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High Power Rocketry

Certification Procedures

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INTRODUCTION

High Power Certification provides model rocket flyers a means to progress to larger rockets using more powerful motors. It aims to promote good modelling practices and safe operating procedures.

This procedure does not replace local, state, and federal laws, and additional permits/licenses for the use of high power motors may be required.

This study guide is available to all ARA members on request. A small fee is charged to cover printing and binding costs, or the document can be downloaded free from the ARA web site.

IMPORTANT - A ONE YEAR LAPSE IN MEMBERSHIP VOIDS CERTIFICATION AT ANY AND ALL LEVELS.

CERTIFICATION IS ONLY VALID WHILE BEING A CURRENT MEMBER

ARA CERTIFICATION LEVELS

The following table lists the levels available to ARA Members and a summary of the requirements:

Level	Requirements	Flight Test	Certification will allow you to fly: (in addition to existing certification)
1	ARA membership. Permits at state level. Experience in flying model rockets.	Fly an H or I powered rocket successfully.	H & I motors Total launch impulse up to 640Ns
2	Level 1 certification. ARA membership. Permits at state level.	Level 2 Exam. Fly a J, K, or L powered rocket successfully.	J, K, & L motors Total launch impulse up to 5,120Ns
3	Level 2 certification. ARA membership. Permits at state level.	Project file. Fly a M, N, or O powered rocket successfully.	M, N, & O motors Total launch impulse up to 40,960Ns

MINIMUM REQUIREMENTS FOR HPR CERTIFICATION

A person seeking HPR Certification must be over 18 years of age. A current Drivers License, Passport, or Birth Certificate are acceptable to use as proof of age. It is required and assumed that the individual applying for certification has had sufficient experience building and flying model rockets. (Note: The term 'sufficient experience', means that the individual has successfully flown more advanced model rockets in the mid-power range. Mid-power meaning E to G impulse class.)

The individual must be a member in good standing with the Australian Rocketry Association (ARA) at the time of certification. If requested by the ARA Section Delegate, proof of membership must be shown prior to the certification attempt.

Motors used for certification attempts must be currently certified by a national organization (e.g., NAR, TRA, CAR, ARA) with a recognized certification program. Single-use, Re-loadable, and Hybrid motors may be used. The rocket must be launched in a single-motor configuration.

EXEMPTIONS

ARA members who are members of a foreign rocket club such as NAR or Tripoli and are level 1 certified or above will have their certifications honoured at the ARA level via administrative means. Upon completing the identification procedure the member shall attach proof of current foreign membership certification (e.g.; photocopy of NAR or consumer confirmation card) to ARA headquarters with a request their certification level be updated.

DUTIES OF INDIVIDUALS

ARA SECTION DELEGATE

The Section Delegate is a section member who performs official administrative duties in relation to certifications and other official business of the ARA, who is delegated this authority by the section committee. A section may have several section delegates to give flexibility.

The ARA Section Delegate must approve all certification attempts (due diligence on behalf of the ARA). Their task is to ensure that the certification attempt is genuine and to ensure that the necessary records are maintained. The ARA Section Delegate can liase between the member, the ARA section committee members, and Flight Test Officer to find the most suitable Flight Test Officer for the certification. A list and contact details of Flight Test Officers is available from the ARA on request. The ARA Section Delegate will give the final authorization upon a successful certification attempt.

FLIGHT TEST OFFICER

The duties of the Flight Test Officer include administering flight tests, administering Level 2 exams, and mentoring individuals applying for certification.

Only current ARA members who themselves are certified to the same level as the certification level required are qualified to administer the flight test. The Flight Test Officer must also be knowledgeable in the motor being flown. For example, if a hybrid motor is being used for the certification attempt, the Flight Test Officer must themselves have had experience in the assembly and flying of these motors. It is the responsibility of the member requiring certification to contact both the ARA Section Delegate and a Flight Test Officer to confirm their availability at a launch to

conduct the flight test. Members should be understanding and patient with scheduling. Flight Test Officers should especially make themselves available at launches to conduct the flight test.

