Aga Khan University Examination Board

Notes from E-Marking Centre on HSSC-I Physics Examination May 2018

Introduction:

This document has been produced for the teachers and candidates of Higher Secondary School Certificate (HSSC) Part I Physics. It contains comments on candidates' responses to the 2018 HSSC-I Examination, indicating the quality of the responses and highlighting their relative strengths and weaknesses.

E-Marking Notes:

This includes overall comments on candidates' performance on every question and *some* specific examples of candidates' responses which support the mentioned comments. Please note that the descriptive comments represent an overall perception of the better and weaker responses as gathered from the e-marking session. However, the candidates' responses shared in this document represent some specific example(s) of the mentioned comments.

Teachers and candidates should be aware that examiners may ask questions that address the Student Learning Outcomes (SLOs) in a manner that requires candidates to respond by integrating knowledge, understanding and application skills they have developed during the course of study. Candidates are advised to read and comprehend each question carefully before writing the response to fulfil the demand of the question.

Candidates need to be aware that the marks allocated to the questions are related to the answer space provided on the examination paper as a guide to the length of the required response. A longer response will not in itself lead to higher marks. Candidates need to be familiar with the command words in the SLOs which contain terms commonly used in examination questions. However, candidates should also be aware that not all questions will start with or contain one of the command words. Words such as 'how', 'why' or 'what' may also be used.

General Observations:

This year candidates performed well on questions related to the dimensions, addition of vectors, fluid dynamics and uniform circular motion. Whereas low-scoring candidates did not perform well in questions based on vectors analysis, concept of impulse, artificial satellites and weightlessness, interference of light, word problems and derivation based on the Carnot engine, work-energy relation, speed of sound, kinetic theory of gases and thermodynamics and also had problem in articulating their answers on reasoning and discussion type questions.

Detailed Comments:

Constructed Response Questions (CRQs)

Question 1:

The dimension for work done and torque is the same i.e. $[M L^{2} T^{-2}]$. Describe the reason for the difference in their S.I. units.

Better responses correctly described the reason for the difference in the dimension for work done and torque. High scoring candidates wrote the difference in terms of scalar and vector quantities, dot/ scalar product and cross/ vector product, Joules and Newton-meter and W = F . d and $\vec{\tau} = \vec{r} \times \vec{F}$.

Example:

Although the dimensions for work done and torque are same i.e $[ML^{2}T^{-2}]$ but their SI units are different because work done is a scalar/dot product of the magnitude of displacement and the effective component of force in the direction of displacement. $W = F \cdot d$, $W = d(F\cos\theta) \Rightarrow W = Fd\cos\theta$ while torque is a vector product of the force and its distance from the axis of rotation: $\tau = r \times F \Rightarrow rF\sin\theta\hat{n}$

So the SI unit of work is Joules (J) and the S.I unit of τ is (Nm) newton metre.

Weaker responses showed candidates' lack of understanding about the comparison and reasons of the application of dimension while measuring different quantities. Few low scoring candidates easily proved the dimension of work done and torque but were unable to reason out the differences in their S.I. units.

Example:

The SI units of torque and work done are different because of the different functions in them ~~because~~ as work has Cosθ and torque has Sinθ. Torque depends on momentum and workdone depends on force and displacement.

Question 2:

Show that $2aS = v_f^2 - v_i^2$ is dimensionally correct.

Better responses correctly showed that $2aS = v_f^2 - v_i^2$ is dimensionally correct as the one shown in the below example of better response image.

Example:

$2aS = V_f^2 - V_i^2$

$2[L][T]^{-2}[L] = [L]^2[T]^{-2} - [L]^2[T]^{-2}$

$[L]^2[T]^{-2} + 2[L]^2[T]^{-2} = [L]^2[T]^{-2}$

$3[L]^2[T]^{-2} = [L]^2[T]^{-2}$

$[L]^2[T]^{-2} = [L]^2[T]^{-2}$ (∵3 is dimensionless)

Hence, $2aS = V_f^2 - V_i^2$ is dimensionally correct.

Weaker responses revealed that candidates' lack of understanding and in-depth knowledge about the concept of dimension. Low scoring candidates had limited knowledge about the dimension of some basic physical quantities; like, mass, time and length but they were unable to apply these dimensions in validating and proving equations related to the mechanics.

Example:

