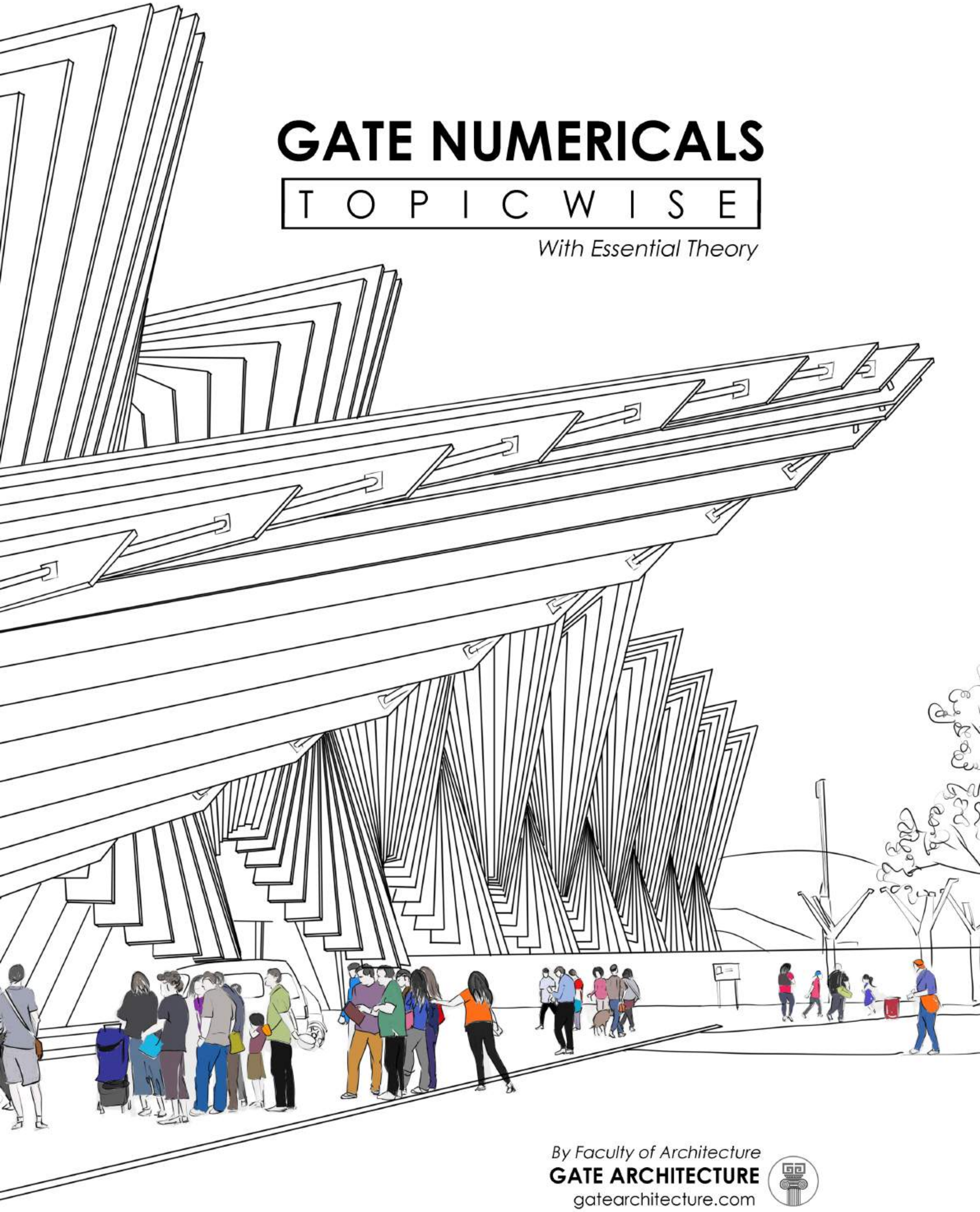
GATE NUMERICALS

TOPICWISE

With Essential Theory



By Faculty of Architecture

GATE ARCHITECTURE

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GATE NUMERICALS

TOPICWISE

by

GATE ARCHITECTURE

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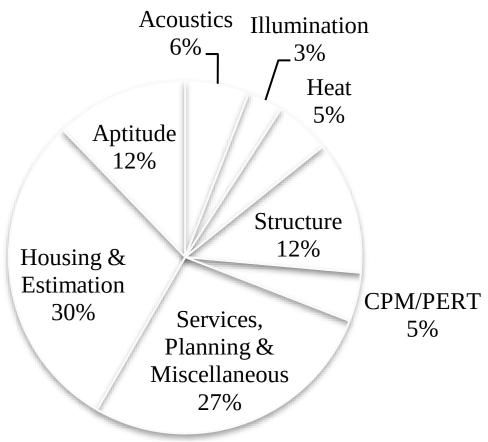


% Distribution of Numerical Questions (2020 - 1991)

Long contents:

Preface

This book will add an edge to your preparation by reviewing sets of numerical questions asked in previous years. In past few years, the pattern of numerical question has changed. It is observed that upto 40% marks are of numerical questions. In GATE 2020, there were total 19 numerical questions of out of total 65 questions. For most of the questions no option had been given. You have to answer the question by using keypad displayed on the screen. (Use of keyboard is prohibited. Touching any key would lock your monitor screen and you may not able to answer any further question!)

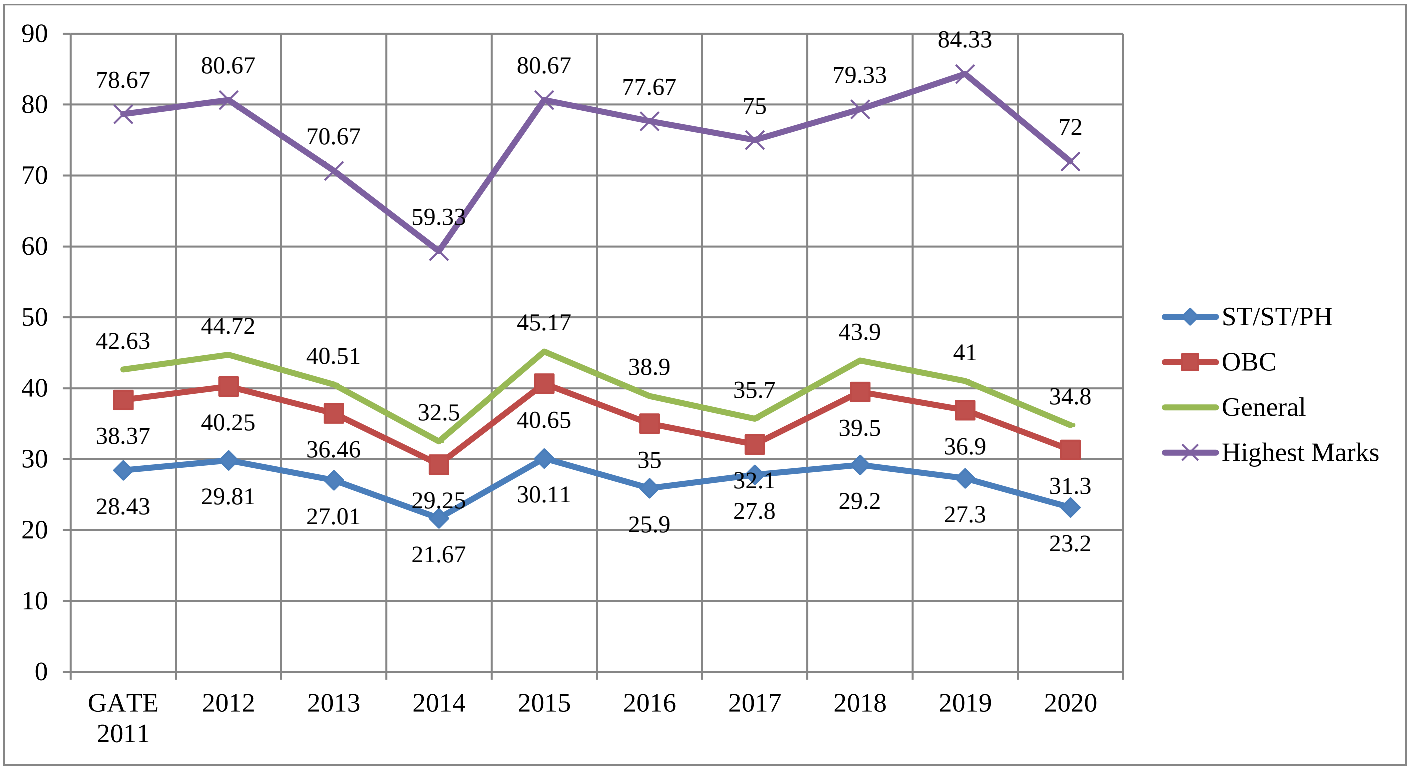
So, for such question pattern, you need through practice. We are hopeful that this book would meet the requirement.

