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11

12 Pages

1 of 2

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.
3. The answers must be legibly written. The Examiners can either ignore illegible script or have it typed and the expense of typing charged to the candidate.
4. Write your answers in ink.
5. Begin each answer on a fresh page. Do all rough work in the answer book and cross it through.
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1	Student Number	1810348
2	Title of Examination Paper	ACDA 6008 SCIENTIFIC PRINCIPLES OF OME DESIGN
3	Module Code	ACDA 6008
4	Date and Time of Examination	5th MAY 2022 1100
5	Examination Venue	FF001
6	Seat Number	—
7	Number of Answer Books handed in	2 1 of 2

List the numbers of the questions you have attempted	Office Use
1	4
2	4
3	2
4	3
5	2.5
6	3
7	2.5
9	2
- Total	62.5%

- Paper 2

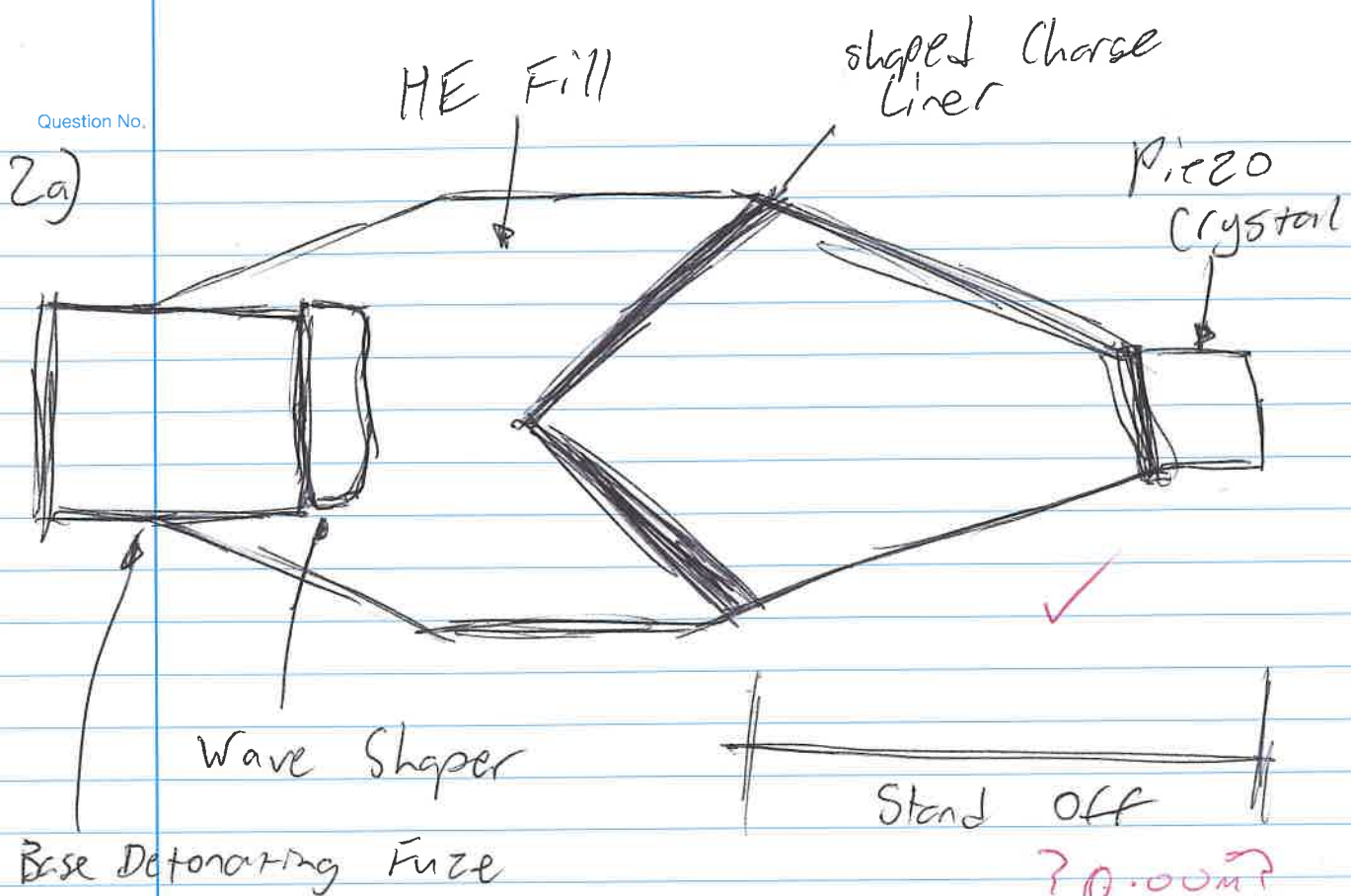
Q1) a) This will depend on the type of warhead. For example fragmentation. The fragment size, material density and fragment mass and velocity will all play a part in the penetrative effects of a fragment. A tungsten fragment for example will be more penetrative than an Aluminium fragment if both are travelling at the same speed and are all of the same size. Material hardness (measured in Rockwell) may also play a part in fragmentation penetration. Ideally you want the fragment to be harder than the target material.

