



## 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.
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.
6. No part of this book is to be torn out; it must be handed in complete.
7. If more books than one are used, fasten them together using the tags available from the invigilator(s).
8. Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.

|   |                                  |                                     |
|---|----------------------------------|-------------------------------------|
| 1 | Student Number                   | 1810444                             |
| 2 | Title of Examination Paper       | SCIENTIFIC PRINCIPLES OF ONE DESIGN |
| 3 | Module Code                      | ACDA 6008                           |
| 4 | Date and Time of Examination     | 05/05/22<br>11:00                   |
| 5 | Examination Venue                | FF001                               |
| 6 | Seat Number                      |                                     |
| 7 | Number of Answer Books handed in | 1                                   |

| List the numbers of the questions you have attempted | Office Use |
|------------------------------------------------------|------------|
| 1                                                    | 4.5        |
| 2                                                    | 4.5        |
| 3                                                    | 0.5        |
| 4                                                    | 5          |
| 5                                                    | 3          |
| 6                                                    | 3          |
| 7                                                    | 29         |
| 9                                                    | 31         |
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|                                                      |            |
|                                                      |            |
| Total                                                | 80.5%      |

1. ~~As per~~ penetration of a target is affected by mode of penetration (hydrodynamic), or velocity and angle of the round relative to the target, the mass and length to diameter ratios of the warhead. 1.5

4.5

Fragment velocity as per Gurney's equation is related to the ratio of mass of case and mass of charge as well as the gurney energy of the explosive material which is proportional to its velocity of detonation. The density of the medium through which fragments travel can have a detrimental effect on the fragments performance: a more dense medium will slow fragmentation quicker.

Q1 = 4.5

$$\text{Gurney Velocity} = \sqrt{2E} \left( \frac{1 + M_r(1 - M_c)}{1 + M_r} \right) c$$

a higher velocity of detonation & therefore higher gurney energy will increase fragment velocity  
a denser explosive (more massive) will increase the fragment velocity

- 2 a shaped charge jet (scj) collapses a liner into a long <sup>SCJ</sup> penetrator (20% of mass) and a slug. The penetrator hydrodynamically deforms the armour creating a narrow channel, up to about 8 cone diameters deep, through the armour which, theoretically, the slug follows to increase the behind armour effect. <sup>typ speed ca 8-2 km/s</sup>
- A tank defends itself by increasing armour thickness, using non-explosive and explosive reactive armours and using angled panels.
- A warhead may contain two shaped charges; one to take out the tank's defences & the second to penetrate the tank's armour.

3<sub>1</sub>

$$F = ma$$

$$a = F/m$$

$$a = \frac{600 \times 10^6 \text{ Pa}}{40 \text{ kg}}$$

$$a = 1.5 \times 10^7 \text{ ms}^{-2}$$

$$a = \frac{18548 \text{ N}}{40 \text{ ms}^{-1}}$$

$$a = 464.95 \text{ ms}^{-2}$$

$$a = 464 \text{ ms}^{-2}$$

$$\text{force in Newtons} = 1 \text{ Pa/m}$$

$$F = \frac{350 \times 10^6}{\pi (155/2)^2} \quad F = P \times A = A$$

$$F = \frac{18548 \cdot 755}{\pi (155/2)^2} \text{ N}$$

Q3  
= 0.5

3<sub>2</sub>

- 4 a centrally initiated spherical charge will create a spherically radiating blast wave of decreasing peak pressure with distance from the centre of the charge. The peak pressure will be the same at all points in the blast wave

blast waves of complex shaped charges will also be more complex and will interact with one another to create triple points and mach stem



for example the sides and ends of a cylinder will each create a wave and as those waves expand and reach

each other they merge <sup>constructively</sup> to create even larger pressures along the line where they meet

Adding aluminium to an underwater explosion increases the total energy released and over a longer time scale to increase the impulse of the over-pressure event and the volume of gas inside the bubble