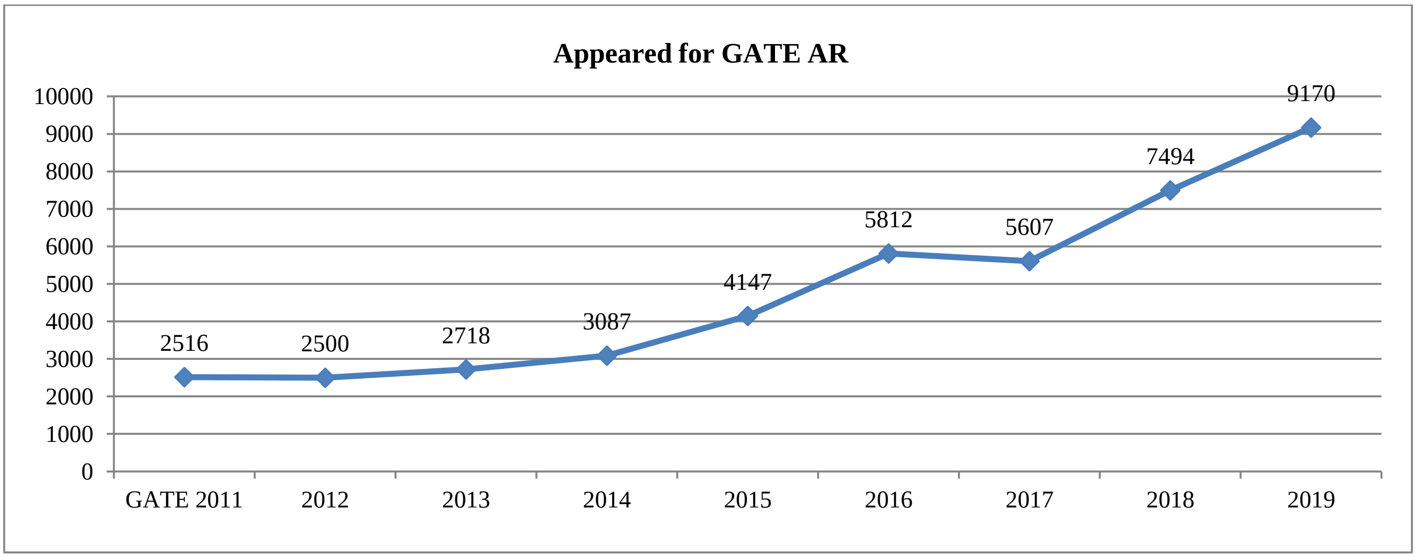
Answering an objective question has its own rule to follow when you have a doubt in choosing the right answer. For so, we have also attached expert opinion for handling objective question well.

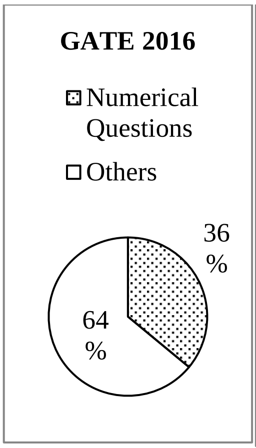
Topicwise Questions: It is an important feature of this book. Based on feedback of GATE aspirants.

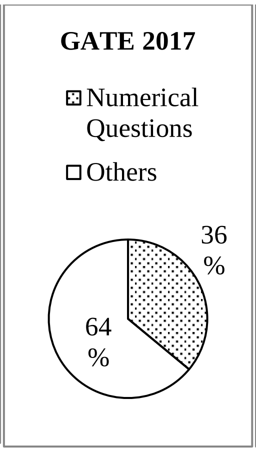
Essential Notes: It has been provided for each topic so that you could easily understand the concept. All questions have been solved except few. Alternative answers have been provided for few questions.

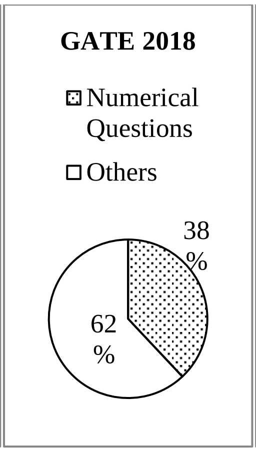
(GATE AR Cut-off marks & Highest mark trend):

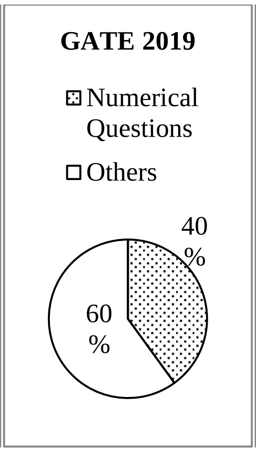


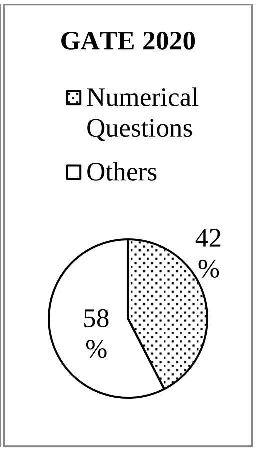












QR-code based book: We have been using QR-code based deep learning for our GATE reference books since 2015. It gave us encouragement when it came in news that a teacher Ranjitsinh Disale got shortlisted for $1mn Global Teacher Prize 2020 for using QR-codes based book for teaching in school.

GATE NUMERICALS TOPICWISE is very concise. It contains very exhaustive source of reference material for deep understanding of the subject. So, it has QR codes. Scan the code fur further studies if you need. There are many QR code scanner available on Google Play Store or apple App Store.

Scan to know more about Ranjitsinh Disale shortlisted for Global Teacher Prize 2020

We recommend you scan the QR-codes with the app that comes with your phone itself. Installing the ‘QR Code Reader’ app from the Google Play Store or the Apple App Store may contain advertisement that could be irritating and downgrade reading experience. Some phone can scan QR-codes directly with its camera itself without any app!

You are always welcome for your valuable suggestion and feedback about this book. If you find better contents or alternative solution, send us to gatearchitecture@gmail.com

We may add contents or solution by you in next reprint or edition!

In pursuit of constantly improving this book, we would delete or add the contains without prior information.

Happy reading. We wish you all the best for GATE 2021.

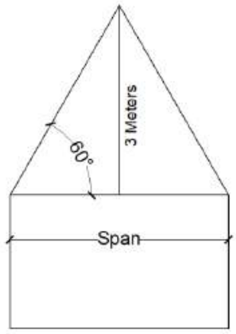
Fab Quote”
“The interesting observation is to try to work with people but even more than that to try to make them successful. If you try to make others successful, they, in turn, will try to make you successful. No matter how brilliant you are, no matter how good you are, no matter how hard you work, if you rely only on yourself and believe you don’t need the help of others, you are sadly mistaken. If you engage everybody around you by helping them, they will help you, in turn. And you will be more successful than you ever dreamed of.” – Former Director, Goldman Sachs

Tips & Tricks

Followings are tips & tricks for handling multiple choice questions suggested by experts from open source online resources. Please note that following insights are not only for Numerical Questions but also for all topics. Some of following are for paper bound exam (not online). You should skip those.

Tips for solving numerical problems:

Drawing the picture of the problem is very important! The correct picture of a numerical problem is more than 80 % of success.



Example (GATE 2013): If the slope of a hipped roof is 60º and height of the roof is 3 m, span of the room, in m, would be _____
Solution: Span of the room = 2 * (3/tan60º) = 3.46 answer.

Having the same units for all variables in the problem. You must ensure that you solve the problem in the same unit. For example, in a given question, force may be given 40 Newton (N) and length of the beam would be l = 50 centimetre. For easy and correct solution, you should change the length in meter (l= 0.5m). Tip: If the option is given as follows: (A) 50Pa (B) 5Pa (C) 10Pa (D) 100Pa. For this type of question, you must recheck your solution before you choose an answer.

Checking the dimensionality of analytical expressions. To arrive at correct answer, you should always write the numerical value with it's unit.

Example: Area of tense steel per meter width of a reinforced concrete slab is 335 sq mm. If 8 mm rods are used as reinforcement, then centre to centre spacing of the reinforcement in mm is

Solution: Total area of steel is 335 sq mm. (which is spread in 1m of width)
Area of 8 mm rod = Πr^2 = 3.14 x 4mm x 4mm = 50.24 sq mm { *8mm rod means it has diameter of 8mm*
So, total no. of rods spread in 1m of width = $\frac{335 sqmm}{50.24 sqmm}$ = 335 /50.24 = 6.67 {*When' sqmm' is divided by 'sqmm', it becomes a dimensionless quantity. So, the result is a just number without any unit. Here, we want to calculate 'no. of rods', which does not have any dimension. So, our calculation is in right direction*.
So, distance between two rods will be 1m/6.67 = 1000 mm/6.67 = 150 mm Answer { *Here, please note that we are dividing 1000mm /6.67 and not 1m/6.67. In the question "per meter" is mentioned. But for correct answer we need to convert 1m to 1000mm.*

Taking Multiple Choice Exams *(Source:1)*
Studying for a multiple choice exam requires a special method of preparation distinctly different from an essay exam. Multiple choice exams ask a student to recognize a correct answer among a set of options that include 3 wrong answers (called *distracters)*, rather than asking the student to produce a correct answer entirely from his/her own mind.

For many reasons, **students commonly consider multiple choice exams easier than essay exams**. Perhaps the most obvious reasons are that:

- The correct answer is *guaranteed* to be among the possible responses. A student can score points with a lucky guess.
- Many multiple choice exams tend to emphasize basic definitions or simple comparisons, rather than asking students to analyze new information or apply theories to new situations.
- Because multiple choice exams usually contain many more questions than essay exams, each question has a lower point value and thus offers less risk.

Despite these factors, however, **multiple choice exams can actually be very difficult and are in this course**.
Consider that:

- Because multiple choice exams contain many questions, they force students to be familiar with a much broader range of material than essay exams do.
- Multiple choice exams also usually expect students to have a greater familiarity with details such as specific dates, names, or vocabulary than most essay exams do. Students cannot easily "bluff" on a multiple choice exam.

Architectural Acoustics

Sound is such a common part of everyday life that we rarely appreciate all of its functions. It provides enjoyable experiences such as listening to music or to the singing of birds.