Unavailability of Flight Test Officers

In the case of a Level 3 certification flight, if a Level 3 Flight Test Officer is unavailable, two Level 2 Flight Test Officers can substitute.

In the case of a Level 2 certification flight, if a Level 2 or 3 Flight Test Officer is unavailable, two Level 1 Flight Test Officers can substitute.

EXAM ADMINISTRATOR

A Flight Test Officer or Section Delegate may administer the Level 2 written exam. It is the responsibility of the member requiring certification to contact either the Flight Test Officer or the Section Delegate to determine a convenient time for both to take the exam. Members should be understanding and patient with scheduling. Section Delegates and Flight Test Officers should especially make themselves available by appointment, at launches or at meetings to administer the exam.

HPR FLIGHT TEST PROCEDURE (All Levels)

1. A flight test may be attempted at any ARA launch where a Flight Test Officer is available.

2. Relevant CASA regulations requiring notification or permits must be complied with.

3. The ARA High Power Rocketry Safety Code must be adhered to as a minimum.

4. The individual attempting certification must complete an ARA High Power Certification Application form prior to their certification attempt and have all current permits/licenses or the supervision of a license holder to suit the state where the launch is to occur. This includes (but is not limited to) pyrotechnics license for the state where the launch is to take place, air space clearance from CASA, council approvals, fire permits, and landowner's consent. In the case of a Level 2 attempt, the individual must pass the exam before attempting the flight test.

5. If certification to a level other than Level 1 is desired, the individual must provide proof of previous certification(s).

6. The rocket will be subjected to a safety inspection prior to flight. The safety inspection form is on the back of or attached to the ARA High Power Certification Application form.

7. During the safety inspection the individual will be expected to answer oral technical questions related to the safety and construction of their rocket. The questions may include (but are not limited to) identification of the rocket's centre of gravity and centre of pressure, methods used to determine rocket stability, and interpretation of the rocket motor's designation. The Flight Test Officer will tick the appropriate boxes in the "pre-flight" section of the High Power Certification Application form.

8. The individual will fly their rocket.

9. The Flight Test Officer must witness the flight.

10. Stability, deployment of the recovery system, and safe recovery should be considered when evaluating safety of the flight.

11. Models experiencing a catastrophic failure of either the airframe, rocket motor and/or recovery system (e.g. shock cord separation) will not be considered as having a safe flight. The condition of the rocket should be that no repairs are needed to re-launch the rocket. This excludes cosmetic damage, damage caused by colliding with objects on landing, getting dragged by the chutes, or damage to the chutes after landing.

12. The model must be returned to the Flight Test Officer immediately after the flight and be inspected to verify motor retention and for evidence of flight-induced damage.

13. The Flight Test Officer will complete the relevant section of the High Power Certification Application form indicating that a safe flight was made and that the post-flight inspection was satisfactory. The Flight Test Officer will sign the certification application and forward the document to the ARA Section Delegate for processing.

14. The ARA Section Delegate will endorse the certification by signing the document. A copy of this document will be retained by the ARA section (state or local rocketry club or incorporation). The original document is kept by the individual as proof of certification.

15. The ARA Section Delegate forwards a summary of the details of the certification to the ARA Secretary who updates the ARA records.

LEVEL 2 CERTIFICATION - ADDITIONAL REQUIREMENTS

Flyer Requirements

Any individual attempting ARA Level 2 Certification must have a valid Level 1 certification and must be an ARA member in good standing.

It is a requirement that the Level 2 Certification Exam is successfully completed before a Level 2 certification flight is attempted.

Level 2 Certification Exam

The Level 2 certification exam is made up of twenty (20) Technical questions and ten (10) Safety Code questions. This is a closed-book written exam to be completed in the presence of the Flight Test Officer or ARA Section Delegate. People with a disability may request alternative arrangements where these do not conflict with the inherent requirements of the task being assessed, provided that these are reasonable adjustments. This may include such things as an oral exam, or the assistance of a person to physically write answers etc.

A passing score is 90% - no more than 3 missed questions out of 30. Upon successful completion of the Level 2 Certification Exam, the Flight Test Officer will keep the exam with the certification application.

