This is a sample paper based on the concept of 'Space Technology'. The actual paper can deal with any present-day topic. The following are the details of the paper pattern and the marking scheme:

- There are three sections- Maths, Physics and Chemistry
- The paper consists of a 45 questions
- Each subject would have two sections:
  - **Section-1:** Passage Questions (Single Correct)– 6 (+3,-1)
  - **Section-2:** Application Oriented MCQs – 2 (+3,-1)
- There is one crossword at the end of the paper, unifying the key concepts from all passages.
  - **Section-3:** Crossword type questions (Single Correct) – 6 (+3,-1)
- There is a separate section for logic and reasoning based questions.
  - **Section-4:** Logic and Reasoning (Single Correct) – 15 (+3,-1)
- The duration of the paper is 2 hrs.
- In case of any discrepancy with any of the questions, the organising committee will provide grace marks to everyone. Students are advised not to waste time questioning the credibility of the paper.
- Students are encouraged to go through the sources provided in the paper to increase their scientific temper further.

Note: *This paper is just a sample paper. Hence it does not contain all the 45 questions. It contains few of the questions pertaining to sections- 1, 2 & 3 to give a clear idea of the paper to the students.*

Altitude of Iridium Flares:

Sites to visit: www.heavens-above.com

Explanation:

The concept of Iridium flares is pretty interesting, especially for the fact that this phenomenon can be observed from almost any location if proper conditions are satisfied. If you are a star grazing enthusiast, you can observe many stars and satellites on a clear night provided your location is devoid of city lights. Sometimes satellites look like airplanes, but airplanes have blinking lights that are usually coloured. What's interesting about Iridium satellites is that they give rise to dramatic flashes in the sky sometimes.

These bright flashes that you may or might have observed earlier could probably be these Iridium flashes which are a result of sunlight bouncing off the satellite's antenna and reflecting back on Earth's surface. Another interesting fact about these flashes is that the element Iridium has got nothing to do with this phenomena. The name comes from the telecommunications-company that has been launching satellites into low, near-polar orbits for use in a new type of wireless phone and paging service. Few years ago, the first of 77 originally proposed Iridium satellites (77 is the atomic number of iridium) was launched. The flotilla of satellites has now been scaled-down to 66.

Knowing when and where these flashes will occur:

Since the Sun's and satellite's position are known, one can predict when and where these flashes can occur. **Heavens Above** is a website (link provided above), which can help you with proper viewing times associated with Iridium flares. You just have to plug in the coordinates of your location or search for it in the list and you're ready to go. The program will show you the **dates** when the flares are visible for the next seven days, the **local time** when you can observe the flare, the **flare intensity**, its **elevation** above the horizon, its **azimuth** (this is basically the direction from due north measured clockwise in degrees), the distance and direction you would have to travel in order for the flare to be at its brightest, and the **satellite number**. Give it a try, and for best results wait for a clear, moonless night

Pre-requisite concepts:

With proper information, one can estimate the altitude of these flashes. All you need to know is some important concepts in Trigonometry. You might come across some negative values dealing with the magnitude of brightness of stars, flashes, etc. Astronomers use an apparent brightness magnitude scale to determine how bright one object is compared to another. The brighter the object, the more negative the magnitude. Each increase in magnitude, from –1 to –2, for instance, is 2.51 times brighter. On this scale, the faintest stars that we can see with the unaided eye have a magnitude of about 5. The brightest star in the Northern Hemisphere, Sirius, has a magnitude of –1.4, Venus at its brightest can reach a magnitude of about –5, and the full moon is approximately –12.