Yet, too often in our modern society, sound annoys us. Many sounds are unpleasant or unwanted - these are called noise. However, the level of annoyance depends not only on the quality of the sound, but also our attitude towards it. For example the type of music enjoyed by some people could be regarded as noise by others, especially if it is loud.

The branch of science which deals with the planning of a building to provide the best quality audible sound to audience is termed as architectural acoustics or acoustics of the building.
Acoustics is the science of sound. It relates to recorded music, to speech and hearing, to the behavior of sound in concert halls and buildings, and to noise in our environment. It is the technology of designing spaces and systems that meet our auditory needs. Architectural acoustics deals with sound in and around buildings of all kinds. Good acoustical design ensures the efficient distribution of desirable sounds as well as the exclusion of undesirable sound. All acoustical situations consist of three parts: *(1) source, (2) Path, and (3) Receiver*.

Sound

- Definition: An energy that is propagated by vibration in an elastic medium such as air, water, most building materials, and earth.
- Cycle, period, and frequency of sound: A full circuit by a particle of a medium displaced by vibration is a *cycle*. Time required to complete one cycle is called the *period*. Number of complete cycles per second is the *frequency* of sound. Unit of frequency is *Hertz (Hz)*.
- Wavelength: The distance a sound wave travels during one cycle of vibration. *Wavelength = Velocity of sound/Frequency of sound*.
- Sound intensity: Sound travels freely in all directions (i.e. spherically). Sound intensity is the strength of sound per unit area of a spherical surface.
- The decibel scale: It is used to measure sound intensity. In decibel scale, (1) min. intensity of perceptible sound is given a value of 0, (2) whole numbers are used, and (3) an increase of every ten units equals a doubling of loudness. It is a logarithmic scale.
    - Inverse-square law: Sound intensity decreases at a rate inversely proportional to the square of the distance from the sound source. The relationship can be expressed as:
        - $I = W/4\pi r^2$
        - Where I = sound intensity in watts per square centimeter; W = sound power in watts; r = distance from the sound source in centimeter.

Sound propagation

- Direct: Reaches the receiver directly from the source.
- Reflection: Occurs when sound waves bounce off a surface at the same angle at which it was incident on the surface.
- Diffraction: It is the bending or flowing of a sound wave around an object or through an opening.
- Diffusion: Scattering or random distribution of sound from a surface.
- Reverberation: Persistence of sound after source of sound has ceased. Results from repeated reflections. Some reverberation is good (particularly for musical performances), but not always desirable. Intelligibility and subjective quality of sound is rated by reverberation time (RT).
- Echo: Distinct repetition of original sound clearly heard above the general reverberation. A reflected sound can be perceived as discrete echo if the reflected sound wave is heard 0.05 second or later after it was heard as a direct sound.

Sound absorption

- When sound energy strikes a surface, part of the energy is absorbed. Reverberation and echoes may be controlled by effective use of sound absorption quality of a surface. Acoustic absorption is defined in terms of an absorption coefficient. It is the ratio of absorbed sound intensity by a material to the intensity of the sound source.
  Absorption coefficient = absorbed sound intensity / total intensity of sound source.
  *Total absorption by a surface = surface area * absorption coefficient*. Unit of sound absorption is *Sabin*.

Ray diagram

- Ray diagram is analogous to specular reflection of light. Analysis of ray diagrams can be used to study the effect of room shape on the distribution of sound and to identify surfaces that may produce echoes. A ray diagram shows both reflected and direct sound paths. The difference between these two paths is called path difference (Path Difference = Reflected Path - Direct Path). A path difference in excess of the distance that can be traveled by a sound wave in 0.05 seconds indicates that the reflected sound can be perceived as discrete echo.

Weighting networks

- **A-weighting network**: Generally, the sensitivity of human hearing is restricted to the frequency range of 20 Hz to 20,000 Hz. The human ear, however, is most sensitive to sound in the 400 to 10,000 Hz frequency range. Above and below this range, the ear becomes progressively less sensitive. To account for this feature of human hearing, sound level meters incorporate a filtering of acoustic signals according to frequency. This filtering is devised to correspond to the varying sensitivity of the human ear to sound over the audible frequency range. This filtering is called A-weighting. Sound pressure level values obtained using this weighting are referred to as A-weighted sound pressure levels and are signified by the identifier dBA. Simply speaking, it may be defined as a frequency-response adjustment of a sound-level meter that makes its reading conform, very roughly, to human response.
- **C-weighted network**: The C-weighted network provides unweighted microphone sensitivity over the frequency range of maximum human sensitivity (over 1000 Hz).

Sound Transmission Class (STC) of Materials

- STC is a single number rating of the air-borne transmission loss (TL) of a construction. It measures the sound transmission loss (TL) of a construction at one-third octave band frequencies.
    - For measurement, analysis, and specification of sound, the frequency range is divided into sections or bands. One common standard division is into ten octave bands identified by their mid-frequencies: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000.
- The STC of a given material is determined by comparing its measured TL values against a standard STC contour using the following criteria:
    - The maximum deviation of the test curve below the standard contour at any single test frequency shall not exceed 8 dB.
    - The sum of deviations below the standard contour at all frequencies of the test curve shall not exceed 32 dB.
- When the contour is adjusted to the highest value (in integral dB) that meets the above requirements, the STC of the material would be the TL value corresponding to the intersection of the standard STC contour and 500 Hz frequency ordinate.

Frequency

A steady sound is produced by the repeated back and forth movement of an object at regular intervals. The time interval over which the motion recurs is called the period. For example if our hearts beat 72 times per minute, the period is the total time (60 seconds) divided by the number of beats (72), which is 0.83 seconds per beat. We can invert the period to obtain the number of complete cycles of motion in one time interval, which is called the frequency.

$$f = \frac{1}{T}$$

where
f = frequency (cycles per second or Hz)
T = time period per cycle (s)The frequency is expressed in units of cycles per second, or Hertz (Hz), in honor of the physicist Heinrich Hertz (1857–1894).
(Source: https://www.academia.edu/3747851/Architectural_Acoustics_-_Malestrom_)

Introduction to Decibel

The decibel is one of the most important units of measure in the audio field. The decibel is an extraordinarily efficient way to describe audio phenomena, and our perception of them. The goal of this chapter is to explain the decibel concept and show how decibels can be applied in many different ways. In particular, we will see how decibels are used to measure sound levels in various applications. Sound levels expressed in decibels clearly demonstrate the wide range of sensitivity in human hearing. The threshold of hearing matches the ultimate lower limit of perceptible sound in air, the noise of air molecules against the eardrum. At the other end of the range, the ear can tolerate very high intensities of sound. A level expressed in decibels is a convenient way of handling the billion-fold range of sound pressures to which the ear is sensitive.

Ratios versus Differences

Imagine a sound source set up in a room completely protected from interfering noise. The sound source is adjusted for a weak sound with a sound pressure of 1 unit, and its loudness is carefully noted.In observation A, when the sound pressure is increased until it sounds twice as loud, the level dial reads 10 units. For observation B, the source pressure is increased to 10,000 units. To double the loudness, we find that the sound pressure must be increased from 10,000 to 100,000 units. The results of this experiment can be summarized as follows:

Observations	**Two Pressures**	**Ratio of Two Pressures**
A	10 - 1	10:1
B	100,000 – 10,000	10:1

Observations A and B accomplish the same doubling of perceived loudness. In observation A, this was accomplished by an increase in sound pressure of only 9 units, where in observation B it took 90,000 units. Ratios of pressures seem to describe loudness changes better than differences in pressure. Ernst Weber, Gustaf Fechner, Hermann von Helmholtz, and other early researchers pointed out the importance of using ratios in such measurements. Ratios apply equally well to sensations of vision, hearing, vibration, or even electric shock. Ratios of stimuli come closer to matching human perception than do differences of stimuli. This matching is not perfect, but close enough to make a strong case for expressing levels in decibels. Ratios of powers or ratios of intensities, or ratios of sound pressure, voltage, current, or anything else are dimensionless. For example, the ratio of 1 W to 100 W is 1 W/100 W, and the watt unit in the numerator and the watt unit in the denominator cancel, leaving, 1/100= 0.01,a pure number without dimension. This is important because logarithms can only be taken of non-dimensional numbers.

Expressing Numbers

Following figure illustrates three different ways numbers can be expressed. The decimal and arithmetic forms are familiar in everyday activity. The exponential form, while not as commonly used, has an almost unique ability to simplify the expression of many relationships. When writing “one hundred thousand” watts, we can express the number as 100,000 W or 10^5 W. When writing a “millionth of a millionth” of a watt, the string of zeros behind the decimal point is clumsy, but writing 10^{-12} is easy. Engineering calculators display the exponential form in scientific notation, by which very large or very small numbers can be expressed. Moreover, the prefix pico means 10^{-12}, so the value can be expressed as 1 pW.