- 5 direct energy - impact of discontinuity of the shock wave hitting the building causes movement, (relocation) and loading

indirect energy - diffraction loading where pressure is created on the far side of an object due to the bending of shockwaves around it

- dynamic loading which is the pressure caused by the fast moving wind after the shock wave which picks up debris causing secondary fragmentation damage

Q5=

3

Q5=

5

6 The amount of time the propellant survives before undergoing irreversible chemical changes (such as the loss of approximately 50% of the stabilizer material) that affect its performance detrimentally

- loss of stabilizer which allows breakdown of nitrocellulose
- environmental conditions i.e. moisture ingress & temperature cycling

Q6=

3

7a) Blast can be used against aircraft, however external blast is generally effective, ~~at~~ high altitudes in particular. At high altitudes the air is less dense and so the shock is transmitted less efficiently. At any pressure, in air, the shock from a blast wave reduces quickly with distance from origin so if the blast is not very close to the target its effects are quickly dissipated to a level which will not cause significant damage.

Internal blast can be effective if the warhead penetrates the target & detonates inside. It is difficult, however, to hit fast-moving targets for accurate penetration.

Systems like rapier use internal blast effectively. Therefore fragmentation, either natural or controlled, is more suitable for the attack of an aircraft.

The lower air density at high altitudes means the deceleration of the fragmentation is lower and the danger volume is increased.

Using a fragmenting warhead also means the weapon can be designed to 'miss' the target and detonate externally. The velocity of the aircraft <sup>(v)</sup> can be used to increase the dynamic velocity of the fragments and increase their effect. ~~EXAMPLE?~~

$$V_d = \sqrt{V_0^2 + V^2}$$

Directed energy warheads can also be used to attack aircraft but suffer from requiring to 'hit' the target to achieve full effect. They can be combined with blast - to create an internal blast effect, or with a fragmenting warhead. ~~EXAMPLE?~~

Fragmenting warheads can use natural fragmentation where the case is broken up by the shockwave. There will still be an element of blast but the warhead can be tuned to maximise the energy going into fragmentation by altering the ratio of masses of charge and case and the density of the

case material. This leads to relatively small explosive components in the warheads 5-10kg typically.

The fragmentation can also be pre-formed, such as expanding rods, to ensure fragments of the right velocities and sizes are formed to maximise the energy coupling to the target. *EXAMPLE?*

The size and velocity of natural fragmentation can only be controlled to an extent & will result in a Bell Curve of sizes.

To attack soft skinned aircraft relatively small fragments are required which will have enough energy to penetrate and still cause behind armour effects. In intended to 'miss' missiles a large volume of fragmentation is desired to cover a large area with sufficient density to almost guarantee hitting the target with enough fragments to cause damage.

Therefore rockets are effective with fragmenting warheads (especially with some in-flight control) as they have an overall small size for a small explosive component but with versatile options for fragmentation. Cannon or directed energy are more effective close to targets but are difficult to aim onto an aircraft moving at considerable speeds. *LAZAR + STARS - CAR*  
*A.M.I.N.*

Aircraft have several vulnerable areas which can be targeted by directed energy warheads to increase their effectiveness. Or detonation of the warhead in the aircraft can be used to cause widespread damage to multiple systems simultaneously.

7b) For submarines, directed energy and blast warheads are more effective than fragmentation. Water is very dense which quickly slows down natural & controlled fragmentation reducing its effective range compared to that in air.

directed energy warheads can be used to breach the first hull of double-hulled submarines and then followed up with an internal blast warhead or a second directed energy attack.