Passage:

A flare of magnitude -7 can be tracked over a portion of the sky that's about the length of your thumb when held at arm's length, until it dies out. In the clear, moonless sky, it takes **8.5 seconds** (according to the stopwatch you have with you) from when you first notice the flaring until you can no longer see it. The minimum velocity needed for a satellite to orbit the Earth is about 17,500 miles per hour (28,000 km per hour), and the Iridium satellites travel a bit faster than this – approximately **18,000 miles per hour (28,800 km per hour).**

Ten degrees of sky is the **angular distance** of the sky covered by your fist when held at arm's length, and 5 degrees is the amount of sky covered by your thumb at arm's length. We don't know if the satellite is moving towards us, away from us or moving laterally. Assume that the satellite is **moving laterally.**

With the information provided above answer the questions that follow:

Q1. If you observe a flare of same magnitude as specified above and tracked it over a portion of the sky spanning your thumb, what's the altitude (**approximate value**) of the flare above the Earth's surface? *(Assume the speed of the satellite is same as mentioned in the passage)*

a) 426 miles
b) 372 miles
c) 486 miles
d) 500 miles

Q2. Consider the case mentioned above. What's the angle of elevation of the flare from the observer? *(Observer is at the Earth's surface)*

a) 85^0
b) 5^0
c) 10^0
d) 90^0

Q3. Given that the flare was observed at an approximate height of 185 miles above the Earth's surface and spanned over your fist's length when held at arm's distance. How long did the flare last?

a) 3.24 sec
b) 7.5 sec
c) 6.52 sec
d) 9.72 sec

Section -2: Single Correct Answers

Q1. In the case described in question 3, what is the distance traveled by the satellite during the time you could observe the flare? *(Find the distance with respect to earth).*

a) 32.6 miles
b) 32.6 km
c) 37.5 km
d) 48.6 miles

Q2. How much brighter is an object with magnitude scale reading - 3 to an object with magnitude scale reading - 2.

a) 2.51 times
b) 0.4 times
c) 1.5 times
d) inadequate data

Chemistry in Rocket Launches

Sources:

http://college.cengage.com/chemistry/intro/zumdahl/intro_chemistry/5e/students/protected/focus/ch07_2.pdf

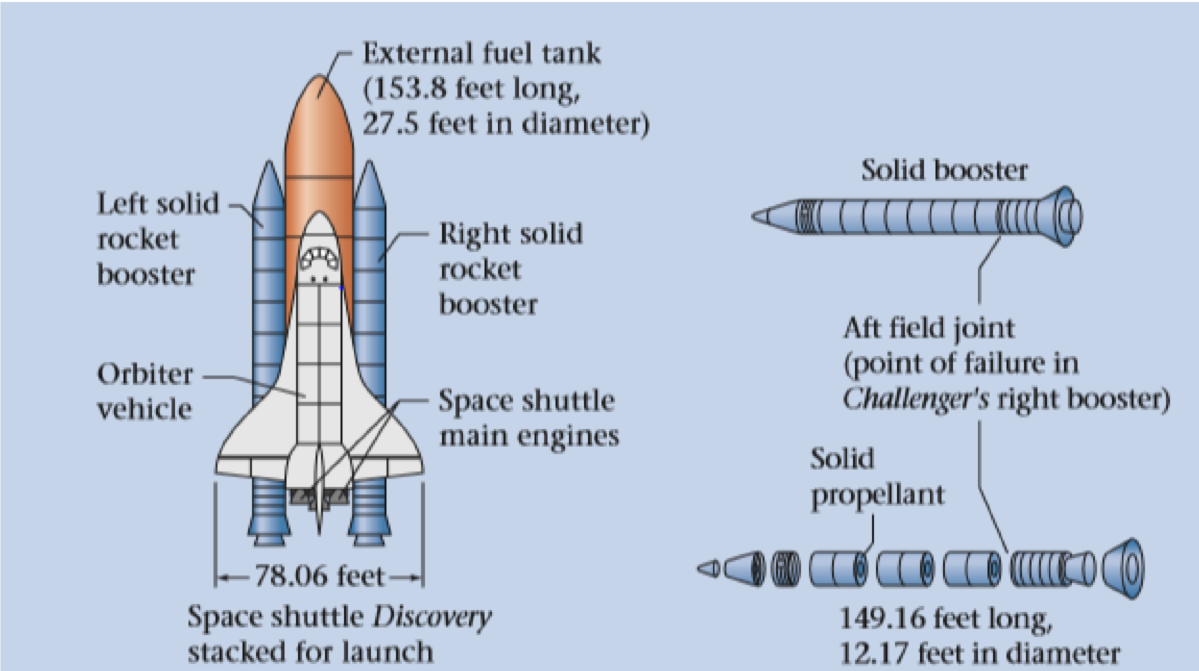
https://chlorine.americanchemistry.com/Science-Center/Chlorine-Compound-of-the-Month-Library/Ammonium-Perchlorate-Helping-to-Launch-the-Space-Shuttle-Discovery/