Decimal Form	Arithmetic Form	Exponential Form
100,000	$10 \times 10 \times 10 \times 10 \times 10$	10^5
10,000	$10 \times 10 \times 10 \times 10$	10^4
1,000	$10 \times 10 \times 10$	10^3
100	10×10	10^2
10	10×1	10^1
1	10/10	10^0
0.1	1/10	10^{-1}
0.01	$1/(10 \times 10)$	10^{-2}
0.001	$1/(10 \times 10 \times 10)$	10^{-3}
0.0001	$1/(10 \times 10 \times 10 \times 10)$	10^{-4}
100,000	(100)(1,000)	$10^2 + 10^3 = 10^{2+3} = 10^5$
100	10,000/100	$10^4/10^2 = 10^{4-2} = 10^2$
10	100,000/10,000	$10^5/10^4 = 10^{5-4} = 10^{-1} = 10$
10	$\sqrt{100} = \sqrt[2]{100}$	$100^{1/2} = 100^{0.5}$
4.6416	$\sqrt[3]{100}$	$100^{1/3} = 100^{0.333}$
31.6228	$\sqrt[4]{100^3}$	$100^{3/4} = 100^{0.75}$

Figure: Ways of expressing numbers

The softest sound intensity we can hear (the threshold of audibility) is about 10^{-12} W/m^2. A very loud sound (causing a sensation of pain) might be 10 W/m^2. (Acoustic intensity is acoustic power per unit area in a specified direction.) This range of intensities from the softest sound to a painfully loud sound is 10,000,000,000,000. Clearly, it is more convenient to express this range as an exponent, 10^{13}. Furthermore, it is useful to establish the intensity of 10^{-12} W/m^2 as a reference intensity I_{ref} and express other sound intensities I as a ratio I/I_{ref} to this reference. For example, the sound intensity of 10^{-9} W/m^2 would be written as 10^3 or 1,000 (the ratio is dimensionless). We see that 10^{-9} W/m^2 is 1,000 times the reference intensity.

Logarithms

Representing 100 as 10^2 simply means that $10 \times 10 = 100$. Similarly, 10^3 means $10 \times 10 \times 10 = 1{,}000$. But how about 267? That is where logarithms are useful. Logarithms are proportional numbers, and a logarithmic scale is one that is calibrated proportionally. It is agreed that 100 equals 10^2. By definition we can say that the logarithm of 100 to the base 10 equals ^{2}, commonly written $\log_{10} 100 = 2$, or simply log 100 = 2, because common logarithms are to the base 10. The number 267 can be expressed as 10 to some power between 2 and 3. Avoiding the mathematics, we can use a calculator to enter 267, push the “log” button, and 2.4265 appears. Thus, $267 = 10^{2.4265}$, and log 267 = 2.4265. Logarithms are handy because, as Table 2-1 demonstrates, they reduce multiplication to addition, and division to subtraction.

Logarithms are particularly useful to audio engineers because they can correlate measurements to human hearing, and they also allow large ranges of numbers to be expressed efficiently. Logarithms are the foundation for expressing sound levels in decibels where the level is a logarithm of a ratio. In particular, a level in decibels is 10 times the logarithm to the base 10 of the ratio of two power like quantities.

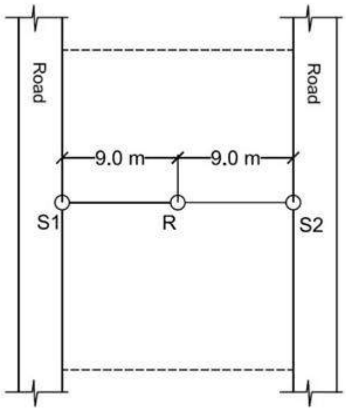
GATE Q&A Architectural Acoustics

GATE 2020

Q1. In the plot shown below, 'S1' and 'S2' are two non-directional point sources, having a sound intensity level of 95 dB and 60 dB respectively at a distance of 1 m from each point source. Considering free field conditions, the effective sound intensity level at the receiver location ‘R' (in dB *rounded off to two decimal places)* is

Solution: For time being, suppose that there is no sound source at S2. Because there will be almost no impact of source S2 at ‘R’ as there is a very very big difference of 35 dB.

For example, of two source of 95 dB are added, the resultant will be 95 + 3 = 98dB. In the similar way, if two sources of 95 dB and 90dB are added, the resultant will be approx 96 dB only.
Another example: The sound coming from your fridge is 60dB and the sound coming from the horn of your car is 95db. Can you feel the effect of sound of fridge with the horn of your car?



Calculation of sound source S1:
Let Intensity of sound at 1 m be I_1 and at 9m be I_2.
So, $I_1/I_2 = 9^2/1^2$ ………………..…….. A
As per question,
$95dB = 10 Log I_1/I_0$ …………………. B
and,
$x\ dB = 10 Log I_2/I_0$……………………. C
B – C,
$95 – x = 10 (Log I_1/I_0 – Log I_2/I_0)$
$95 – x = 10 (Log I_1/I_2)$
95 – x = 10 Log 81/1
95 -x = 19.1
x = 75.9 dB Answer

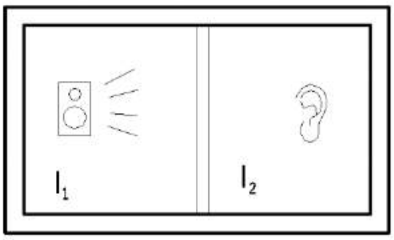
Alternate solution:
Sound intensity level at ‘R’ due to S1 = 95dB – 10 log($9^2/1^2$) = 75.9
Sound intensity level at ‘R’ due to S2 = 60dB – 10 log($9^2/1^2$) = 40.9

So, the resultant intensity at ‘R’ would be = 10 log ($10^{7.5} + 10^{4.0}$) = 75.9 Answer

Official GATE answer range is 75 to 79

GATE 2019

Q.2 A room is separated by a partition wall. The average intensities of sound in the source and receiving sides across the partition are 10^{-4} W/m^2 and 10^{-7} W/m^2 respectively. The transmission loss (TL) of the partition wall is _________ dB.



Solution: Here I_1 = 10^{-4} W/m^2 and $I_2 = 10^{-7}$ W/m^2
We simply cannot subtract intensities I_1 and I_2. We have to take *log* value.
Also the required answer is in dB.
Sound level at source side = 10 log (10^{-4} / 10^{-12}) = 80 dB
Sound level at receiver side = 10 log (10^{-7} / 10^{-12}) = 50 dB
So, transmission loss = 80 – 50 = 30dB Answer.

Q.3 The internal dimension of a room is 10m × 10m × 4m (height). The total area of the doors and windows are 16 m^2. Keeping the doors and windows closed, the reverberation time of the room becomes 1.2 second. Assume all the interior surfaces including doors and windows have same sound absorption coefficient. If all the doors and windows of the room are kept fully open, the reverberation time will be ________ second (*rounded off to two decimal places*).

Solution: Consider the uniform absorption coefficient = a
Using, $R_T = 0.16V/A$

- ⇨ 1.2 = 0.16 * 400/360a (Total surface area of the room is 360 m^2)
- ⇨ 360a = 400*0.16/1.2
- ⇨ A = 0.148

New RT = 0.16 * 400/ (344*0.148 + 16*1) = 0.956 Answer
Note: Out of 360m^2 of room area, 344m^2 has absorption coefficient of 0.148 and rest 15m^2 area has absorption coefficient of 1 because opened door or window has absorption coefficient of 1 as it would absorb all sound)

Architectural Illumination Essential Notes

Important Terms

Black Body A "Perfect" emitter and absorber of radiation.

Brightness The subjective measurement of luminance.

Candela (cd) Unit of luminous intensity approximately equal to one candle power.

Chroma An index of colour saturation. Ranges from 0 for neutral grey to 10 for strong colours.

Chromatic Adaptation The eye adapting to changes in the colour of light sources.

Colour Rendering (of a light source) The ability of the source to render colours accurately. "Good colour rendering" suggests the source is rendering colours similar to the way daylight would.

Colour Rendering Index (CRI) (of a lamp) Is a measure of a lamp's colour rendering ability.

Colour Temperature (of a light source) The temperature of a black body which emits radiation of the same chromaticity as the light source being considered.

Correlated Colour Temperature (CCT)(of a light source) This is used to define the colour appearance of a light source. It is the temperature (K) of a black body which emits radiation nearest in chromaticity to the light source being considered. e.g. the CCT of a white fluorescent lamp is 3500 K.

Cylindrical Illuminance The mean illuminance on the surface of a small cylinder located at a specific point in a room. The axis is taken to be vertical unless stated otherwise. (Unit Lux)

Daylight Factor The illuminance at a point indoors, due to daylight, as a % of the horizontal illuminance outdoors, (direct sunlight is excluded from both values).

Diffuse Reflection Reflected light from a matt surface.

Diffuse Lighting "Soft" lighting in which the luminous flux comes from many directions, none of which predominates.

Direct Lighting Lighting in which most of the luminous flux reaches the working plane directly without reflection from other surfaces.

Directional Lighting Lighting on a task predominantly from one direction.

Disability Glare Glare which impairs vision.

Discomfort Glare Glare which causes discomfort.

Diversity The ratio of minimum to maximum illuminance (or luminance) over a specified area. (See also uniformity)

Downlighter Direct lighting luminaire which emits light only within a relatively small angle to the downward vertical.

Downward Light Output Ratio (DLOR) The ratio of downward light of a luminaire to its total light output.
EFFICACY The ratio of lamp luminous flux divided by the power consumed by the lamp. The unit used is lumens per watt (lm/W). Where control gear is taken into account the unit becomes lumens per circuit watt.

Energy Management System (EMS) A computerised system for controlling energy use. FLICKER The visible modulation in light output due to the cyclic variation of a.c.

Flux Fraction Ratio (FFR) The ratio of upward luminous flux to downward luminous flux.

General Lighting Lighting illuminating a whole area.

Glare Discomfort or disability glare occurring when parts of the visual field are excessively bright.

Glare Index A quantification of discomfort glare in an installation.

Luminance (symbol L) - The fourth stage of this process is the light leaving the surface which has been illuminated by the source.