L.H.S — $a = \frac{m}{s^{-2}}$, $S = m$

$[M][T^{-2}] \times [M]$ — $V_f^2 - V_i^2 = \Delta V^2 = \frac{m^2}{s^2}$

$= [M^2][T^{-2}]$

R.H.S — L.H.S = R.H.S

$V_f^2 - V_i^2 = \Delta V^2$

$= [M^2][T^{-2}]$

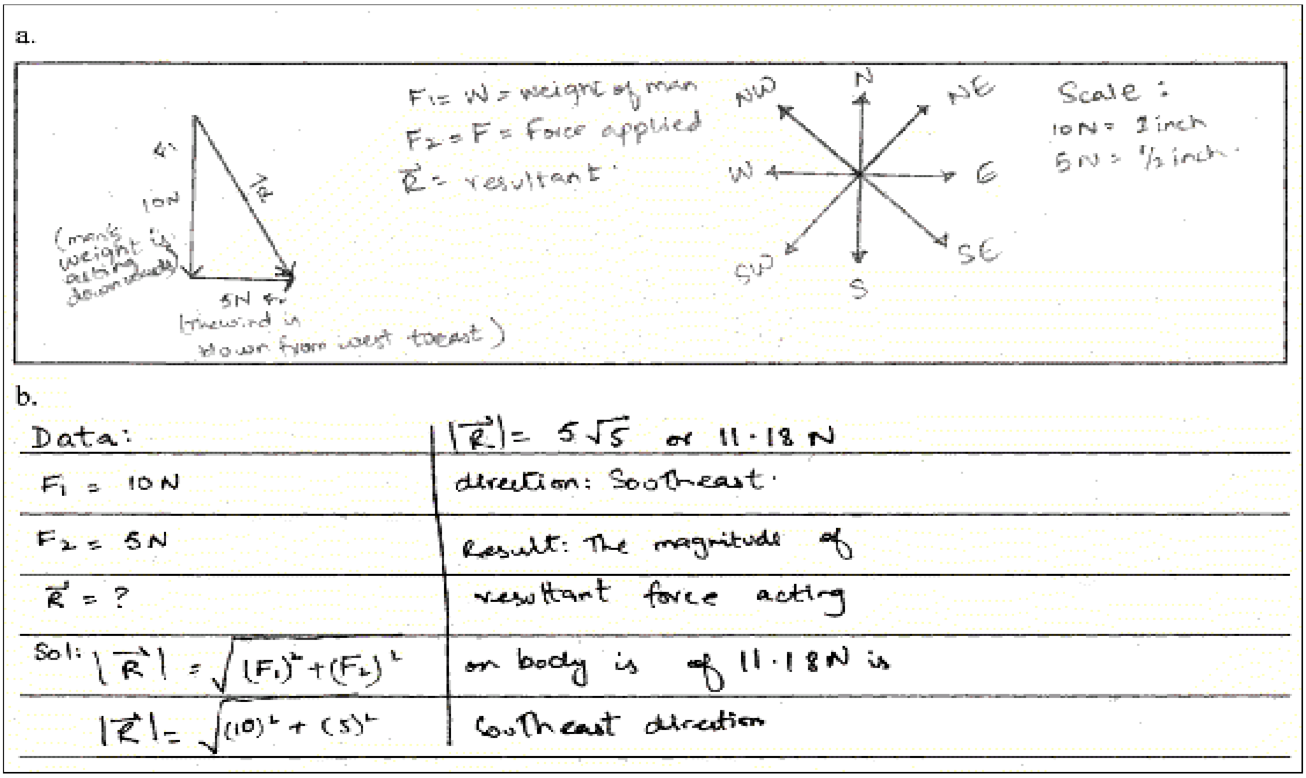
Question 3:

An object undergoes a free fall motion. The weight of the object is 10 N and a force of 5 N is applied on the object by the wind blowing from west to east.

a. Sketch a labelled diagram to determine the resultant force.
b. Calculate the magnitude of the resultant force acting on the object.

Better responses sketched and determined the labelled diagram and resultant force respectively in part (a). One of the better response examples is shown in the below image. Similarly, high scoring candidates correctly calculated the magnitude of the resultant force by applying the formula, $F = \sqrt{F_x^{\,2} + F_y^{\,2}}$.

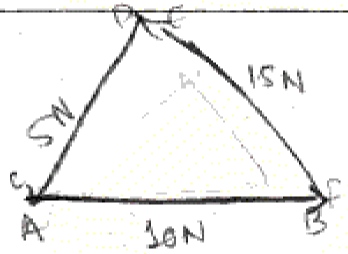
Example:



Weaker responses reflected that candidates were unable to sketch the labelled diagram and therefore, failed to determine the resultant force. Some of the candidates also could not calculate the magnitude of the resultant force correctly.

Example:

a.



b.

Data:

w = 10N

F = 5N

Ef = AB + CD

Ef = 10N + 5N

Ef = 15N

Question 4:

Identify and discuss the principle used in airbags, truck's arrestor beds and bending your knees when you jump off a chair and land on the ground.

Most candidates were not able to perform well in this question.

Better responses presented correct identification and discussion on the principle used in airbags, truck's arrestor beds and bending knees when a person jumps off a chair and lands on the ground. High scoring candidates discussed the impulse as it improves safety and reduces the chances of injuries, change in momentum, time during when the change in momentum is increased, forces that produced by colliding vehicles with different objects and in term of the formula, $F = \Delta P / \Delta t$.

Example:

> Airbags, truck's arrestor and bending of knees work on principle of impulse. They increase the time interval of impact and decrease the impulsive force. Impulse is change in momentum caused by impulsive force. When you get in a accident, the above given methods increase the time interval of impact, due to which you can avoid severe injuries.

Weaker responses presented incomplete or partially correct identification and discussion. In many cases, low scoring candidates wrote about torque, turning effect of force, rotation, equilibrium etc. which are irrelevant to the demand of the question.

Example:

> The principle used in airbags, truck's arrestor beds and bending your knees when you jump off a chair and land on the ground involves torque which is turning effect of force when we bend our knees our legs move around the axis of rotation i.e the knee which bends and it bend the legs and we can ~~no~~ move around or jump on the grand.

Question 5:

List any THREE sources of non-conventional energy.

The question was generally well-attempted by the candidates.

Better responses wrote correct list of three non-conventional energy sources. Most of the high scoring candidates wrote solar energy, geothermal, bio-mass, energy from tides and energy from waves as the non-conventional energy sources.

Example:

1. Solar Energy
2. Tidal Waves energy
3. Geothermal Energy

Weaker responses failed to list down all the correct non-conventional energy sources. Some of the candidates wrote wood, coal, petrol, diesel, papers, oil etc. in their answers which were totally irrelevant to the demand of the question.