Members who fail an exam shall not be allowed to re-take the exam for a minimum of seven (7) days. Failed exams shall not be kept on file.

LEVEL 3 CERTIFICATION – ADDITIONAL REQUIREMENTS

Flyer Requirements

Any individual attempting ARA Level 3 Certification must have a valid Level 2 certification and must be an ARA member in good standing.

A project file must be presented to the Flight Test Officer before the certification flight with sufficient time for the Flight Test Officer to analyse the information. This will include (but not limited to):

- Drawings of the rocket showing airframe components, fins, bulkheads, longerons, adhesive joints, recovery system components, payloads, etc.
- Stability calculations/simulations.
- Flight simulations.
- A parts listing that includes material descriptions, adhesive types, screw sizes, gauges, thicknesses, etc.
- Schematics of recovery system electronics that show batteries, circuit designs, wiring diagrams, etc.
- Pre-flight checklist describing field assembly of the rocket, motor installation, recovery system preparation, launcher installation, system arming, etc.

Rocket Requirements

1. The certification rocket must be substantially built by the individual applying for certification. "Substantially built" will be defined, as a minimum, as:

   a) Fabrication of the engine mount with centring rings (if applicable).
   b) Alignment and mounting of the individual fins (prefabricated fin canisters are specifically disallowed).
   c) Installation of attachment points for the recovery system.
   d) Mounting and installation of airframe electronics.
   e) Final flight preparations including pyrotechnics installation, recovery system packing, motor assembly (as required) and motor installation.

   Only the builder of the rocket may use that rocket for a certification attempt – anything outside this is specifically disallowed. Certification rockets may be built from commercially available kits and may contain components built to the specifications of the individual but fabricated by others. For example, fins can be fabricated by someone else, however, they must be mounted by the individual applying for certification.

2. The recovery system must have a backup method of deployment. Redundancy must be present in the power sources, recovery control electronics and output devices (e.g. bridge wires, electric matches). Redundancy is not required in the pyrogen materials, parachutes, attachment points, risers, and disconnects.

   All attachment points of the recovery gear must be secured to prevent unplanned detachment during flight, that is to say any bolts are to be prevented from spinning, rope attachments especially knots are to be held tight using tape, shrink on, laced etc.

   Rockets recovered by alternate methods, e.g. glide or autorotation, must be reviewed by a Flight Test Officer on a case-by-case basis.

Motor ejection charges may be used as part of a redundant system but not as the primary ejection for any recovery event.

All chutes, electronics, and ropes of recovery system are to be protected from heat damage (not including cosmetic damage) that arises from pyrogen ejection charges.

A safe rate of descent of 20ft/sec (or 6m/sec) or slower is recommended within 2,000 feet (600m) of landing for any component weighing in excess of 22.6 grams.

3. External safe and arm provisions must be installed on a rocket for any items that have onboard control of an explosive charge, projectile or motor. This means the ability to physically break the connection between a pyrotechnic device and its power source.

4. The rocket must conform in all respects to any restrictions imposed by the ARA.

LEVEL 2 CERTIFICATION QUESTIONS

PART A (Technical Questions)

1. How does Newton's Third Law "To every action there is always an equal and opposite reaction" relate to rocketry?

a. That the blast deflector must be strong enough to push the rocket off the launch pad at ignition.
b. That a rocket flies because the rocket motor "pushes" the rocket in a direction opposite of the exhaust jet.
c. That the thrust of a rocket motor is proportional to the air density at the launch site.

2. What are the three forces acting upon a rocket during the course of its flight?

a. Thrust, rocket diameter and finish.
b. Nose cone shape, thrust and drag.
c. Gravity, thrust and aerodynamic drag.

3. What are the major factors that determine the maximum altitude of a high power rocket in vertical flight?

a. Lift-off weight, propellant weight and motor thrust.
b. Fin size, propellant weight and motor thrust.
c. Motor thrust, weight and aerodynamic drag.

4. For an inherently stable rocket, what is the relationship of center of gravity (CG) to the center of pressure (CP)?

a. The CG must be behind the CP relative to the desired direction of flight.
b. The CG must be forward of the CP relative to the desired direction of flight.
c. The CG must be in front of the fins of a rocket.

