10^{-6} \times 7850 = 7.85 \times 10^{-3}$$

$$\text{Volume of fragment} = 0.01 \times 0.01 \times 0.01 = 0.000001 = 1 \times 10^{-6} \text{ m}^3$$

bi If the fragment were a sphere the drag coefficient would change along with the mass of the fragment due to spheres having lower volume than cubes.

c $K_E = \frac{1}{2} m v^2$

$$K_E = \frac{1}{2} \times 7.85 \times 10^{-3} \times 19.5^2$$

$$K_E = 1.49 \text{ J}$$

Given the total kinetic energy of the fragment is 1.49 J it would not exceed the 6 J mm needed to penetrate into the car.

9d IM compliance is the insensitive munitions standard that should be met by all in service weapons. Its goals are that a system ~~is~~ is inert until needed to be used. The system can only be used by the intended user. The system should be safe to store and handle without any additional safety equipment. The system will not produce long term environmental damage.

for a weapon such as this these can be achieved by having an arming system that only becomes active after being dropped by the aircraft meaning it is safe up to that point.

If the system is deployed by being used into the aircraft only the pilot will be able to use the weapon. without being armed it would be safe to move and store. A modern fill would prevent environmental damage by not containing materials such as lead.



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