Introduction:

If you try to dig deep into the science behind a rocket launch, you will surely end up with a headache in a couple of minutes. There's lot of math involved, chemical reactions that lift up millions of pounds and an unimaginable thrust force that puts our beast into the space. Putting aside all these mind-boggling calculations, we will simply focus on the chemistry in a rocket launch. Some basic chemical reactions, compositions and in the process you will equip yourself with the knowledge of the chambers of a rocket that make the launch possible.

We would familiarize you with NASA's space shuttle *Discovery* to explain the concepts.

Concept:



Space Shuttle Basics:

A space shuttle consists of three main components:

- **Orbiter -** the winged vehicle we think of as the space shuttle in which the astronauts live and work.
- **Solid Rocket Boosters –** Two solid rocket boosters are present on either side of the Orbiter and are essential for lift-off. Each of them is around 12 ft. in diameter and around 150 ft. long. Each booster contains about 1.1 million pounds of fuel: **Ammonium Perchlorate** (**NH_4ClO_4**) and **powdered Aluminum** mixed with a **binder** ('glue').
  Due to their large size, the boosters are built in segments and assembled at the launch site as shown in the figure. The binder holds all the materials together. The entire mixture has the consistency of a pencil eraser. A catalyst like iron oxide is added to speed the reaction.
- **External Tank -** the large orange tank attached to the orbiter at the time of lift-off. Filled with liquid hydrogen and oxygen fuels, the tank helps thrust the orbiter into space.

Chemistry of Lift-off:

The following is the **unbalanced** equation that takes place in the **boosters.**

$$Al + NH_4ClO_4 \rightarrow Al_2O_3 + AlCl_3 + H_2O + N_2$$

The propellant in the solid rocket boosters is ignited giving rise to an irreversible reaction. Oxygen from ammonium perchlorate combines with aluminium metal to produce aluminium oxide--the white solid Al_2O_3-- and aluminium chloride, $AlCl_3$, water vapour and nitrogen gas. This reaction heats the inside of the solid rocket boosters to **5,800 ^{0}F**, causing the two gases to expand rapidly. The expanding water vapour and nitrogen lift the rocket boosters with a tremendous force. All the fuel is burned in about two minutes.

Each solid rocket booster exerts a thrust, or force, of over **three million pounds** at launch. They provide "**lift**" for the orbiter to a distance of about 28 miles into the atmosphere. Then the boosters separate from the rocket, but continue on an upward path. Seventy-five seconds after separation the boosters reach their highest altitude (about 41 miles) and begin to fall back to Earth. Since they don't cross the atmosphere, they land into the ocean without disintegrating and can be reused.

Meanwhile, the **orange external tank** uses up its fuel in just over eight minutes-enough time to help get the orbiter into space and orbiting. The fuel present in this tank is **liquid hydrogen and oxygen** and their reaction generates water vapour at extremely high temperatures **(6000 ^{0}F).** The external tank then separates from the orbiter, falls back to Earth and **disintegrates** as it re-enters the atmosphere. The reaction taking place in the external tank is as follows:

$$2H_2 + O_2 \rightarrow 2H_2O$$

With the information given above you are ready to answer the questions that follow:

(*The questions* ***may*** *have multiple correct answers)*

Q1. Balance the chemical reaction that takes place in the boosters. Let the coefficient of Al_2O_3 be **'x'.** What weight of Oxygen would react with aluminium to form 'x' moles of Al_2O_3 ?

A. 48g
B. 96g
C. 192g
D. 96 kg

Q2. What kind of reactions take place in the boosters?

A. Redox Reactions
B. Exothermic Reactions
C. Decomposition Reaction
D. Double Displacement Reaction

Q3. Consider the famous thermite reaction where Aluminium reacts with Ferric Oxide. Let the coefficient of Al in the reaction taking place in the solid boosters be **'y'.** What's the weight of Aluminium Oxide formed if 'y' moles of Al are involved in the reaction?