Consider a situation where the same amount of light strikes both a “dark” surface and a “bright” surface. The illuminance is the same in each case but due to the greater reflectance of the “bright” surface it now becomes a secondary source of light. Its luminance will therefore be much greater than that of the dark surface. Luminance is measured in lumens emitted per sq.m. (not to be confused with Illuminance which is lumens received per sq. m.) and the unit used is “APOSTILB” which is not a S.I. unit. The luminance may be thought of as the brightness of the surface. The term brightness is a subjective term however, whereas luminance is objective. Luminance is usually be measured in candela per square metre, the illuminated surface being considered a secondary light source.

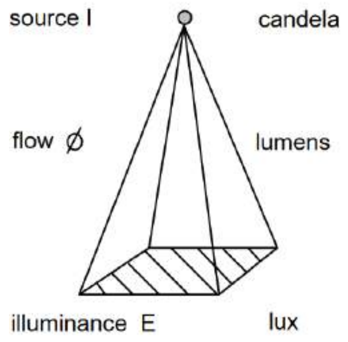


Figure: Illustrating illumination terms

Consider a situation where the same amount of light strikes both a “dark” surface and a ”bright” surface. The illuminance is the same in each case but due to the greater reflectance of the “bright” surface it now becomes a secondary source of light. Its luminance will therefore be much greater than that of the dark surface.

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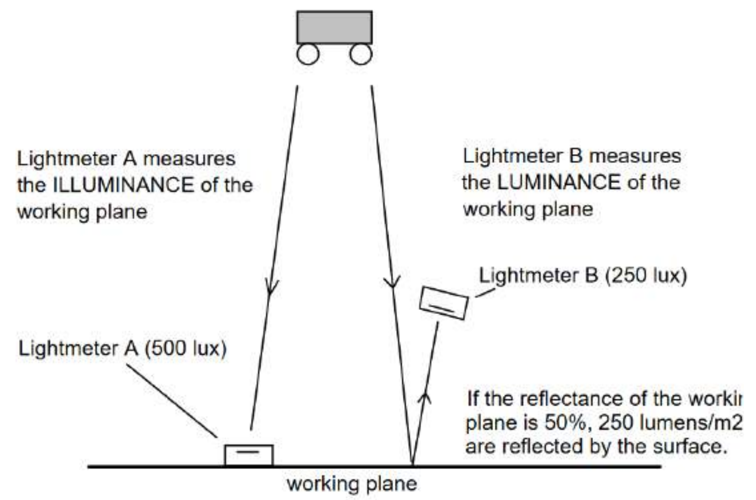


Figure: Experiment to illustrate the difference between Illuminance and Luminance

Note: $1 cd/m^2 = 3.14$ Apostilb $= 3.14\ lm/m^2$

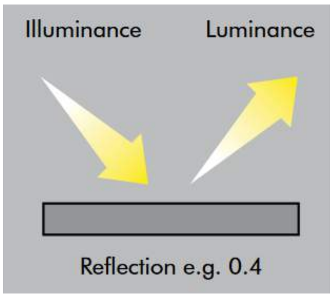


Figure: Illuminance onto a surface, Luminance off the surface.

The luminance of a surface depends upon the amount of light arriving multiplied by the per unit reflectance R (p.u.).

The measure of luminance is most appropriate for flat diffuse surfaces that emit light evenly over the entire surface, such as a (computer) display. Luminance is a derived measure, expressed in Candela per square metre (cd/m^2). An alias for the unit cd/m^2 (unofficial, but still commonly used) is "Nit".

Example: The illuminance (E) on the working plane in Fig. 1.10 is 500 lux. The reflectance is 50%, calculate the luminance of the working plane.

$L = E \times R(p.u.) = 500 \times .5 = 250$ Apostilbs $= 250 / 3.14 = 80\ cd/m^2$

Laws of Light

Rectilinear Propagation of light. This means that light travels in straight lines. It travels at 300,000 km/S and requires no medium for propagation.

Inverse Square Law: The area illuminated by the point light source increases in proportion to the square of the distance. It follows that the average illuminance would decrease by the same ratio.

$$E = \frac{I}{d^2}$$

where d = the distance between the source and the object.

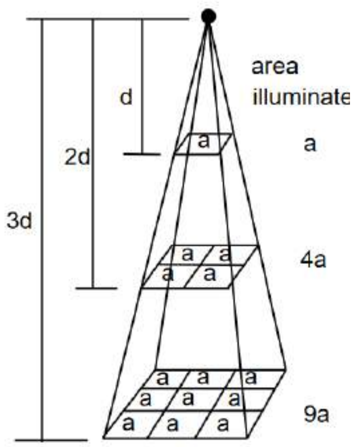


Figure: Inverse Square Law

GATE Q&A Architectural Illumination

GATE 2019

Q.1 The illumination level of a room is 300 lux and the efficacy of the lamps is 60. The Light Power Density (LPD) of the room in Watt/m^2 is ______.
Solution: Illumination, E = 300 lux = 300 lumen/sqm
Efficacy = 60 lumen/watt
LPD = Illumination / Efficacy = (300 lumen/sqm) / (60 lumen/Watt) = 5 Watt/sqm Answer
Tips: Please solve this type of question with numerical value and unit attached.

GATE 2018

Q.2 The indoor illumination requirement for a building is 350 Lux. If the daylight factor is 2.7 and the design sky illuminance is 9000 Lux, then the required supplementary artificial lighting is ________Lux.

Solution: D = (ei/eo)*100
2.7 = (ei/9000)*100
ei = 243
So, 350-243=**107 lux Answer**

GATE 2017

Q.3 Find the 'Lux' at a distance of 3 m from the light source. The light source has power of 40 Watts and Efficacy of 40 lm/W.

Solution: (40Watt x 40 Efficacy) / (Square of 3m) = 1600/9 = 178 lux
Solution: First find, how much lumen the light source emits. Luminous Efficacy helps out to find that.
Luminous efficacy is a measure of how well a light source produces visible light. It is the ratio of luminous flux to power, measured in lumens per watt in SI.
So, Luminous efficacy = (Lumen)/(Power in Watt)
Here, 40 = Lumen/ 40
Therefore, lumen = 40 X 40 = 1600
Now apply "Inverse square law" which says; The intensity of illumination is proportional to the inverse square of the distance from the light source.
Lux found = (lumen of light source)/(square of distance) = 1600/9 = 178 lux **Answer**

GATE 2016

Q4. A lamp source of 3200 candela is mounted on a wall at a height of 2 meter from the work-plane. It subtends an angle of incidence of 60 degree with the center of the work plane. The illumination at the centre of the work plane in Lux is __________ (2 marks).

Solution: We have to find 'x'
Cos 60º = 2/x
or, 1/2 = 2/x
or, x = 4

E (lux) = [I (candela)/distance square] * Cos 60º
= 3200/4x4*0.5 = 100

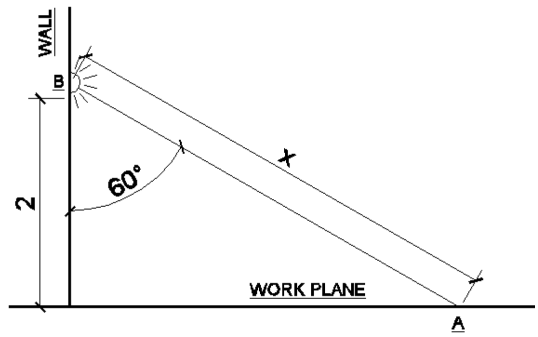


Figure: Solution diagram, Q.No. 4.

GATE 2015

Q5. The ratio between *illumination at a working point indoor to total light available simultaneously outdoor* is known as
(A) Daylight Factor (B) Sky Component
(C) Internally Reflected Component (D) Externally Reflected Component

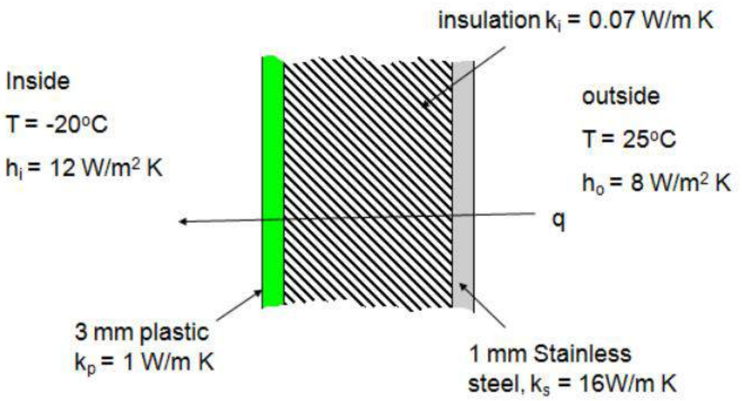
Answer (A) **Daylight factor** (DF) is the ratio of the light level inside a structure to the light level outside the structure. It is defined as: DF = (Ei / Eo) x 100%

GATE 2014

GATE 2013

Q6. Flux emitted from a 1cd light source in all directions, in lumens, would be _______.

Example: An industrial freezer is designed to operate with an internal air temperature of -20°C when the external air temperature is 25°C and the internal and external heat transfer coefficients are 12 W/m^2K and 8 W/m^2K, respectively. The walls of the freezer are composite construction, comprising of an inner layer of plastic (k = 1 W/mK, and thickness of 3 mm), and an outer layer of stainless steel (k = 16 W/m K, and thickness of 1 mm). Sandwiched between these two layers is a layer of insulation material with k = 0.07 W/m K. Find the width of the insulation that is required to reduce the convective heat loss to 15 W/m 2 .