Q1
=4

b) A warhead needs to have a high density pressed explosive that is physically pressed to a high density. A velocity of detonation that is high is also required. For example Comp B has a lower VOD than OKFOL (95% HMX, 5% WAX). Comp B is approx 7000 m/s, OKFOL is approx ~~8500 m/s~~ 6500 m/s.

Factors which detriment can include case thickness, if the fragmentation is natural or controlled, if it's natural the explosive needs to expend more energy to overcome the confining stresses of the casing.

2a)



Schematic of PG-7 (not to scale)

The PG-7 is a good example of a shaped charge system. The PG will contact the tank, the piezo crystal at the tip then sends an electrical signal to the fuze to initiate, this initiates the HE Fill which with a wave shaper "shapes" the shockwave to interact with the cone. The solid copper cone liner then under high temperature and pressure performs hydrodynamically and forms into a copper jet which is capable of perforating 300-400mm of Rolled Homogenous Armour.

The tank can defend itself through the use of Explosive Reactive Armour systems of the

future use of electric reactive armour systems, both of which disrupt the formation of the shaped charge jet. Other methods include Bar armour which prevent the piezo crystal impacting the tank and also shorts out the cone which carries the signal to the fuze thus rendering it blind, this however does not work against the Iranian "Nada" variant of PG which relies on the cone creating a short circuit to function.

In order to overcome these defence systems the use of tandem warheads can be used and there is a PG-7 VLT which is the tandem shaped charge variant.

Q2
=4

Q3)

~~$P = 350 \text{ MPa}$~~
 ~~$\text{Area} = \frac{\pi D^2}{4}$~~

Set bullet pressure is 350 MPa

Calibre of shell is 155 mm

Assume pressure acts on Calibre of shell at 155 mm

$$\text{Area} = \frac{\pi D^2}{4} = \frac{\pi \times (155 \times 10^{-3})^2}{4} = 0.01877 \text{ m}^2$$

Pressure = Stress

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} \therefore \text{Force} = \text{Stress} \times \text{Area}$$

$$\text{Force on shell} = (350 \times 10^6) \times 0.01877 = 6.6 \times 10^6 \text{ N} = 6.6 \text{ MN}$$

$$a = \frac{F}{m} = \frac{6.6 \times 10^6}{40} = 165000 \text{ m/s}^2$$

$$165000 \div 9.81 = 16819.57 \text{ g}$$

This seems absurdly high ???

Q3b) Governing section is projectile itself therefore the mass forward of it should be 0. (according to Marks explanation ??)

It however the question is, guess the mass of the shell casing in going to assume a distance of governing section of 750 mm and steel at a density of 8250 kg/m³

~~$\text{Area} = \frac{\pi D^2}{4}$~~

Area of cylinder cross section

$$A = \frac{\pi (D_2 - D_1)^2}{4} = \frac{\pi (155 - 135)^2}{4} = 3.1415 \times 10^{-4} \text{ m}^2$$

Volume of cylinder = Ah $F = P \times \text{Area}$

$$= 3.1415 \times 10^{-4} \times 780 \times 10^{-3} = 2.356 \times 10^{-4} \text{ m}^3$$

$$\begin{aligned} \text{Mass} &= \rho \times \text{Volume} \\ &= 8250 \times 2.356 \times 10^{-4} \\ &= 1.9437 \text{ kg} \end{aligned}$$

It's a bit lower than what I would expect but is guesstimating the shell as a cylinder.

- Q4) a) The wave initiates out in all directions at the same speed and pressure ✓
- b) The corners and radii of it. The ~~curvature~~ curvature of the charge the standoff of the charge from the target material - The Monroe effect? ✓

Q4

=3

3

- Q4c) The aluminium adds fuel to the detonation ✓ therefore increased impulse and increased brisance to improve bubble pulse effect.

Q5)

Blast wave ✓

The blast wave interacting with the structure in both positive and negative phases. makes the structure shake thus affecting what is inside it ✓

Q5

=2.5

3.5

Internal Effects ✓

Blast wave causes internal issues such as internal fragmentation or incendiary effects internally ✓

Response

Structure fails and crashes down and is destroyed

Q6a) How long the propellant is viable before ballistic performance is reduced below specification.
- lazy propellants.

b) Heat cycling of propellant, stabilizer consumption, things to prevent it going auto catalytic combustion. Theatre propellants are used in for example arctic or desert.