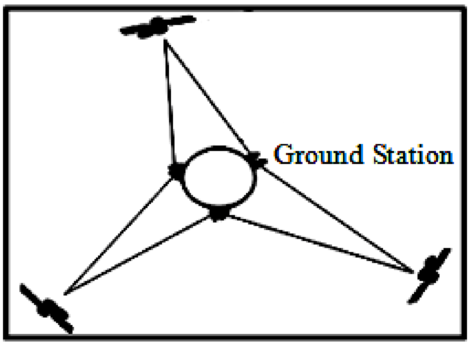
Example:

1. wood
2. Petroleum products like petrol, CNG, LPG
3. Coal

Question 6:

a. Describe geostationary satellites with respect to the given diagram.

b. Artificial gravity can be produced when a manned-satellite revolves around the Earth. Give TWO reasons to support the given statement.



Better responses correctly described geostationary satellites with respect to the given diagram in the question by mentioning that these satellites remain at a certain height above the equator of the earth and move in the same direction as the earth is rotating.

In the second part of the question, high scoring candidates wrote the reasons about artificial gravity which is produced when a manned-satellite revolves around the earth by writing that an artificial gravity is created in a satellite by spinning the satellite around its own axis, the amount of artificial gravity produced, rotation frequency and also depends on the radius of the satellite.

Example:

Geostationary satellites are satellites which orbit around the Earth with a time period synchronized with the rotation of Earth ie they orbit around the Earth in a time of exactly one day (24 hrs) and thus always seem to be at the same place over a specific point on Earth when looked. They are effective for communication and transmitting news of weather conditions.

b.

↳ Artificial gravity is produce in manned-satellite when it revolves around the earth around its axis by a frequency $f = \frac{1}{2\pi}\sqrt{\frac{g}{R}}$ same as of earth, allowing it to experience of force of gravity similar as on Earth. ↳ Due to this frequency (when R = 10m, f = 0.157 Hz) a force is exerted /experienced by the objects within a satellite which pulls them and the effect of weightlessness is eliminated. Astronaut exerts a force on the rim of satellite and feet feel like at Earth, giving us with artificial gravity during its revolution.

Weaker responses demonstrated that candidates were unable to describe geostationary satellites. Some of low scoring candidates were also failed to provide the reason in support of the artificial gravity that can be produced when a manned-satellite revolves around the earth. They wrote about the gravitational field, mass and velocity of a revolving object around the earth which are irrelevant to the demand of the question.

Example:

The geostationary satellites are objects moving around the earth's surface with a very high constant speed so that Earth doesn't pull them down due to its gravitational force.

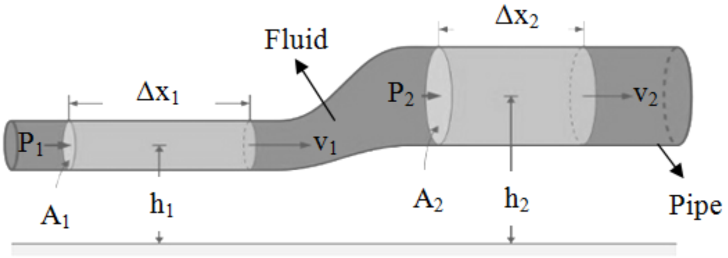
b.

→ When a satellite revolves around the earth's surface under the gravitational field the revolving speed stops it from falling on earth and it produces artificial gravity in satellite.

→ Gravity depends on mass and velocity of revolving of object so it can be produced.

Question 7:

a. By looking at the given diagram of a pipe, write an appropriate equation for the fluid flow.



b. To understand features of fluids in motion, the behaviour of fluids should satisfy THREE conditions. Mention these conditions.

The question was generally well-attempted by the candidates.

Better responses correctly wrote the equation for the fluid flow as $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$ (or) $A_1V_1 = A_2V_2$ and in the second part of the question, most of the high scoring candidates mentioned all three conditions of fluids' behaviour, like, incompressible fluid, non-viscous fluid and steady state flow/ streamline flow.

Example:

$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

b.

1. Fluid flow should be streamline.
2. Fluid should be incompressable.
3. Fluid should be non-viscous.

Weaker responses depicted that candidates were able to write the correct equation for the fluid flow but, few of the low scoring candidates failed to write the conditions of fluids' behaviour. They wrote about the area of pipe, pressure and speed/ velocity of the fluid(s), turbulent flow, viscosity of a fluid etc. which are irrelevant to the demand of the question.

Example:

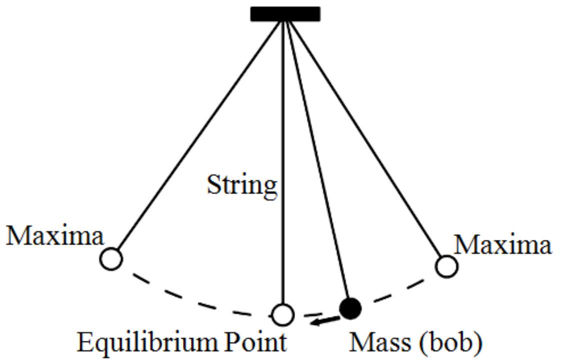
$$P_1 + \rho g h_1 + \frac{1}{2} m v_1^2 = P_2 + \rho g h_2 + \frac{1}{2} m v_2^2$$

b.

1. ~~The area where speed of fluid is higher than~~
2. less Area will provide high speed to fluid.
3. high pressured area have less speed of fluid

Question 8:

A simple pendulum consists of a point mass (bob) suspended by a weightless and inextensible string from a fixed support.



Mention TWO factors on which time period of simple pendulum depends.

The question was generally well-attempted by the candidates.

Better responses presented the correct factors on which the time period of a simple pendulum depends, like, the one shown in the below example of better response image.

Example:

1. Length of the pendulum
2. Gravitational acceleration (ie force due to gravity)

Weaker responses revealed that candidates were unable to write the correct factors that showed lack of understanding and in-depth knowledge about this very basic topic of simple pendulum. Most of the candidates wrote about amplitude, mass, velocity of the simple pendulum which were irrelevant to the demand of the question.