A. 56g
B. 630g
C. 1020g
D. 215g

Section-2: Single Correct Answers

Q.1 Let us assume that the maximum height covered by the booster after each reuse decreases by 10%. Calculate the total time spent by the booster weightlessly in the space after it is used for the 10th time. Find the answer in terms of 't' where t is the time taken in first freefall by the booster.

Hint: If Sn= a + ar + ar^2 + ar^3 ......+ ar^{n-1} then:

$$S_n = \frac{a_1(1-r^n)}{1-r}, \qquad r \neq 1$$

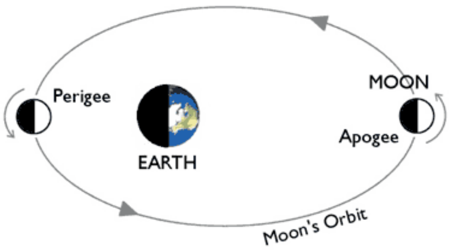
Q.2 In the reaction, **2 H_2 (g) + O_2 (g) → 2 H_2O (g)**

483 KJ of heat is evolved per mole of H2O formed. If the same reaction is conducted in a vessel containing 20 moles of H2 and 5 moles of O2, and 1% of heat evolved is used to lift a small rocket of mass 10 kg vertically, calculate the maximum height to which the rocket could be lifted.

a) 483 km
b) 517 km
c) 483 m
d) 517 m

Apogee, Perigee and the mighty Ellipse!

Apogee and perigee refer to the distance from the Earth to the moon. Apogee is the farthest point from the earth. Perigee is the closest point to the earth and it is in this stage that the moon appears larger. Looking at the moon in the sky without anything to compare it to, you wouldn't notice any size difference. But the difference in size can in fact be quite significant.



It's clear from the given diagram that the orbit of the moon around the earth is an Ellipse with Earth at one of the foci.

An ellipse is a curve in a plane surrounding two focal points such that the sum of the distances to the two focal points is constant for every point on the curve. The shape of an ellipse is represented by its **eccentricity**, which for an ellipse can be any number from 0 (the limiting case of a circle) to arbitrarily close to but less than 1. The two **foci** or **focal points** of an ellipse are two special points F_1 and F_2 on the ellipse's major axis that are equidistant from the centre point. The sum of the distances from any point P on the ellipse to those two foci is constant and equal to the major axis. The larger of these two axes, which corresponds to the larger distance between antipodal points on the ellipse, is called the **major axis** whose length is 2a. The eccentricity of an ellipse, usually denoted by **e**, is the ratio of the distance between the two foci, to the length of the major axis or e = 2f/2a = f/a.

Consider the centre of the ellipse as origin and the ellipse to be symmetrical about X and Y axes.

Answer the questions that follow:

{You might be needing the following data:

Mass of Earth = 5.972 x 1024 kg

Radius of Earth = 6371 km

Gravitational Constant = 6.67 x 10-11 m3 kg-1 s-2

Radius of the Moon = 1737 km

Mass of the Moon = 7.348 x 1022 kg}

Q1. Consider the Earth – Moon system. If the apogee is approximately 405,400 km and perigee is around 362,600 km, what is the eccentricity of the Moon's elliptical orbit around Earth?

A. 0.08

B. 0.055

C. 0.6

D. 0.56

Q2. Take the same system as mentioned above with the same values of apogee and perigee. What is the gravitational force of attraction between the Earth and the Moon when it's closest to the Earth?

A. 3.5 x 1025 N

B. 2.65 x 1026 N

C. 2.26 x 1026 N

D. 8.5 x 1025 N

Q3. Except for apogee and perigee, the moon forms a triangle with the two foci of the elliptical orbit at any time in its trajectory. How long would it take to cover the perimeter of this triangle at a speed of 10,000 km/hr?