Q6
=3

Q7)

a) Attack of an aircraft. An aircraft is generally a light skinned structure there are many delicate components such as control surfaces and turbine engines which can be rendered inoperable to defeat the aircraft. In order to achieve this a blast fragmentation warhead is best utilised. Blast effects are reduced at altitude therefore engagement altitude is a consideration when designing a system. For example a ~~MANPAD~~ manPAD may have an engagement distance of 7km and an engagement altitude less than ~~10,000~~ 10,000 feet. A full surface to air battery may have an engagement distance beyond visual range and at up to 60,000 feet. Therefore the delivery system needs to match these and the warhead also needs to match these. For example SA7 "Grail" has a warhead of roughly 3kg. SA15 "Gauntlet" has a warhead of 15kg. SA15 is a full SAM battery and SA7 is a MANPAD.

Because of the reduced effects at altitude fragmentation is the preferred lethal mechanism. This can be carried out a number of ways. Natural fragmentation is where the casing breaks apart, normally at grain boundaries within the material. This is good because no additional machining is required however it can be pot luck on fragment size and shape.

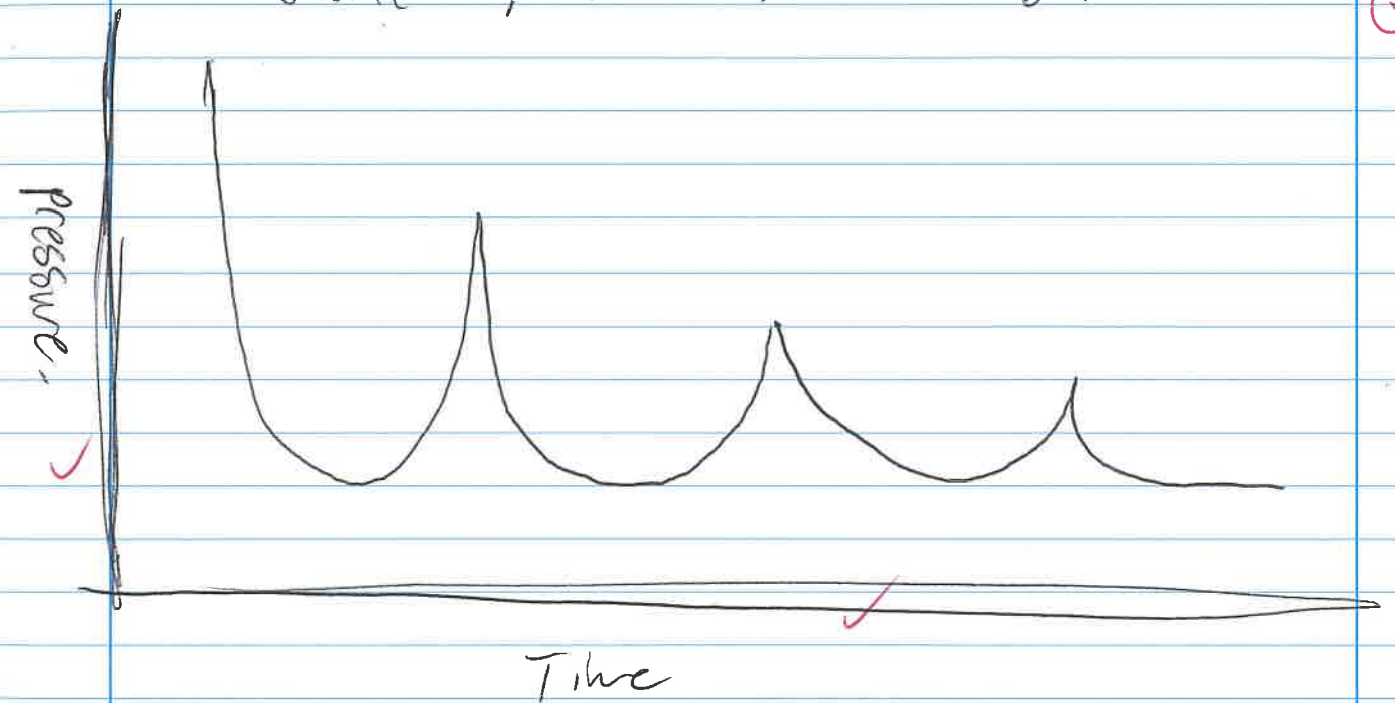
The next method is controlled fragmentation where the inside of the casing is machined and scored thus introducing stress raising features into the casing and controlling where it will break apart. The next method is a fragmentation liner where fragments line the casing and are ejected at velocity or in the case of continuous rod create a ring to "catch" the aircraft and tear it apart. Examples of this for example SA7 has a scored casing controlling where it breaks apart. Bloodhound had a continuous rod fragmentation warhead and the S300 which downed MH17 had a "bowtie" shaped fragmentation liner in its warhead.