Example:

1. It depends on the amplitude
2. It depends on mass.

Question 9:

Describe any THREE characteristics of simple harmonic motion.

Better responses depicted that candidates correctly described all three characteristics of simple harmonic motion. For example, acceleration is always directed to the equilibrium position or mean position, acceleration is proportional to the displacement, force is directly proportional to the displacement of the body measured from its mean position or equilibrium position, total energy of mass executing SHM is conserved throughout its displacement and mass executing SHM moves under the action of a restoring force.

Example:

1) Simple harmonic motion is to and fro movement of a body which performs periodic motion. (2) The velocity of an object is maximum at the mean position and P.E is maximum at the extreme position. (3) The acceleration is always directed toward the center, opposite to the direction of displacement i.e $a = -x\omega^2$

In weaker responses, candidates were not able to properly articulate their answers. Some of the low scoring candidates wrote about the to and fro motion, free and forced vibrations, motion of a simple pendulum etc. which were irrelevant to the demand of the question.

Example:

1, To and Fro motion two towards the mean position.
2) No restriction, free motion.
3, Simple harmonic motion stops after the short interval of time.

Question 10:

'A radar works to determine the elevation and speed of an airplane using the principle of Doppler's effect.'

Explain the working of a radar system with the help of the given statement.

Most candidates were not able to perform well in this question.

Better responses correctly explained the working of a radar system. High scoring candidates explained the working as it uses radio waves to determine the elevation and speed of an airplane and it is a device which transmits and receives radio waves. Furthermore, when an airplane approaches towards the radar, then the wavelength of the wave reflected from airplane would be shorter and it moves away, then the wavelength would be larger that can determine the distance at different time period, elevation and speed.

Example:

In a radar system, the radar gives off radiowaves which are reflected back by a moving plane. When the plane is moving towards the earth then the waves which are reflected back and received have a reduced wavelength as compared to the original wavelength from source. Similarly if the plane is moving away then the reflected waves have an increased wavelength. This Doppler shift allows us to calculate the speed of the airplane (observing object) as well its frequency. It is helpful in warfare and navigation.

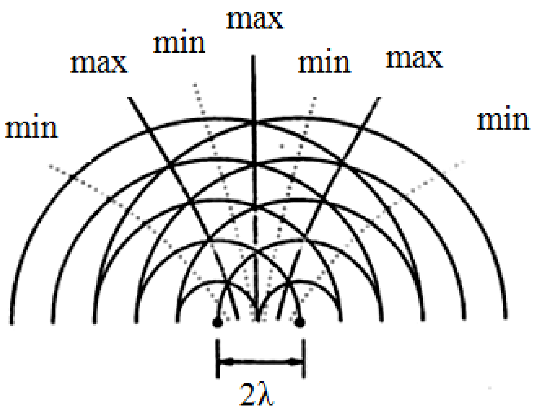
Weaker responses exhibited that candidates were unable to explain the working of a radar system. Some of the low scoring candidates wrote the phenomena of Doppler's effect and its different cases which were not the demand of the question.

Example:

Radar works on the principle of Dopplers effect. Radar send its wave with the help of medium (air) to observer because of which radar (source) dectect the properties like velocity, speed, size etc of a thing.

Question 11:

a. Identify the phenomenon of light shown in the given diagram.



b. Define the phenomenon identified in part (i).

c. State any TWO conditions required for the occurrence of this phenomenon.

Most candidates were not able to perform well in this question.

Better responses correctly identified and defined the phenomenon of light shown in the given diagram as the 'interference of light waves' and it happens when two light waves of same frequency and amplitude traveling in the same direction are superimposed in such a way that they support each other at some points while cancel at the other points. Most of the high scoring candidates also stated the correct conditions for the occurrence of interference of light waves. For example, sources should be monochromatic, coherent/ in same phase, must lie very close to each other and should be very narrow and slit size should be comparable to the wavelength.

Example:

a.

Interference of light.

b.

When two waves of light travelling in the same medium, with same direction and have the same frequency or are generated by a source having same frequency superpose then it is called interference. In constructive interference, the amplitude of resultant wave is greater than the individual waves, in destructive interference it is less than both.

c.

1) For interference of light occurs when the two waves are monochromatic ie have a single wavelength.

2) For interference the two waves must be coherent ie have a constant phase difference with respect to each other.

Weaker responses showed candidates' inability to identify and defined the phenomenon of light, they wrote about beats, defined it. Furthermore, some of the low scoring candidates stated the different cases of Doppler's effect which were irrelevant to the demand of the question.

Example:

a.
Beats

b.
Beats is the phenomenon in which two sound waves with slightly different frequeinces are kept together.

c.
1. The frequency of both the sound waves must slightly differ from each other.
2. Both the sound waves should be driven from two different sources.

Question 12:

A Carnot heat engine with an efficiency of 65% absorbs heat from a reservoir at 590 K. Calculate the exhaust temperature of the engine.

The question was generally well-attempted by the candidates.

Better responses correctly calculated the exhaust temperature of the Carnot heat engine. High scoring candidates wrote the correct formula of Efficiency (%) $= \left(1 - \frac{T_2}{T_1}\right) \times 100$ and mentioned the value of temperature as 206.5 K.