Solution:

$q = U\Delta T$ where U is the overall heat transfer coefficient given by:

$$U = \frac{q}{\Delta T} = \frac{15}{25-(-20)} = 0.333 W/m^2K$$

$$U = \left[\frac{1}{h_i} + \frac{L_p}{k_p} + \frac{L_i}{k_i} + \frac{L_s}{k_s} + \frac{1}{h_o}\right]^{-1} = 0.333$$

$$\left[\frac{1}{h_i} + \frac{L_p}{k_p} + \frac{L_i}{k_i} + \frac{L_s}{k_s} + \frac{1}{h_o}\right] = \frac{1}{0.333}$$

$$L_i = k_i\left\{\frac{1}{0.333} - \left[\frac{1}{h_i} + \frac{L_p}{k_p} + \frac{L_s}{k_s} + \frac{1}{h_o}\right]\right\} = 0.07\left\{\frac{1}{0.333} - \left[\frac{1}{12} + \frac{0.003}{1} + \frac{0.001}{16} + \frac{1}{8}\right]\right\}$$

$$L_i = 0.195m \qquad \text{(195 mm)}$$

(Source: https://sustainabilityworkshop.autodesk.com/buildings/total-r-values-and-thermal-bridging)

Solar constant (GATE 2008): The average rate at which the Earth receives radiation from the Sun is known as the solar constant. When measured at the edge of the Earth's atmosphere with the sun directly overhead, it is 1.35 kilowatts per square meter. A more technical measurement, taken outside the Earth's atmosphere and when the Earth is at its mean distance from the Sun, gives a solar constant of 1.94 calories (as a measure of heat) per minute per square centimeter.

GATE 2020: Equinox & Solstice

Solstice

- On **21st June**, the northern hemisphere is tilted towards the sun. The rays of the sun fall directly on the **Tropic of Cancer**. As a result, these areas receive more heat.
- The areas near the poles receive less heat as the rays of the sun are slanting.
- The north pole is inclined towards the sun and the places beyond the **Arctic Circle** experience continuous daylight for about six months.
- Since a large portion of the northern hemisphere is getting light from the sun, it is summer in the regions north of the equator. The **longest day and the shortest night** at these places occur on **21st June**.
- At this time in the southern hemisphere all these conditions are reversed. It is winter season there. The nights are longer than the days. This position of the earth is called the **summer solstice.**
- On **22nd December**, the Tropic of Capricorn receives direct rays of the sun as the south pole tilts towards it. As the sun's rays fall vertically at the **Tropic of Capricorn** (23½° s), a larger portion of the southern hemisphere gets light. Therefore, it is summer in the southern hemisphere with longer days and shorter nights. The reverse happens in the northern hemisphere. This position of the earth is called the **winter solstice.**

Equinox

- On **21st March** and **September 23rd**, direct rays of the sun fall on the equator. At this position, neither of the poles is tilted towards the sun; so, the whole earth experiences equal days and equal nights. This is called an equinox.
- On 23rd September, it is **autumn season [season after summer and before the beginning of winter]** in the northern hemisphere and **spring season [season after winter and before the beginning of summer]** in the

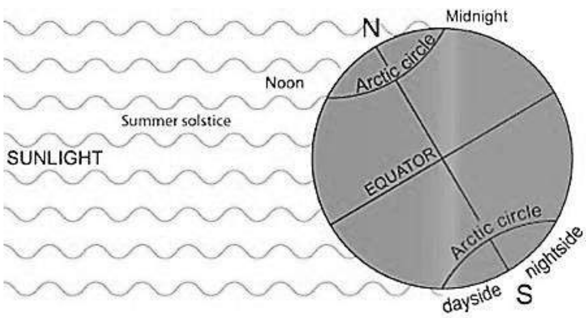
southern hemisphere. The opposite is the case on 21st March, when it is spring in the northern hemisphere and autumn in the southern hemisphere.

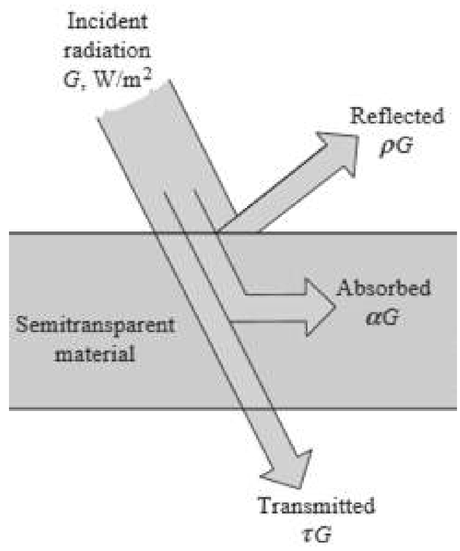
- Thus, you find that there are **days and nights and changes in the seasons because of the rotation and revolution of the earth respectively**.
- ***Rotation === Days and Nights.***
- ***Revolution === Seasons.***

Why regions beyond the Arctic circle receive sunlight all day long in summer?

- This is because of the tilt of the earth.
- Earth's axis at the north pole is tilted towards the sun in summer.
- So the whole of Arctic region falls within the 'zone of illumination' all day long in summer.

Source: https://www.pmfias.com/rotation-revolution-days-nights-seasons/





GATE 2006: The absorption, reflection, andtransmission of incident radiation by a semitransparent material.

Absorptivity: $\alpha = \frac{\text{Absorbed radiation}}{\text{Incident radiation}} = \frac{G_{abs}}{G}, \quad 0 \le \alpha \le 1$

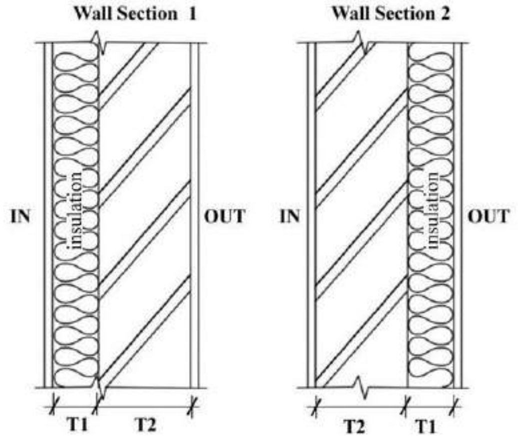
Reflectivity: $\rho = \frac{\text{Reflected radiation}}{\text{Incident radiation}} = \frac{G_{ref}}{G}, \quad 0 \le \rho \le 1$

Transmissivity: $\tau = \frac{\text{Transmitted radiation}}{\text{Incident radiation}} = \frac{G_{tr}}{G}, \quad 0 \le \tau \le 1$

GATE Q&A Thermodynamics

GATE 2020

Q1. For the same thickness of material layers, relative position of insulation in the wall sections l and 2 shown below will have an impact on



(A) Thermal Time Constant
(B) Thermal Resistivity
(C) Thermal Transmittance
(D) Thermal Conductivity

Solution: The **Thermal Time Constant** indicates a time required for a thermistor to respond to a change in its ambient temperature. When the ambient temperature is changed from T1 to T2, the relationship between the time elapsed during the temperature change *t* (sec.) and the thermistor temperature T can be expressed by the following equation. [τ (tau in sec.) in the equation denotes the thermal time constant.]

$$T = (T_2 - T_1)\left(1 - \exp(-t/\tau)\right) + T_1$$

Please note that the above equation doesnot depend on the thickness of the material. But when we look at the formula of Thermal Resistivity, Thermal Transmittance & Thermal Conductivity , all depend on the thickness of the material.

So, the correct option is **(A) Thermal Time Constant.**
(Please also note that T1 & T2 in the question figure is different from the T_1 & T_2 in the answer equation.)
Source: https://www.shibauraelectronics.com/products/technical/physical_04.html

Q2. The solar altitude angle on April 16 at 7:00 AM in Kochi is 16°. The same solar altitude angle will occur at the same time in the same year at the same location on

(A) October 21 (B) July 21 **(C) August 27** (D) September 23

Solution: March and September, we have Equinox. June and December we have summer and winter solstice. It means during June, the sun has direct rays on tropic of cancer in Northern hemisphere. And in the same way during Dec it will be on tropic of Capricorn in Southern hemisphere.