The fragmentation scattered by the warhead creates a damage volume, the missile doesn't need to hit the aircraft to disable it but create a volume of fragments the aircraft can pass through to disable equipment such as engines and cause damage to the airframe.

Q7b) A submarine requires weapon systems such as torpedoes and depth charges.

The main lethal mechanism is blast the creation of a bubble pulse next to a submarine can cause it to become unstable in the water, pressurised compartments can be affected, valves and pipes can rupture and crews can become disoriented.

The bubble pulse shown below



This is caused by the explosion creating the bubble initially and overcoming the pressure of water as the bubble expands the water then overcomes the gas pressure and compresses the gas which then in a similar way to a diesel engine heats up and expands again and this repeats until energy is balanced. This can cause a significant amount of shock and vibration in the submarine.

Q7c
=12

Q7b
=13

Heavy weight torpedoes carry blast warheads in excess of 400kg of explosives to create a significant blast effect. Light weight torpedoes carry an additional warhead which is that of a shaped charge warhead which is able to penetrate the hull of the vessel to then be able to send a follow through blast charge to disrupt the submarine. Blast internally of the submarine can cause significant damage as what happened during the Kursk disaster however the sealable compartments worked and kept crew alive after the initial explosion. Typical shaped charges may be in the 50kg range for such a target type. For example Spearfish.

Q9a) ~~Monoprop~~

Liquid monopropellants are propellants which when either exposed to oxygen or passed over a catalyst decompose rapidly. Monopropellants are normally used for reaction control systems in spacecraft to adjust altitude for docking or for example post the Columbia disaster they were used to flip the shuttle so heatshields could be inspected. Typical monopropellants can include hydrogen peroxide with a manganese based catalyst. Such monopropellants were actually used to propel the ME163 comet during WWII. Such materials are considered to be hypergolic.

Bi-propellants are where a fuel is mixed with an oxidiser and the combustion takes place in a chamber and gas is produced. Such ~~bi-propellants~~ bi-propellants can include Liquid Hydrogen and Liquid Oxygen, Fed running nitric acid, and RP1 - a form of kerosene designed for rocket applications which is mixed with liquid oxygen. Such uses are heavy lift rockets such as Falcon 9 from Space X or the Apollo Saturn rockets which used Liquid Hydrogen and Liquid Oxygen.

Q9a

= 9

Q9b) Both solid and liquid propellants have advantages and disadvantages.

Liquid propellants can be throttleable in that as the energy required to accelerate diminishes the engine can be reduced in power to conserve fuel.

~~The hazards can also be~~ The liquid propellants can also be started and shut off and restarted on demand therefore if an issue did arise the engine can be shut down entirely. Reliability is also another advantage. The technology is so proven now that high reliability is achievable. Disadvantages come in the form of complexity. The engines themselves require a huge amount of plant to keep running such as turbo pumps, turbo compressors, turbines, and associated control and instrumentation. Another area is hazard, these materials can be cryogenic which creates specific hazards and can have detrimental effects on materials.

Solid propellants offer advantages which include cheap and easy to manufacture, no complex plant to make use of the energy there, can provide a huge thrust to weight ratio and huge specific impulse. Disadvantages come in that greater levels of quality control are required to inspect grains to keep reliability high. ~~they~~ they can have a limited shelf life as materials like stabilisers get consumed whilst stabilising the propellant. They burn quite dirty compared to

Liquid propellants releasing a lot of nasty substances to atmosphere, particularly Ammonium perchlorate based motors. It can't be throttleable like liquid propellants and in the event of an issue it cannot be shut down.

9c) Grainizing is where additives are added to the propellant to plateau the burn rate of the motor. This can be advantageous if the use of the motor is to ascend through altitude as the air gets thinner the thrust required to overcome it reduces therefore reducing the burn rate will increase the duration of the motor. Disadvantages are it may have an effect on the shelf life of the motor and interact with other materials creating an additional hazard. Specific impulse may also be reduced due to the additive reducing the burn rate of the motor.

9d) The use of a rubbery composite means the fuel and oxidizer of the motor can be bound together, it can be case bonded to the rocket motor reducing voids and hotspots thus improving reliability. It can either be cast in the rocket motor or extruded to create a grain. It can expand and contract thus reducing the chance of cracking during heat cycling or whilst in use. It can however affect specific impulse adversely as it lowers the energetic content of the

motor, and may interact adversely with other materials in the motor and may itself ~~off gas~~ offgas producing an additional hazard in the motor casing.

Q9d
=2

Q9
d

2

Q9
TOTAL

9+8+2+2