5. The center of pressure (CP) of a rocket is generally defined as:

a. The balance point of the rocket without the motor.
b. The total area of the fins, airframe and nose cone divided by two.
c. The point at which aerodynamic lift on a rocket is centred.

6. What is the "rule-of-thumb" for a stable rocket?

a. That the centre of gravity is one body diameter in front of the centre of pressure.
b. That the centre of gravity is at the same point as the centre of pressure.
c. There is no rule-of-thumb because there are too many variables.

7. When determining the center of gravity (CG) of a rocket with a heavier motor at the launch site, one can:

a. Install the motor, recovery system and payload and determine the balance point of the rocket as it is ready for flight.
b. Balance the rocket with an empty motor because that is the condition of the rocket after motor burnout.
c. It is not necessary to test for the centre of gravity when using a more powerful motor because it has more thrust.

8. What happens to the center of gravity (CG) of a rocket during a solid rocket motor's thrusting phase?

a. The Centre of gravity stays the same.
b. The Centre of gravity shifts forward.
c. The centre of gravity shifts aft.

9. How can a statically unstable rocket be made stable?
a. Using a heavier motor.
b. Adding weight to the nose.
c. Making the rocket shorter.

10. What are three methods used to shift the center of gravity (CG) of a rocket forward?
a. Add weight to the nose, make the rocket longer, install larger fins.
b. Add weight to the nose, make the rocket longer, use a smaller (or lighter) motor.
c. Add weight to the nose, make the rocket shorter, use a smaller motor.

11. What are three methods used to shift the center of pressure (CP) aft?
a. Make the rocket shorter, use larger fins, increase the number of fins.
b. Make the rocket shorter, use smaller fins, add weight to the nose.
c. Make the rocket shorter n change the number of fins, use a longer launch rod,

12. What is the definition of coefficient of drag (Cd)?
a. A dimensionless number that represents the effect of gravity and Mach number of the rocket.
b. A dimensionless number representing the rocket configuration, Mach number and angle of attack.
c. A dimensionless number that represents the friction of the launcher and launch velocity.

13. What happens to the coefficient of drag (Cd) as the rocket approaches the speed of sound?
a. The Cd decreases.
b. The Cd stays the same.
c. The Cd increases.

14. For a subsonic rocket, what major factors affect the coefficient of drag (Cd)?
a. Motor thrust, body diameter, nosecone shape and fin shape.
b. Speed, airframe dimensions, nosecone shape and fin shape.
c. Gravity, airframe dimensions, nosecone shape and fin shape.

15. The flight of a high power rocket can be separated into three portions; they are:
a. Ignition, burnout and peak altitude.
b. Powered flight, un-powered ascent and peak altitude.
c. Powered flight, un-powered ascent and descent.

16. What is the function of a motor liner and the O-ring seals in a solid rocket motor?
a. To hold all of the parts in place prior to ignition of the rocket motor.
b. To make the motor easier to clean if it is a reloadable motor.
c. To keep the hot gasses of the motor from burning or melting the motor case.

17. What is the most common oxidizer in commercially available high power composite solid rocket motors?
a. Ammonium Perchlorate.
b. Ammonium Nitrate.
c. Ammonium Chlorate.

18. A small hole is typically recommended near the top, but below the nosecone or payload section, of a high power rocket's booster section. Why?
a. This hole allows excessive ejection charge pressures to vent to reduce shock cord stress.
b. The hole is used to give air pressure readings for on-board altimeters.
c. The hole vents internal air pressure as the rocket gains altitude to prevent premature separation.

19. A rocket with a motor cluster consisting of a central composite motor and four black powder motors using thermalite igniters or electric matches:

a. will result in all motors starting about the same time.
b. will result in the composite motor starting first followed by the black powder motors.
c. will result in the black powder motors starting first followed by the central composite motor.

20. In general terms, the specific impulse of a rocket motor is:

a. The total thrust force of a motor throughout its action time.
b. The total impulse divided by unit weight of propellant.
c. Dependent on the diameter and length of the propellant grain.