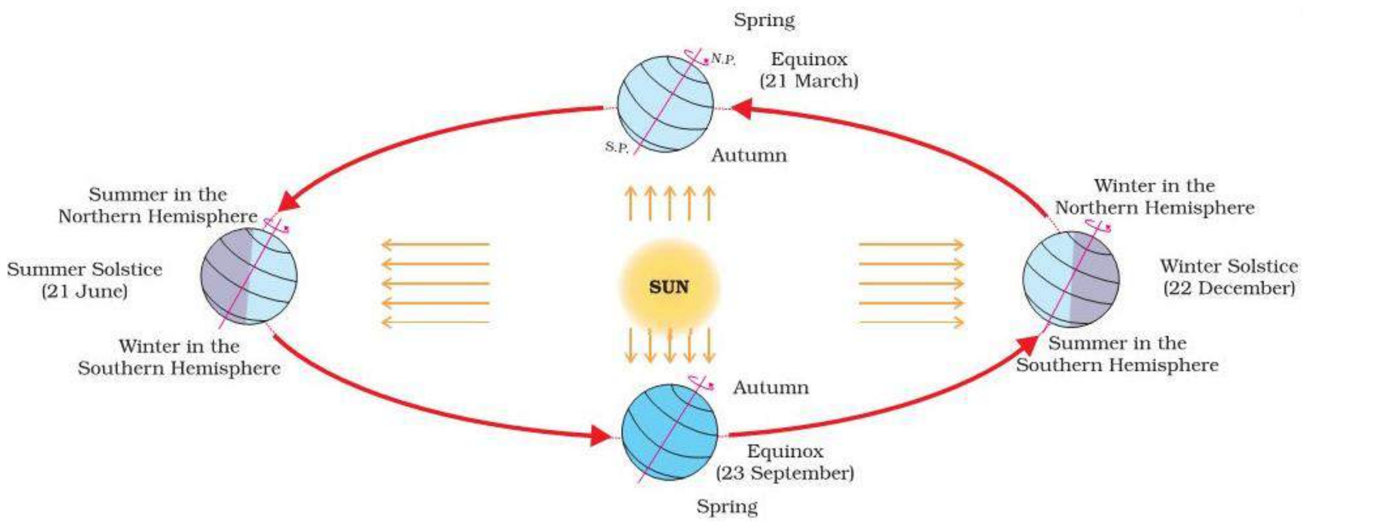


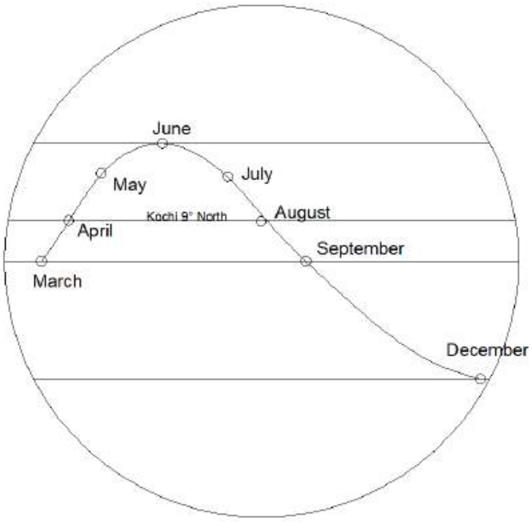
Figure: Revolution of the earth and seasons

So if the sun starts moving slowly towards tropic of cancer from March to June. It will go via Kochi (which is northern hemisphere) on April (one month after equinox) so then after reaching June Solstice it will retreat back to Sept equinox. In this journey, it will reach Kochi one month before Sept.

So it will reoccur on August.

Given, Kochi date was April 16. It means approx. 26days after March 20 equinox.

So it will be approx 26 days before Sept 23 equinox. So, the answer should be Aug 27.



Q3. A room measures 5m x 10m x 3m (LxBxH). Consider the following conditions,
Total solar radiation incident on the roof surface= 800 W/m^2
Outdoor air temperature = 40°C
Outside film coefficient of the roof surface = 18 W /m^2
The outdoor mean radiant temperature is equal to outdoor air temperature

The minimum reduction required in solar absorptance of the roof *(rounded off to two decimal places)* to achieve a 20° reduction in sol-air temperature is ____________.

Solution: **Sol-air temperature:** For building design purposes, it is useful to combine the heating effect of radiation incident on a building with the effect of warm air. This can be done by using the sol-air temperature concept.
Ts = To + [(I x a)/fo]
Where,
Ts = sol-air temperature in ˚C
To = outside air temperature in ˚C
I = radiation intensity in W/m²
a = absorbance of the surface
fo = surface conductance (outside), W/m2 ˚C

As per question,
Ts_1 = 40 ˚C + [(800W/m^2 * a_1) / 18 W/m^2˚C] ………………………………..(A)

Also,
Ts_2 = 40 ˚C + [(800W/m^2 * a_2) / 18 W/m^2˚C]
⇨ Ts_1 - 20 ˚C = 40 ˚C + [(800W/m^2 * a_2) / 18 W/m^2˚C] ………………..(B)

(A) – (B),

20 ˚C = [800W/m^2 / 18 W/m^2˚C] * ($a_1 - a_2$)
⇨ ($a_1 - a_2$) = (20 * 18) / 800 = **0.45 Answer**
⇨ ($a_1 - a_2$) is reduction required in solar absorptance

Note: There is slight error in question itself. The error is in the unit of ‘outside film coefficient’. It is given 18 **W /m^2** but it should be 18 **W /m^2 ˚C**

The GATE official answer range is 0.43 to 0.47

GATE 2019

Q4. Solar panels are proposed to be installed on a building roof top to generate electricity. The size of each solar panel is 2 m^2. The efficiency of each panel is 75%. The orientations of the solar panel and related solar data are given in the table below.
Solution: **As per the proposal, 28.5 kWh solar power will be generated daily.**

Given data				*Data calculation*	
Orientation	No. of Panels	Average daily solar radiation in W/m2	Average solar hours per day	*Total electricity generation*	*At 75% efficiency*
South	10	400	4	*10*400W/m^2*2m^2*4hours = 32 kWh*	*0.75*32 kWh = 24kWh*
West	5	300	2	*5*300W/m^2*2m^2*2hours = 6 kWh*	*0.75*6 kWh = 4.5 kWh*

Total energy generation = 24 + 4.5 = 28.5 kWh Answer
GATE official answer range: 28.4 to 28.6

GATE Question Structure Analysis

GATE 2020

Q1. A simply supported RCC beam of cross section 0.4 m x 0.6 m covers a span of 8 m. It is subjected to a uniformly distributed load of 30 kN/m. If the unit weight of concrete is 24 kN/m^3, the tensile stress (in N/mm^2, *rounded off to two decimal places)* at the bottom of the beam at mid-span is ____________.

Solution: First we will calculate total UDL (Uniformly Distributed Load)
Volume of RCC beam = 0.4m x 0.6m x 8m
Load due to self weight of RCC beam = $24kN/m^3$ x (0.4m x 0.6m x 8m)
UDL due to self weight of RCC beam = Load due to self weight / Length = [$24kN/m^3$ x (0.4m x 0.6m x 8m)] / 8m = 5.76 kN/m
So, Total UDL = Subjected UDL + Self weight UDL = 30kN/m + 5.76kN/m = 35.76kN/m
Maximum Moment = $WL^2/8$ = [35.76kN/m * $(8m)^2$]/8 = 286kN/m
Tensile Stress = My/I where, M = Bending moment, y = distance from mid point (CG), I = moment of inertia
We have, M = 286kN / m, y = 0.3 meter, I = $bd^3/12$ = 0.4m * $(0.6m)^3$ / 12 = 0.0072 m^4
Tensile Stress = My/I = [(286kN/m) * (0.3m)] / 0.0072 m^4 = 11916.67 kN/m^2 = 11.92N/mm^2

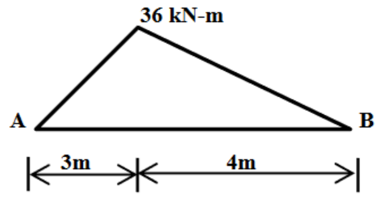
Official GATE answer range is 11.8 to 12

GATE 2019

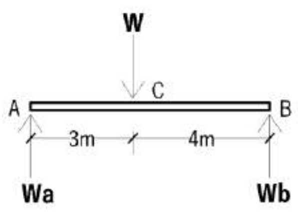
Q2. The load on a RCC column is 150 kN. The soil bearing capacity is 80 kN/m^2. Assuming a factor of safety of 1.2, the side of the square column footing is _______ meter *(rounded off to one decimal place).*

Solution: Load on column = 150 kN
Design load consisting factor of safety = 150 * 1.2 = 180 kN
Soil bearing capacity = $80kN/m^2$
Let side of the square column footing be S
So, area of the column = S^2
So, total load on column = $80kN/m^2$ * S^2
As per question,
$80kN/m^2$ * S^2 = 180kN
- ⇨ S^2 = 2.25
- ⇨ S = 1.5 m Answer. *(GATE official answer range: 0.75 to 0.85)*

Q3. A simply supported beam AB has a clear span of 7 meter. The bending moment diagram (BMD) of the beam due to a single concentrated load is shown in the figure below. The magnitude of the concentrated load in kN is _____________.



Solution: Let the concentrated load be W and the reaction force at A and B be Wa and Wb respectively.
As sum of all forces must be zero.
So, Wa + Wb = W …………………………………. (1)



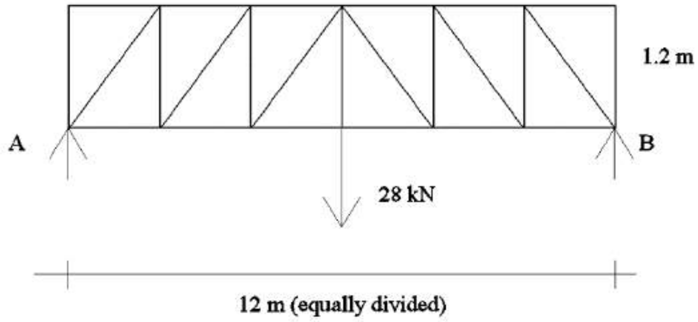
Point A:
Sum of moment at point A should be zero.
So, Wb*7 – W*3 = 0
So, Wb = 3W/7 …………………………..(2)

Point B:
Sum of moment at point B should be zero.
So, W*4 – Wa*7 = 0
So, Wa = 4W/7 …………………………..(3)

SFD (Shear Force Diagram):

GATE 2005

Q45a. The pin-joint truss shown in the figure is
(A) Stable and statically determinate
(B) Stable and statically indeterminate
(C) Unstable and statically indeterminate
(D) Unstable and statically determinate



In general:			
If			The structure is:
Number of unknowns	<	Number of equation	Unstable
Number of unknowns	=	Number of equation	Stable & Determinate
Number of unknowns	>	Number of equation	Indeterminate

Q46b. Calculate the force in the member marked (x)
(A) 14 kN tensile **(B) 28 kN tensile**
(C) 28 kN compression (D) zero

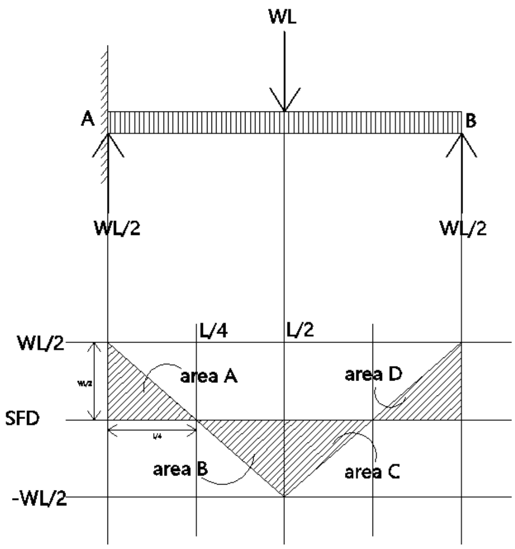
Scan above QR codes to further studies.