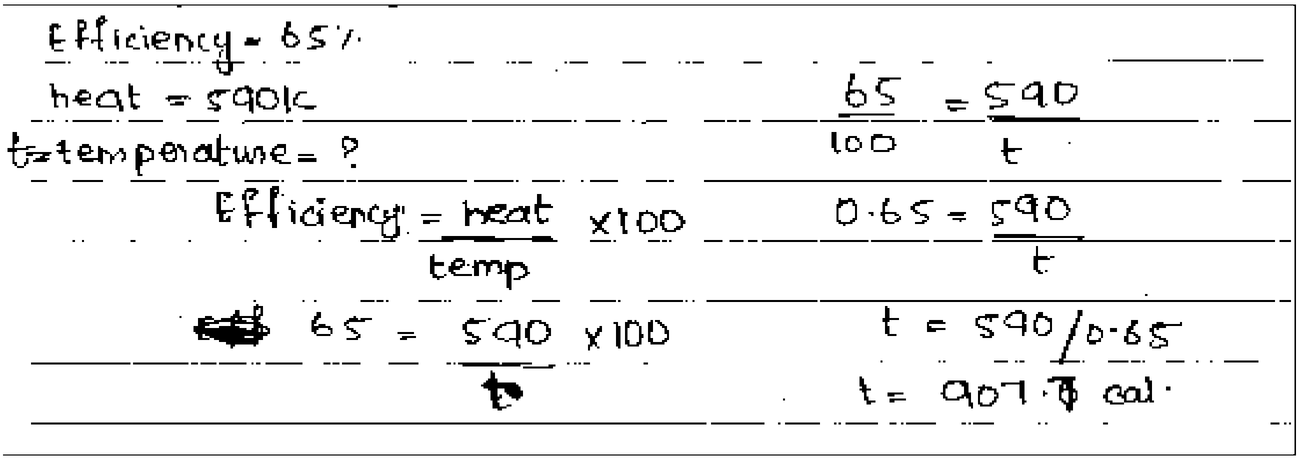
Example:

$T_1 = 590$ K
efficiency = 65%
$T_2 = ?$
Efficiency (η)% $= \left(1 - \frac{T_2}{T_1}\right) 100$
$65 = \left(1 - \frac{T_2}{590}\right) 100$
$65 = \frac{590 - T_2}{590} \times 100$

$3835 = 5900 - 10T_2$
$10T_2 = 5900 - 3835$
$T_2 = \frac{2065}{10} = 206.5$ K
$T_1 - T_2 = 590 - 206.5$
$= 383.5$ K
The exhaust temperature of the engine is 383.5

Weaker responses revealed that candidates were unable to calculate the exhaust temperature of the Carnot heat engine. Some of low scoring candidates even failed to write the correct formula of efficiency and therefore, could not found the correct value of temperature.

Example:



Efficiency = 65%
heat = 590K
t = temperature = ?
Efficiency = $\frac{heat}{temp} \times 100$
$65 = \frac{590}{t} \times 100$

$\frac{65}{100} = \frac{590}{t}$
$0.65 = \frac{590}{t}$
$t = 590/0.65$
t = 907.[illegible] cal.

Extended Response Questions (ERQs)

These questions offered a choice between part **a** and **b**

(**Note**: Majority of the candidates attempted Question **13a** and they scored well in this part.)

Question 13a:
Derive mathematical relationship between force, velocity and power applied on a moving object.

The question was generally well-attempted by the candidates.

Better responses correctly derived a mathematical relationship between force, velocity and power applied on a moving object. Most of the high scoring candidates mentioned the following mathematical steps shown in the given example of better response image.

Example:

(a)

'P' Power is defined as Workdone 'W' in given time 't'. SI unit of power is Watt.

mathematically $P = \frac{W}{t}$ — ①

Workdone 'W' is defined as dot product of force '$\vec{F}$' and displacement '$\Delta\vec{d}$', mathematically

$W = \vec{F}\cdot\Delta\vec{d}$ — ②

substituting value of 'W' i.e ② in ①.

$P = \frac{\vec{F}\cdot\Delta\vec{d}}{t} \Rightarrow P = \vec{F}\cdot\frac{\Delta\vec{d}}{t}$ — ③

$\frac{\Delta\vec{d}}{t}$ expression is defined as change in displacement in the given time 't' as velocity '$\vec{v}$' $\Rightarrow \vec{v} = \frac{\Delta\vec{d}}{t}$

Substituting $\vec{v} = \frac{\Delta d}{t}$ in — ③

$\boxed{P = \vec{F}\cdot\vec{v}}$

Hence $P \propto \vec{F} \rightarrow$ applied force

$P \propto \vec{v} \rightarrow$ velocity of object.

Weaker responses showed that candidates misunderstood the question. Few of the low scoring candidates first tried to prove dimensionally, assumed some values of force, velocity and power and lastly, put these supposed values in relation $P = F.v$ that showed their lack of understanding on the given concept.

Example:

$P \propto F \propto v$, where F = force, P = power, v = velocity

$P = \text{constant } F.v$ ∴ $P = [M][L]^2[T]^{-3}$, $F = [M][L][T]^{-2}$

$P = (F)^a.(v)^b.$ ∴ $V = [L][T]^{-1}$

$[M][L]^2[T]^{-3} = [M]^a[L]^a[T]^{-2a}.[L]^b[T]^{-1b}$

$\Rightarrow [M] = [M]^a$, $a = 1$

$\Rightarrow [L]^2 = [L]^{a+b}$, $a+b = 2$, $1+b = 2$, $b = 1$

$[T]^{-3} = [T]^{-2a-b}$, $-3 = -2a - b$, $-3 = -2(1) - 1$, $-3 = -3$.

relation formula is derived by taking the dimensional analysis putting values of exponents.

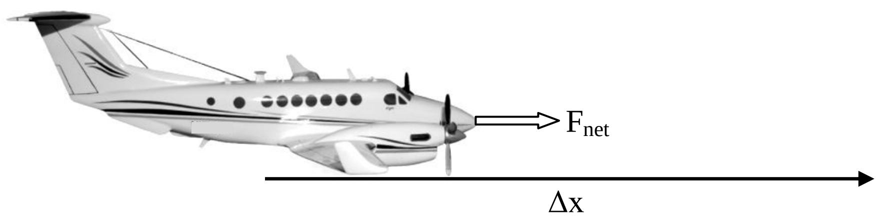
$F^a.v^b = P = kF^1.V^1 = P$

$P = kF.V$ → relation derived.