21. In general terms, the total impulse of a rocket motor can be described as:

a. The product of the average motor thrust and its burn time.
b. The product of the propellant weight and its burn time.
c. The product of the propellant weight and the motor thrust.

22. The average thrust of a rocket motor is 100 Newtons and the burn time is 4 seconds, what is the total impulse?

a. 25 Newton-seconds
b. 400 Newton-seconds
c. 400 newtons

23. Which motor has a higher total impulse?

a. J200
b. J400
c. K200

24. Which motor has a higher average thrust?

a. J200
b. J400
c. K200

25. What is the difference between a J640 and a J320 high power rocket motor (assume full 1280 Newton-second J motors)?

a. The J320 burns out twice as fast as the J640.
b. There is no difference between the motors, the numbers are manufacturer reference only.
c. The J640 burns out twice as fast as the J320.

26. Which of the following has a total impulse in the J motor range?

a. It = 600 Newton-seconds
b. It = 1000 Newton-seconds
c. It = 1290 Newton-seconds

27. What is a Newton?

a. The amount of force required to accelerate one pound one foot per second per second.
b. The amount of force required to accelerate one kg, one foot per second per second.
c. The amount of force required to accelerate one kg, one meter per second per second.

28. What does the motor designation I220-8 mean?

a. The motor is in the I impulse range with an average thrust of 220 Newtons and an 8 second delay from motor ignition.
b. The motor is in the I impulse range, having a total impulse of 620 Newton-seconds with an average thrust of 220 Newtons and an 8 second delay from motor burn-out.

c. The motor is in the I impulse range with an average thrust of 220 Newtons and an 8 second ejection delay from motor burn-out.

29. What is the purpose of a launch rod, rail or tower?
a. To keep the rocket pointing in the right direction prior to flight.
b. To control the rocket's flight long enough to allow aerodynamic stability.
c. Both a and b.

30. What is the purpose of a launch lug?
a. To add drag to the rocket at launch.
b. To guide the rocket along the launch rod or rail.
c. Both a and b.

31. A rocket with a motor cluster consisting of a central composite 54mm J415 motor and four 29mm G80 composite motors using thermalite igniters or electric matches:
a. will result in all motors starting about the same time.
b. will result in the J415 motor starting first followed by the G80's.
c. will result in the G80's starting first followed by the J415.

32. What can happen if all the motors of a cluster do not ignite at launch?
a. Nothing, the rocket is inherently stable.
b. The rocket may not fly straight.
c. The rocket will shred.

33. What is a shred?
a. A failure of the rocket air frame during boost resulting in destruction of the rocket.
b. A failure of the recovery system during boost.
c. A failure of the motor causing early ejection.

34. What is a cato?
a. A failure of the rocket resulting in failure of the air frame during boost.
b. A failure of the recovery system during boost.
c. A failure of the motor causing flight termination.

35. What is the primary requirement for a rocket motor igniter?
a. It must transfer sufficient heat to the propellant to assure ignition.
b. It must produce hot, high velocity gasses to assure ignition.
c. It must have a high resistance to be reliable.

PART B (Safety Code)

1. What is a complex high power rocket?
a. A rocket having more than one stage.
b. A rocket having a cluster of rocket motors.
c. Both a and b.

2. What are the rocket motor criteria (minimum) that defines a high power rocket?
a. A rocket with a single motor with more than 160 Newton-seconds total impulse or an installed impulse of 320 Newton seconds and no more than 40,960 Newton-seconds.
b. A rocket with a single motor having an average thrust in excess of 80 Newtons.
c. Both a and b.

3. What is the lower weight limit of a high power rocket?
a. A rocket weighing more than 1500grams.
b. A rocket weighing less than 20kg.
c. Both a and b.

4. When is a recovery device not necessary in a high power rocket?
a. When the high power rocket is intended for ballistic flight.
b. When the rocket has a bursting charge.
c. A recovery device is always necessary.