GATE 2004

Q47. Moment at the fixed end 'A' of the beam indicated below is
(A) $-WL^2/12$ (B) $-WL/16$ (C) $-WL^2/8$ (D) $-WL/8$

Solution: Let's start from the basic. Unit of Moment is Newton-meter. In the question, W is UDL (uniformly distributed load). So, its unit is Newton /meter. Unit of length L is meter.
Now, unit of WL is (W Newton/meter)*(L meter) = WL Newton (which is essentially a force. So WL/16 is also a force, not a moment. Therefor options (B) and (D) are incorrect).

Now, you are left with options (A) and (D). You should try your luck. If not, you should know that the area in SFD (Shear Force Diagram) is actually a value of moment.
Here, Moment at A should be sum of area of triangle A & B.
Moment at A = Area (ΔA + ΔB) = Area [(1/2*WL/2*L/4) + (1/2*WL/2*L/4)] = $WL^2/8$ Answer



GATE 2003

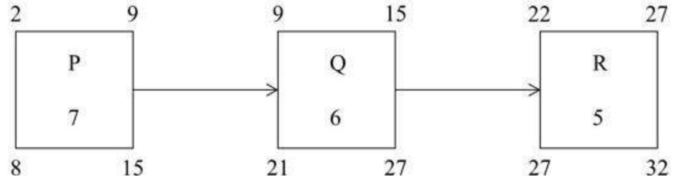
Q48. Safe axial load for a short R.C. square column having cross section as 300 mm x 300 mm and 4 long longitudinal bars of diameter 20 mm (using M 20 concrete and Fe 415 steel) is near to
(A) 100 kN (B) 10 kN (C) 1000 kN (D) 10000 kN

Solution: Answer (C) **Safe axial load for a short R.C. square column is 1000 kN.**
Area of bars = $4*\pi r^2 = 4*\pi*(0.01)^2$ = 0.0012 sq.m.
Area of Concrete = (0.3m x 0.3m) - 0.0012 sq.m. = 0.0887

GATE Q&A CPM/PERT

GATE 2020

Q1. The activity duration, early start, early finish, late start and late finish of the three activities ‘P', 'Q' and ‘R’ are shown in the following figure. The **independent float** of activity 'Q' is _________.



Solution: Independent Float
= ES of succeeding activity – LF of preciding - Duration of the activity of which Independent float is to be counted
= ES of R – LF of P – Duration of Activity Q
= 22 – 15 – 6
= 1 Answer

Scan for pdf on Total, Free, Independent & Interfering float.

Scan for video lecture on Total float & Free float.

Scan for video lecture on Independent float

Figure: Scan for explanation on YouTube for Independent Float

GATE 2019

GATE 2018

Q2. In Critical Path Method (CPM) for time scheduling, ‘forward pass calculation’ is carried out for determining
(A) Late start and early finish time **(B) Early start and early finish time**
(C) Late start and late finish time (D) Early start and late finish time

Q3. For an activity, ‘optimistic time duration’ is 4 days, ‘pessimistic time duration’ is 11 days and ‘most-likely time duration’ is 8 days. The PERT value of time duration is ________ days (up to one decimal place).

Solution: PERT value of time duration = (optimistic time duration + 4*most-likely time duration + pessimistic time duration) /6 = (4+4*8+11)/6 = 47/6 = **7.83 Answer** *(Official GATE answer varies from 69.5 to 70.5)*

GATE 2017

GATE 2016

Q4. A CPM network of a construction project is given in the figure below. The activity durations are mentioned in weeks. The project completion time in weeks will be _____________ (2 marks).

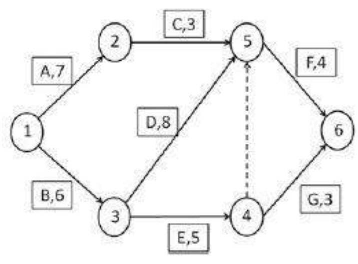


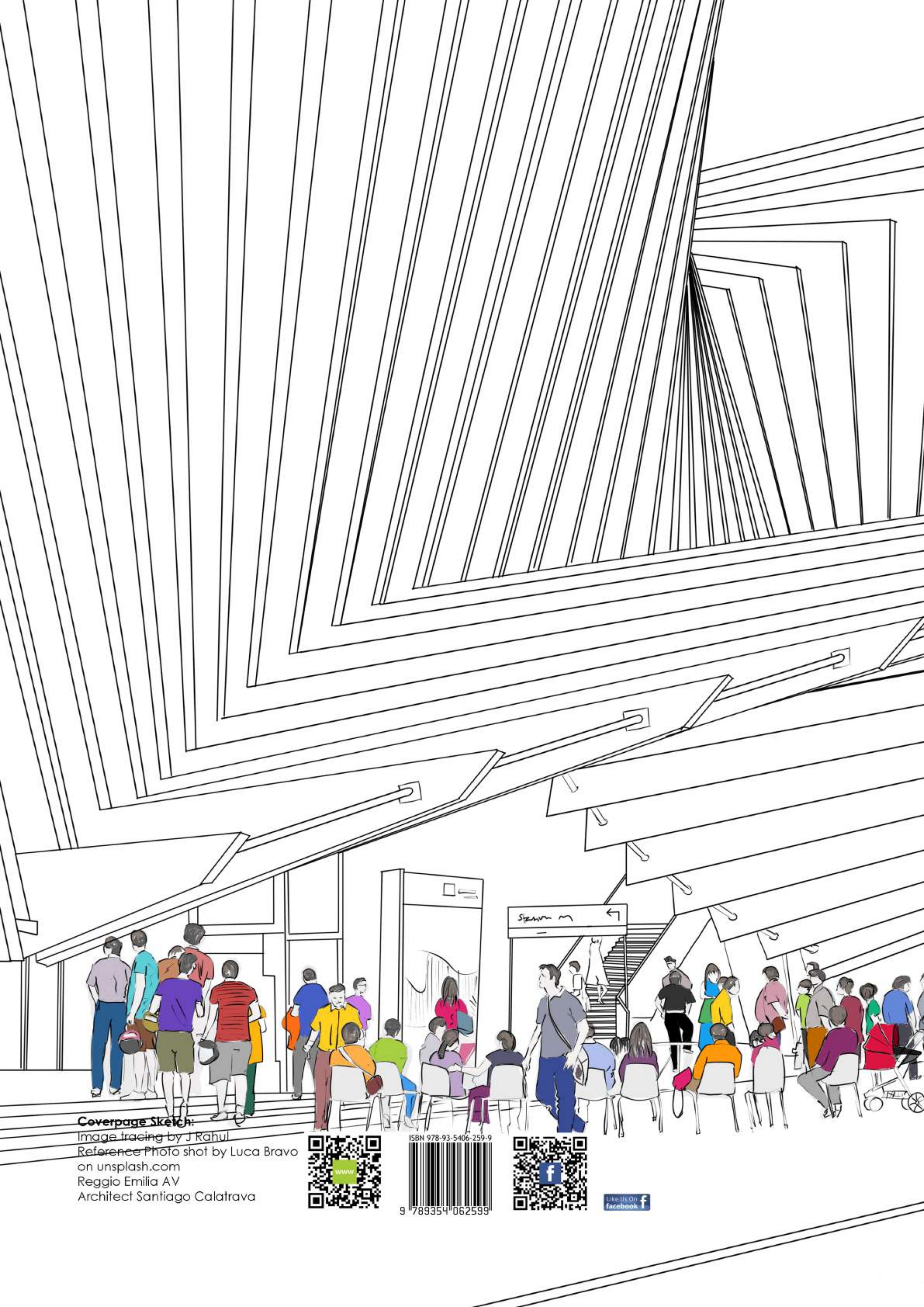
Figure: Part of problem statement of Q. No. 21.

Solution: To complete the project (1) to (6), we have four paths to complete.
(1) > (2) > (5) > (6) and it takes 7 + 3 + 4 = 14 weeks
(1) > (3) > (4) > (6) and it takes 6 + 5 + 3 = 14 weeks
(1) > (3) > (5) > (6) and it takes 6 + 8 + 4 = 18 weeks
(1) > (3) > (4) > (5) > (6) and it takes 6 + 5 + 0 + 4 = 15 weeks

The longest duration time is 18 weeks during which all activity paths would be completed. So, the completion time for the project would be 18 weeks.

GATE 2015

GATE 2014



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