An underwater blast warhead attacks submarines through two mechanisms; the initial shock wave & subsequent bubble energy. As water has a very low compressibility, the peak shockwave from an explosive is significantly larger than in air and travels much faster. It can impart a large shock into the submarine which can cause structural damage internally & externally; buckling the hull, damaging internal equipment & weakening rivets. This is then followed by an oscillating bubble of hot gas from the explosion which initially expands beyond hydrostatic equilibrium so the external pressure causes its collapse, again over-shooting equilibrium creating an oscillation. This causes surrounding water to flow and the bubble migrates into the nearest rigid surface i.e. the submarine. The collapse of the bubble on the submarine creates a very efficient energy coupling and the energy passes to the submarine causing more damage. Coupled with a shaped charge this creates three modes of damage in a single warhead. The use of a shaped charge also decreases the total explosive required by the warhead but requires a more accurate positioning of the warhead. The amount of explosives required to attack submarines is 10's to 100's of kg which means large

devices with thin, light casings - to reduce/minimise the energy lost to the fragmentation following case break up.

Using only blast, the devices can be very simple, like depth charges, or more complex like guided torpedoes. Coupling blast with shaped charges requires the use of guided missiles to ensure the shaped charge jet is at optimal distance and orientation.

Submarines tend to have relatively small volumes which means multiple critical systems are located near each other for targetting with guided weapons.

Q7b  
=14

9a) liquid monopropellants, such as hydrazine, can burn in atmospheres with no external oxygen as they contain both fuel and oxygen. They can be homogeneous; where fuel and oxygen are contained in the same molecule, or heterogeneous where two types of molecule (one fuel & one oxidiser) are mixed together. Monopropellants all require an external ignition method to start the burning. Monopropellants tend to have lower specific impulses and so are primarily used in smaller systems.

Bipropellants consist of two separate liquids, one the fuel eg. hydrazine and one the oxidiser eg. liquid oxygen. They can be classed as cryogenic or non-cryogenic depending on their storage requirements. Cryogenics are almost exclusively used in space travel. Cryogenic and non-cryogenics are never mixed in a cryogenic fuel is always used with a cryogenic oxidiser. Bipropellants can also be split by initiation method; whether or not they are hypergolic. Some fuel/oxygen mixes will initiate on contact others require an external stimuli. As bipropellants have higher specific impulses they are used in large systems such as space rockets and ICBNs.

9b) disadvantages of liquids: require complex motor systems  
toxic chemicals  
can require 2 storage solutions  
may require cryogenic storage temperature  
lower density  
advantages of liquids: higher specific impulses  
burn rate can be controlled  
burn can be stopped  
low smoke outputs

9a

10

Q9a=  
10

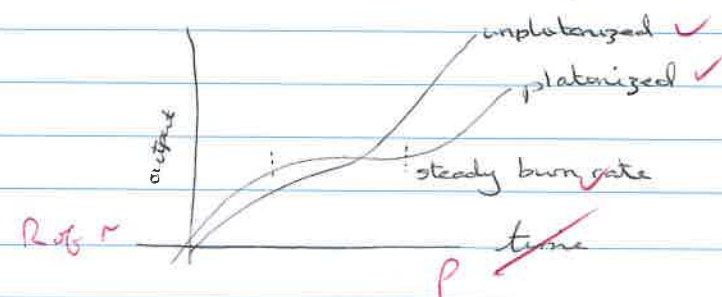
Q9

10

Q9b  
=10

amount of fuel not limited by size of motor ✓  
 relatively cheaper ✓  
 allows cooling of nozzle ✓

- 9c) platonizers control the output to generate a more even burn rate for the majority of the burn & ✓  
 reduce fluctuations from manufacturing tolerances and ✓  
 allow 100% burn for longer at lower barrel temperatures ✓



The addition of a platonizer reduces the overall explosive component & therefore energy created. They also increase the smoke outputted during burning.

- 9d) rubbery composites can be cast & extruded into complex geometries, have a lower sensitiveness to external stimuli, are easier to manufacture, high specific impulse, high glass transition temperature, lower temperature of ignition.

disadvantages: cannot be platonized ✓  
 smoky burn ✓  
 cannot be pressed into casings

Q9

Q9c

=4

4

Q9d

=7

Q9

TOTAL =

(10+10+7+4)

=31