$P = \text{constant } F.V$, $P = F.V$

Question 13b:

A constant force (F_{net}) acts on an airplane of mass (m) and it covers a distance (Δx) with an increase in its velocity from (v_i) to (v_f).



Deduce an equation of the work-energy principle for the given situation.

Better responses correctly deduced the equation of the work-energy principle for the given situation in the question. Most of the high scoring candidates deduced the required equation by the method shown in the given example of better response image.

Example:

b. Work is a way of transfer of energy. It is product of magnitude of force and displacement and cosine angle between them

$W = F \cdot d = |F||d| \cos\theta$

$= |F||\Delta x| \cos(0°) \quad (d = \Delta x)$

$= m a \Delta x \text{ —(i)} \quad (\because F = ma)$

By using third equation of motion

$2as = V_f^2 - V_i^2$

$2a\Delta x = V_f^2 - V_i^2 \quad (\because S = \Delta x)$

$a\Delta x = \frac{V_f^2 - V_i^2}{2}$

Substituting value of $a\Delta x$ in eq(i)

$W = m\left(\frac{V_f^2 - V_i^2}{2}\right)$

$W = \frac{1}{2}mV_f^2 - \frac{1}{2}mV_i^2$

$\therefore W_{net} = \Delta K.E$

So, net work done is equal to change in kinetic energy.

Weaker responses failed to deduce the equation of the work-energy principle. In some of the low scoring responses, law of conservation of energy was written. This showed lack of in-depth understanding of the candidates on this topic. One of the example of this kind of answer is shown in the given weaker response image.

Example:

$$(P_1 - P_2)\frac{m}{\rho} = K.E + P.E$$

$$(P_1 - P_2)\frac{m}{\rho} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 + mgh_2 - mgh_1$$

$$(P_1 - P_2)\frac{m}{\rho} = m\left(\frac{1}{2}v_2^2 - \frac{1}{2}v_1^2 + gh_2 - gh_1\right)$$

$$P_1 - P_2 = \rho\left(\frac{1}{2}v_2^2 - \frac{1}{2}v_1^2 + gh_2 - gh_1\right)$$

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho gh_2 - \rho gh_1$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$$

$$\boxed{P + \frac{1}{2}\rho v^2 + \rho gh} = \text{constant}$$

$$\rho_1 v_1 = \rho_2 v_2$$

(**Note**: Majority of the candidates attempted Question **14a** and they scored well in this part. In both parts, candidates who did not score well lacked understanding of the speed of sound and its related topics.)

Question 14a:

Describe Newton’s formula for the speed of sound in air and the correction made by Laplace to this formula.

Better responses correctly described Newton’s formula for the speed of sound in air and the correction made by Laplace in this formula. Most of the high scoring candidates wrote in their answers two most important mathematical steps along with other substitution steps which were $v = \sqrt{\frac{P}{\rho}}$ and $v = \sqrt{\frac{\gamma P}{\rho}}$.

Example:

According to the newton $v = \sqrt{\frac{P}{\rho}}$ at constant temperature. But laplace made a correction that compressions and rarefactions are so fast that there is no time to deliver heat to neighbouring regions. So he proposed a formula ie: PV^{γ} where γ is

$$\gamma = \frac{\text{molar specific heat at constant pressure}}{\text{molar specific heat at constant volume}}$$

Changes made in Newton's formulas were derived as below:

$$(P + \Delta P)(V - \Delta V)^{\gamma} = PV^{\gamma}$$

$$(P + \Delta P)V^{\gamma}\left(1 - \frac{\Delta V}{V}\right)^{\gamma} = PV^{\gamma}$$

$$(P + \Delta P)\left(1 - \frac{\Delta V}{V}\right)^{\gamma} = P$$

Applying Binomial theorem

$$(P + \Delta P)\left(1 - \frac{\gamma \Delta V}{V}\right) = P$$

$$P - \frac{P\gamma \Delta V}{V} + \Delta P - \frac{\Delta P \Delta V \gamma}{V} = P$$

Neglecting $\frac{\Delta P \Delta V \gamma}{V}$

$$\Delta P - \frac{P\gamma \Delta V}{V} = 0$$

$$-\frac{P\gamma \Delta V}{V} = -\Delta P$$

$$P\gamma = \frac{\Delta P}{\Delta V / V} = E$$

Thus, $v = \sqrt{\frac{P\gamma}{\rho}}$ (laplace formula).

Weaker responses showed that candidates were unable to describe Newton's formula and the correction made by Laplace on it. They wrote about speed of sound in air and in different media. Some of candidates wrote only one correct mathematical step that was $v = \sqrt{\frac{p}{\rho}}$ but failed to provide complete mathematical evidence of Laplace's correction.

Example:

Newton's formula for the speed of sound
in air was that he done a mistake
while make a formula and the
mistake was corrected by laplace
The formula of newton is

$$v = \sqrt{\frac{\rho}{\rho}}$$

there is a mistake γ is
a constant which was added
by laplace to this formula
and γ is the constant so by
this formula we can get the
exact value of sound in air
which is 334

Question 14b:

i. The speed of sound is affected by the variation of pressure, temperature and air density of the atmosphere.
Discuss the given statement by showing mathematical relations and how temperature and density of air affects the speed of sound in gases.

ii. 'The speed of sound is much higher in solids than that of liquids and gases.'
Justify the given statement.