5. A high power rocket may be constructed of what materials?
a. Paper, wood,**rubber,** fiberglass or plastic with a minimum amount of metallic parts.
b. Paper wood, fiberglass, plastic and aluminium.
c. There are no restrictions on construction materials.

6. What is a high power rocket motor?
a. A rocket motor with more than 80 Newton-seconds of total impulse and 80 Newtons average thrust.
b. A rocket motor with more than 160 Newton-seconds of total impulse or 80 Newtons average thrust.
c. A rocket motor with more than 160 Newton-seconds of total impulse and 160 Newtons average thrust.

7. What are the structural or load-bearing parts of a high power rocket?
a. Nose cone, body tube and motor mount.
b. Nose cone, body tube and fins.
c. Nose cone, motor mount and fins.

8. Who may operate a high power rocket?
a. Any member of a nationally recognized rocketry organization.
b. Only those licensed by the federal government.
c. A person that is a member of a rocketry club and is certified to fly high power rocketry.

9. What criteria apply to the construction of a high power rocket?
a. Use suitable materials to withstand operating stresses and retain structural integrity in flight.
b. Use only the lightest weight materials for the construction-of high power rockets
c. Use materials that allow minimal flex of the rocket in flight.

10. When must the stability of a rocket be determined?
a. If the safety monitor requests it.
b. When designing a new rocket.

c. Before its first flight, except when launching a rocket of already proven stability.

11. What is the maximum weight of a high power rocket?
a. Less than maximum weight recommended by the motor manufacturer for a given motor.
b. Less than 50kg.
c. There is no maximum high power rocket weight.

12. When is it permissible to catch a high power rocket?
a. If the rocket weights less than 2.2 pounds or 1 kg.
b. It is never permissible to catch a high power rocket.
c. Neither a or b.

13. What payloads are not permitted in a high power rocket?
a. Payloads that are flammable or explosive or intended to cause harm.
b. Vertebrate animals.
c. Both a and b.

14. When must a high power rocket launching device incorporate a blast deflector?
a. When necessary to prevent the rocket motor's exhaust from impinging on flammable materials.
b. All launch systems must incorporate a blast deflector.
c. When the design of the launch device requires it.

15. What is the maximum launch angle from vertical for a high power rocket?
a. 30°
b. 20°
c. There is no maximum launch angle.

16. What are the elements of an ignition system?
a. Remotely controlled, electrically operated, a launch switch that returns to OFF when released.
b. Remotely controlled, electrically operated and a removable safety interlock in series with the launch- switch.
c. Remotely controlled, electrically operated, a launch switch that returns to OFF when released and a removable safety interlock in series with the launch switch.

17. When can a high power rocket be flown through cloud?
a. When authorized to do so by the Range Safety Officer (RSO).
b. When authorized to do so by the Range Safety Officer (RSO) and with written permission from CASA.
c. Neither a or b.

18. What is the limit of surface wind for launching a high power rocket?
a. 42kph.
b. 32kph.
c. 22kph.

19. When/What is the minimum distance from an occupied building or public highway for a launch site?
a. 260 meters.
b. 460 meters.
c. No Minimum distance.

20. When may a high power rocket be launched?
a. After warning the spectators and giving a 5 second countdown.
b. When all systems are ready and after a 5 second countdown.

c. After informing & getting permission and attention from the RSO.

21. What permit must be obtained to purchase Easy Access high power rocket re-load engines?

a. Blasting Permit from authorized blasting operator.
b. No Permit required.
c . Explosives Permit at a state level

22. What quantity of rocket motors, motor reloading kits and pyrotechnic modules may be stored in an indoor magazine?

a. 20kg.
b. 35kg.
c. 50kg.

23. When may a solid propellant high power rocket motor be shipped and stored with the igniter installed?

a. It is never permissible to ship or store a solid propellant high power rocket motor with the igniter in place.
b. When the rocket will be launched within 48 hours of igniter installation.
c. Neither a or b.

24. What is the age limit Australian Rocketry Association recognizes for a certified solid propellant high power rocket motor user?

a. 21 years of age.
b. 18 years of age.
c. There is no age limit.

