

The harmonic mean of a set of positive numbers is the reciprocal of the set of numbers. That is, if $a_1, a_2, \dots, a_n$ are positive numbers, then $\frac{1}{a_1}, \frac{1}{a_2}, \dots, \frac{1}{a_n}$ are the reciprocals of the set of numbers. Thus, if $a_1, a_2, \dots, a_n$ are positive numbers, then $\frac{1}{a_1}, \frac{1}{a_2}, \dots, \frac{1}{a_n}$ are the reciprocals of the set of numbers. Thus, if $a_1, a_2, \dots, a_n$ are positive numbers, then $\frac{1}{a_1}, \frac{1}{a_2}, \dots, \frac{1}{a_n}$ are the reciprocals of the set of numbers.

$$\frac{1}{\frac{1}{a_1} + \frac{1}{a_2} + \dots + \frac{1}{a_n}}$$

and the reciprocal of this arithmetic mean, that is the harmonic mean of the numbers.

$$\frac{1}{\frac{1}{a_1} + \frac{1}{a_2} + \dots + \frac{1}{a_n}}$$

Definition 5.5

The harmonic mean of a set $\{a_1, a_2, \dots, a_n\}$ of positive numbers is defined as

$$\frac{1}{\frac{1}{a_1} + \frac{1}{a_2} + \dots + \frac{1}{a_n}}$$

In particular, the harmonic mean of two positive numbers a and b is $\frac{2ab}{a+b}$.

It can be proved that "For any set of n positive numbers, the geometric mean is equal to the harmonic mean". That is, $GM \geq HM$.

Let us prove this inequality $GM \geq HM$ for two non-negative numbers.

Theorem 5.3: If GM and HM denote the geometric mean and the harmonic mean of two positive numbers, then $GM \geq HM$. The equality holds if and only if $a = b$.

Proof: Let a and b be any two positive numbers. Then

$$GM = \sqrt{ab} \text{ and } HM = \frac{2ab}{a+b}$$

$$GM - HM = \sqrt{ab} - \frac{2ab}{a+b}$$

$$= \frac{\sqrt{ab}(a+b) - 2ab}{a+b}$$

$$= \frac{\sqrt{ab}(a+b) - 2ab}{a+b}$$

$$= \frac{\sqrt{ab}(\sqrt{a} - \sqrt{b})^2}{a+b}$$

$$\geq 0$$

Thus $GM - HM \geq 0$ and hence $GM \geq HM$.

Proof: Let a and b be any two positive real numbers. Then

$$AM = \frac{a+b}{2}, \quad GM = \sqrt{ab}, \quad \text{and } HM = \frac{2ab}{a+b}$$

$$AM \times HM = \left(\frac{a+b}{2}\right) \left(\frac{2ab}{a+b}\right) = ab = (\sqrt{ab})^2 = GM^2$$

Thus, $AM \times HM = GM^2$ and hence AM, GM and HM are in geometric progression.

We now list the following interesting results.

- If a, b, c are in arithmetic progression, then $\frac{1}{a}, \frac{1}{b}, \frac{1}{c}$ are in harmonic progression.
- If a, b, c are in geometric progression, then $\frac{1}{a}, \frac{1}{b}, \frac{1}{c}$ are in arithmetic progression.
- If a, b, c are in harmonic progression, then $\frac{1}{a}, \frac{1}{b}, \frac{1}{c}$ are in arithmetic progression.

If a vehicle travels at a speed of x kmph, covering certain distance and it returns the same distance with a speed of y kmph, then the average speed of the vehicle in the whole travel is the harmonic mean of the upward and downward speeds. Indeed, if d is the distance, then time taken for upward journey is $\frac{d}{x}$ and the time taken for downward journey is $\frac{d}{y}$.

$$\text{Then average speed is } \frac{2xy}{x+y}$$

For example, if a vehicle travels at a speed of 30 kmph, covering certain distance and it returns the same distance with a speed of 40 kmph, then the average speed of the vehicle in the whole travel is the harmonic mean of 30 and 40. That is, $\frac{2 \times 30 \times 40}{30+40} = 34.28$ kmph.

Exercise - 5.2

1. Write the first 5 terms of the sequences whose n^{th} terms are given below and classify them as arithmetic progression, geometric progression, arithmetic-geometric progression, harmonic progression and none of them.

$$(i) \frac{(n+1)(n+2)}{(n+3)(n+4)} \quad (ii) \left(\frac{1}{2}\right)^n \quad (iii) \frac{2n+1}{3n+4} \quad (iv) \frac{3n-2}{5n+1}$$

2. Write the first 5 terms of the sequences whose n^{th} term a_n is given below.

$$(i) a_n = \begin{cases} n+1 & \text{if } n \text{ is odd} \\ n & \text{if } n \text{ is even} \end{cases} \quad (ii) a_n = \begin{cases} 1 & \text{if } n = 1 \\ 2 & \text{if } n = 2 \\ a_{n-1} + a_{n-2} & \text{if } n > 2 \end{cases}$$

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