Better responses correctly discussed the factors on which the speed of sound depends like; the variation of pressure, temperature and air density of the atmosphere by writing all the important mathematical steps. For example, $v \alpha \sqrt{T}$, $v=\sqrt{\frac{\gamma P}{\rho}}$, $E=\frac{\Delta P}{\Delta V / V}$ and $v=\sqrt{\frac{E}{\rho}}$.

In the second part of the question, high scoring candidates correctly justified that the speed of sound is much higher in solids than that of liquids and gases by writing that the molecules in solid are closer to each other than in liquid and gas. These molecules respond more quickly to any disturbance and as well as the elastic effect of solids is greater than their density effect. Therefore, sound waves travel faster in solids than in gases

Example:

b. 1. Effect of Pressure: Speed of sound is independent of pressure because pressure doesn't affects the speed of sound.

2. Effect of temperature:

- Speed of sound is affected by variation in temperature because when temperature increases speed of sound also increases similarly, speed of sound decreases with decrease in temperature.

$$V \propto \sqrt{T}$$

Speed of sound is directly proportional to the square root of temperature.

3. Effect of Density:-

Speed of sound is inversely proportional to density of air because speed of sound is higher in those where density is lesser but speed of sound is lower in those with higher density. $V \propto \frac{1}{\rho}$

e.g speed of sound is higher in Hydrogen but lower in oxygen because of difference in their densities.

ii. The speed of sound is much higher in solids than that of liquids and gases, because molecules of solids are more compressed than liquids and gases and also the elastic modulus of solids is higher.

Weaker responses revealed that the candidates were unable to provide all the relevant description neither in the discussion nor in the reasoning part. Some of the low scoring candidates mentioned few of the correct mathematical relations, like, $v \alpha \sqrt{T}$, $v \alpha \sqrt{P}$, etc.

Example:

b:

inversely

(i) Speed of sound is proportional to pressure.

$V \alpha \frac{1}{P}$

Speed of sound is directly proportional to temperature.

$V \alpha T$

Speed of sound is directly proportional to density.

$V \alpha \sqrt{\rho}$

When temperature of gase increases, sound travels faster from it as kinetic energy of molecule is higher, they absorb, vibrate and release sound energy much more faster.

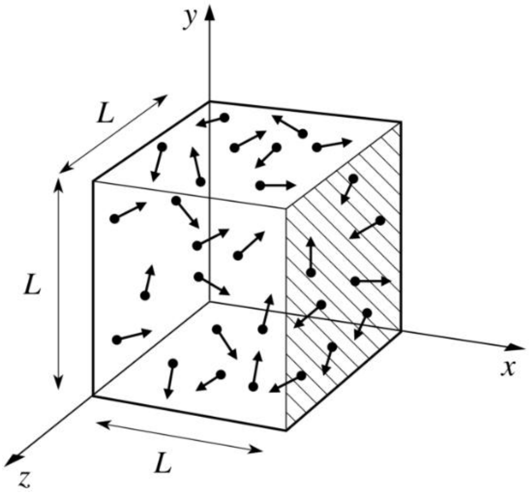
When the density of air is greater, its molecule come closer to each other, in that case speed of sound will be greater, as molecules are closer, they will vibrate faster and transfer there energy to neighbouring molecule much quicker.

(ii) Speed of sound is much higher in solids because molecules of sound are tightly packed, they will vibrate at fastest level when energy is provided to them. the molecules of liquid as compared to solid are much apart so, they vibrate greater than gas molecule but slower than solids. As is the case gas in which molecules are much apart, less vibrate and low sound speed.

Majority of the candidates attempted Question **15b** and they scored well in this part.

Question 15a:

The given figure shows a cube of length **L**.



The pressure exerted by the gas molecules in one dimension inside this cube is equal to $P_x = \frac{m}{V} N v_x^2$, where ($P_x$) is the pressure in one dimension, (m) is the mass of the gas, (N) is the total number of molecules, (v_x^2) is the average square speed of the molecules in one dimension.

Deduce an equation for the total pressure exerted by the gas molecules inside the cube.

Better responses correctly deduced the equation for the total pressure exerted by the gas molecules inside the cube given in the question. Most of the high scoring candidates mentioned all the important mathematical steps in their derivation. For example, $P_x = \frac{m}{V} N {v_x}^2$, $v^2 = {v_x}^2 + {v_y}^2 + {v_z}^2$

$v^2 = 3vx^2$, $P_x = \frac{m}{V} N v_x^2$, $vx^2 = \frac{1}{3} v^2$ and $P = \frac{1}{3V} mNv^2$.

Example:

Consider a molecule strikes the wall ABCD with some initial momentum and the strike is supposed to be perfectly elastic so the molecule travels along x-axis and strikes wall EFGH & again bounces back to the wall ABCD covering the distance 2L then

Initial momentum of molecule = mV_x

Final momentum of molecule = $-mV_x$

Change in momentum = $-2mV_x$ — (i)

time taken to cover 2L distance is given as $\Delta t = \frac{2L}{V_x}$ — (ii)

Rate of change in momentum is give as

$$= \frac{-2mV_x}{\frac{2L}{V_x}} = -\frac{mV_x^2}{L}$$

This rate of change in momentum is also equals to the force exerted by wall on the molecule then the molecule also exerts a force on the wall with equal magnitude but in opposite direction. $= -\left(-\frac{mV_x^2}{L}\right)$

$$F_x = \frac{mV_x^2}{L}$$

The total force exerted along the x-axis is given as

$$F_{total\,x} = \left(\frac{mV_{x1}^2}{L} + \frac{mV_{x2}^2}{L} + \ldots \frac{mV_{xn}^2}{L}\right)$$