25. What is the maximum altitude allowed for flying HPRs if there is a cloud ceiling of 3000ft

a. 3500ft.
b. To the limit of the CASA permission
c. Neither a or b.

End Part B

LEVEL 2 EXAM QUESTION ANSWERS

Answers: Part A (Technical)

1. **b**. The rocket motor's thrust causes the rocket to accelerate in the direction opposite the motor's thrust. Thus a rocket motor pushes only on the rocket, not on the air or launch pad.
2. **c**. Gravity, thrust and drag are the forces acting on a rocket.
3. **c**. The motor thrust, weight and aerodynamic drag are the primary forces considered when determining the altitude of a rocket. Please note that the weight of the rocket must consider the lift-off weight and the weight at burn-out to be complete.
4. **b**. The centre of pressure (CP) is where the aerodynamic lift, due to the rocket being at a non-zero angle of attack, is centred. For an aerodynamically stable rocket with the CP behind the centre of gravity(CG)n the lift which is centred aft of the CG will create a corrective moment to return the rocket to zero degrees angle of attack. Conversely, if the CP is ahead of the CG the lift will attempt to turn the rocket around so that the CP will again be behind the CG. This resultant "tumbling" is characteristic of an unstable rocket.
5. **c**. The centre of pressure (CP) is the point on the rocket where the aerodynamic lift is centred, This means that aerodynamic lift, if the rocket is at a non-zero angle of attack, forward of this point is balanced by the aerodynamic lift aft of that point.
6. **a**. Keeping the centre of gravity (CG) one body diameter in front of the centre of pressure (CP) typically allows an adequate margin for rocket stability.
7. **a**. Measuring the centre of gravity (CG) by balancing the rocket requires that the rocket be prepared as though ready for flight. It is especially important to check when using a heavier motor than previously flown.
8. **b**. As the propellant burns the motor gets lighter and thus moves the balance point or centre of gravity (CG) forward, This is why a marginally stable rocket will "act squirrelly" at launch, then stabilize and fly straight.
9. **b**. Adding enough weight to the nose will shift the centre of gravity (CG) forward of the centre of pressure (CP).
10. **b**. Moving the CG forward requires judicious design changes. The following are given as "rules-of-thumb," n Adding weight to the nose moves the CG forward by counterbalancing the rocket. Think of the rocket as a lever' making the rocket longer shifts the CG forward by making the lever longer. Using a smaller (or lighter) motor reduces the weight aft thus shifting the CG forward.
11. **a**. Moving the CP aft requires judicious design changes. The following are given as "rules-of-thumb." increasing the total fin area will move the CP aft. This can be accomplished by increasing the area on each fin and/or increasing the number of fins. The CP can also be shifted aft by making the rocket shorter. This alone is generally not preferred because the CG is also shifted aft and CP/CG stability relationship may be compromised.
12. **b**. The coefficient of drag (Cd) is a number that is used in equations for calculating the aerodynamic performance of a rocket. Values that make up the Cd are the rocket configuration (nose cone shape, airframe diameter(s), transition sections, fin size and sharpen etc.), the rocket velocity as Mach number and the angle of attack.
13. **c**. The coefficient of drag (Cd) increases and can be greater than 1 as the rocket exceeds Mach 1.
14. **b**. As speed increases, the drag number changes. The length and diameter of the rocket factors into the total surface area, The nose cone shape effects the airflow over the front of the nose cone. The fin shape and fin area factor into the total surface area.
15. **c**. The three phases of flight of a high power rocket: (1) Powered flight - the period of time when the rocket motor is producing thrust against gravity and drag. (2) Un-powered ascent - the period after powered flight where the rockets momentum allows the rocket to coast to peak altitude and is effected by gravity and drag, (3) Descent - the return of the rocket to earth effected by gravity and drag.