(Consider the same parameters as mentioned in the first question)

A. 90 hrs

B. 81 hrs

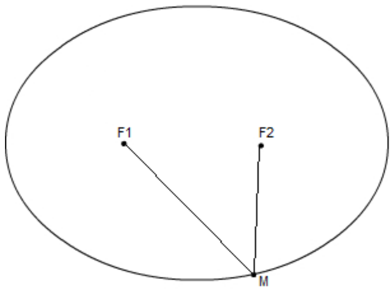
C. 72 hrs

D. 100 hrs

Section-2: Single Correct Answers

Q1. Consider a planet with a satellite having an elliptical orbit of eccentricity $\frac{1}{2\sqrt{2}}$. The planet is at focus F_1 and the satellite (denoted by M) is on a point on the orbit such that the ratio of MF_1 to MF_2 is 1:1. Let the area MF_1F_2 at this time be Δ_1.

After some time t, the ratio of MF_1 to MF_2 becomes 2:1 and the area MF_1F_2 is now Δ_2. Compute the ratio $\frac{\Delta 1}{\Delta 2}$



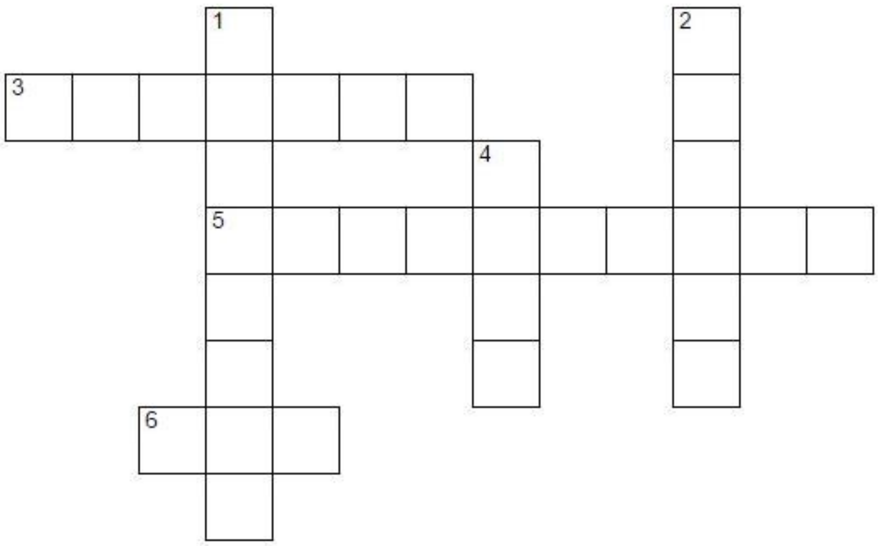
A. 1
B. 0.5
C. 1.5
D. 3

Q2. Compute the approximate instantaneous velocity of the moon when it is at a distance of 398,000 km from the earth.

Hint: If an object is moving under the influence of an attractive force, the force it experiences at any instant must be equal to mv^2/r where m is the mass of the revolving object, v is the velocity and r is the distance between the revolving object and the centre of revolution.

A. 1 km/s
B. 0.4 km/s
C. 1.6 km/s
D. 2 km/s

Section-3: Based on the answers obtained to the crossword given, answer the questions that follow



Down

1. Gas liberated from solid rocket boosters.
2. Brightest star in the northern hemisphere.
4. Eccentricity of circle.

Across

3. Moon appears larger in this position.
5. Iridium flares involve this phenomenon of light.
6. Coefficient of Aluminium in boosters' reaction.

Down :-

1. What is the atomic number of the gas liberated?

   a) 9
   b) 7
   c) 1
   d) 11

2. Number obtained by adding the first three and subtracting the last three digits

   a) 0
   b) 5
   c) 3
   d) 2

4. What's the eccentricity of a circle?

   a) 1
   b) 0
   c) 0.5
   d) 0.75

Across :-

3. If for every odd alphabet we assign 1 and for every even alphabet we assign 0, what is the sum of these letters?

   a) 5
   b) 6
   c) 3
   d) 7

5. Sum of the alphabets

   a) 107
   b) 110
   c) 109
   d) 121

6. Digits in the tens place of the coefficient of Al in the booster's reaction

   a) 0
   b) 2
   c) 1
   d) 3