Since we know $P = F/A$ and

so $P = \dfrac{\left(\frac{mV_{x1}^2}{L} + \frac{mV_{x2}^2}{L} + \frac{mV_{x3}^2}{L} + \ldots \frac{mV_{xn}^2}{L}\right)}{L^2}$

$$P = \frac{1}{L^3}\left(mV_{x1}^2 + mV_{x2}^2 + \ldots\right)$$

$$P = \frac{m}{L^3}\left(V_{x1}^2 + V_{x2}^2 + V_{x3}^2 + \ldots n\,term\right)$$

$$\because \left(V_{x1}^2 + V_{x2}^2 + V_{x3}^2 + \ldots n\right) = \overline{V_x^2}$$

$$P = \frac{m}{L^3}\overline{V_x^2} \quad \text{— (iii)} \qquad \because \frac{m}{L^3} = \rho$$

$$P = \rho\overline{V_x^2}$$

$$\overline{V^2} = \overline{V_x^2} + \overline{V_y^2} + \overline{V_z^2}$$

Since $\overline{V_x^2} = \overline{V_y^2} = \overline{V_z^2}$

$$\overline{V^2} = 3\overline{V_x^2}$$

$$\overline{V_x^2} = \frac{1}{3}\overline{V^2} \quad \text{— (iv)}$$

putting equation iv in eq (i) we get

$$P = \frac{1}{3}\rho V_x^2 \quad \text{— (v)}$$

This Equation is also known as Kinetic Equation.

Weaker responses reflected that the candidates break the complete derivation into small segments; like, in *x*, *y* and *z* axis unnecessarily. Few of the low scoring candidates were only able to derive the equation uptill the pressure exerted by a single molecule of a gas.

Example:

As for elastic collision momentum is the ~~force~~ equal to mv^2. The force applied by container ~~in~~ is equal to $-mv^2$.

$$F_x = F_{1x} + F_{2x} + \dots + F_{Nx}$$

$$F_y = F_{1y} + F_{2y} + \dots + F_{Ny}$$

~~$A_x = A_{1x} + A_{2x} + \dots + A_{Nx}$~~

~~$A_y = A_{1y} + A_{2y} + \dots A_{Ny}$~~

$$P_x = \frac{F_{1x}}{A} + \frac{F_{2x}}{A} + \dots \frac{F_{Nx}}{A}$$

$$P_y = \frac{F_{1y}}{A} + \frac{F_{2y}}{A} + \dots \frac{F_{Ny}}{A}$$

$$P_x = \frac{1}{A}\left[F_{1x} + F_{2x} + \dots + F_{Nx}\right]$$

$$P_y = \frac{1}{A}\left[F_{1y} + F_{2y} + \dots + F_{Ny}\right]$$

$$P_x + P_y \quad P_x = \frac{m}{V} N v_x^2$$

$$P_y = \frac{m}{V} N v_y^2$$

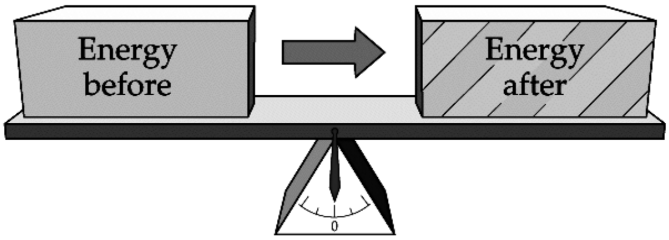
$$P_x + P_y = \frac{m}{V} N v_x^2 + \frac{m}{V} N v_y^2 \qquad \because \frac{m}{V} = \rho$$

$$= \rho N v_x^2 + \rho N v_y^2$$

$$= \rho N (v_x^2 + v_y^2)$$

Question 15b:

i. Interpret the given diagram in light of the first law of thermodynamics. Provide a mathematical equation to support your interpretation.



ii. Deduce an equation for the first law of thermodynamics in the isothermal process.

Better responses correctly interpreted the given diagram in light of the first law of thermodynamics along with mathematical equation. For example, high scoring candidates wrote about the total energy in a closed system is constant, means that energy is conserved in any transfer of energy from one form to another and the heat absorbed by the system/ gas is partly turned into work done while the remainder causes an increase in the internal energy of the system/ gas. This relation can be shown mathematically as, $\Delta Q = \Delta U + \Delta W$.

Example:

i) The given diagram indicates that the work has been done on it, and shows the energy changes.

Energy is increased.

1^{st} law of Thermodynamics is:-

$$\Delta Q = W + \Delta U$$

where, ΔQ is the change in heat, W is the work done on a body. ΔU is change in internal energy.

(ii)

1^{st} law of Thermodynamics:-

$$\Delta Q = W + \Delta U$$

For Isothermal process:-

$$\Delta Q = W + \cancelto{0}{\Delta U} \quad \because \Delta U \text{ is zero.}$$

ΔU is reaching zero because in Isothermal process temperature is constant, then of Course internal energ (U) will be constant (zero).

Weaker responses showed that the candidates were unable to completely articulate their answers. Few of the low scoring candidates wrote law of conservation of energy, heat gain and lost and while expressing mathematical expressions, they wrote mathematical relations about isobaric, isochoric, adiabatic and isothermal processes.

Example:

i) This Diagram says that energy before is equal to energy after. This is indeed true as we know through the law of conservation of energy that energy can neither be created nor be destroyed but is lost in the waste of heat, sound and resistance.

ii) $\Delta Q = \Delta U + P\Delta T$

for Iso-thermal

$\Delta Q_p = \Delta U + P\Delta V$

since $\Delta Q_p = nC_p\Delta T$ so,

$nC_p\Delta T = \Delta U + P\Delta V$

$$\boxed{nC_p\Delta T + P\Delta V = \Delta U}$$