16. **c**. The liner serves to keep the burning propellant (typically >5000°F) from touching the motor case (aluminium melts at 1075-F) while the O-rings seal the ends to keep the hot gasses where they belong, that is going out of the nozzle.
17. **a**. Ammonium Perchlorate is NH4CIO4 and is used in practically all modern solid rocket motors.
18. **c**. Air pressure external to the rocket decreases as the rocket ascends. Trapped (higher) pressure within the rocket can prematurely separate the rocket. The hole vents this internal pressure to prevent separation. Note: The hole size is dependent on the size of the rocket and volume of air to be vented; larger airframes require larger holes. Use caution in locating the hole so the nose cone or payload coupler does not block the hole. Be sure to position the hole such that ejection charge pressure is not vented before recovery system deployment.
19. **c**. black powder motors do not have a significant start up time and will ignite as soon as a flame front is encountered. Ammonium perchlorate based composite motors require heat and pressure to start the combustion process and generally require at least a half-second before ignition occurs.
20. **b**. specific impulse is a term used to define the efficiency of a rocket propellant and is the total impulse derived from a given mass of propellant.
21. **a**. Total impulse is the amount of thrust produced by a motor over its action time. For instance, a motor may produce 10 pounds of thrust for 4 seconds resulting in a total impulse of 40 pound-seconds.
22. **b**. Multiply the average thrust (100 Newtons) by the burn time (4 seconds) to get the total impulse of 400 newton-seconds.
23. **c**. The J motor has a range of 641 to 1280 Newton-seconds and the K motor has a total impulse range of 1281 to 2560 newton-seconds.
24. **b**. Even though the total impulse of the K motor is greater than the J motor, the J motor's average thrust is 400 Newton's versus the K motor's 200 Newtons.
25. **c**. The burn time is determined by dividing the total impulse (J = 1280) by the average thrust of each motor. The burn time for the J640 is: 1280 Newton-seconds divided by 640 Newtons = 2 seconds, and for the J320 is: 1280 Newton-seconds divided by 320 Newtons = 4seconds.
26. **b**. A J motor is in the range of 640.01 to 1280 Newton-seconds. Therefore, a 1000 Newton-second motor is a midrange J. The 600 Newton-second motor is an I motor and the 1290 Newton-second motor is a K motor.
27. **c**. The Newton is an international (metric) unit of force and is the force required to accelerate one kg (2.2 lbs) one meter (39 inches) per second per second.
28. **c**. This is an I motor with a total impulse range of 320.01 to 640 Newton-seconds, an average thrust of 220 Newton's and an ejection delay of 8 seconds from burn-out.
29. **c**. The purpose of the launch rod, rail or tower is to guide the rocket at the beginning of its flight to allow it to gain sufficient velocity for a stable flight. This is achieved when the air flowing over the rocket and its fins allows the rocket to correct its flight by forcing rotation around the rocket's centre of gravity,
30. **b**. The launch lug attaches the rocket to the launch rod or rail allowing the rocket to be guided by the rod or rail at launch.
31. **c**. Composite (Ammonium Perchlorate) motors require heat and pressure to ignite. The motor core diameter is smaller in the 29mm G80 motors and heat and pressure is more concentrated resulting in faster ignition of the motors.
32. **b**. Not having ignition of all clustered motors results in the thrust being unsymmetrical. This unbalanced thrust may force the rocket to fly in an unanticipated arc that will not achieve a vertical flight.
33. **a**. A shred happens when the rocket is improperly built or has a rocket motor too powerful for that particular rocket. The typical shred sequence is that the velocity of the rocket has increased to a point where airframe, fins or other structural parts cannot take the loads. When that part fails, it typically causes the rocket to become unstable resulting in the rapid destruction of the rocket.

34. **c**. A cato is short for catastrophic motor failure. This occurs when the nozzle, forward bulkhead or casing fails. The immediate result is abrupt termination of thrust which results in the rocket failing.
35. **a**. A motor igniter must deliver sufficient heat to the propellant to get it ignited. This may be in the form of hot gas, hot burning particles, a hot wire or a combination of all three.

Answers : Part B (Safety Code)

1. c.
2. c.
3. a.
4. c.
5. a.
6. b.
7. b.
8. c.
9. a.
10. c.
11. a.
12. b.
13. c.
14. b.
15. b.
16. c.
17. c.
18. b.
19. b.
20. c.
21. c.
22. c.
23. a.
24. b.
25. c.