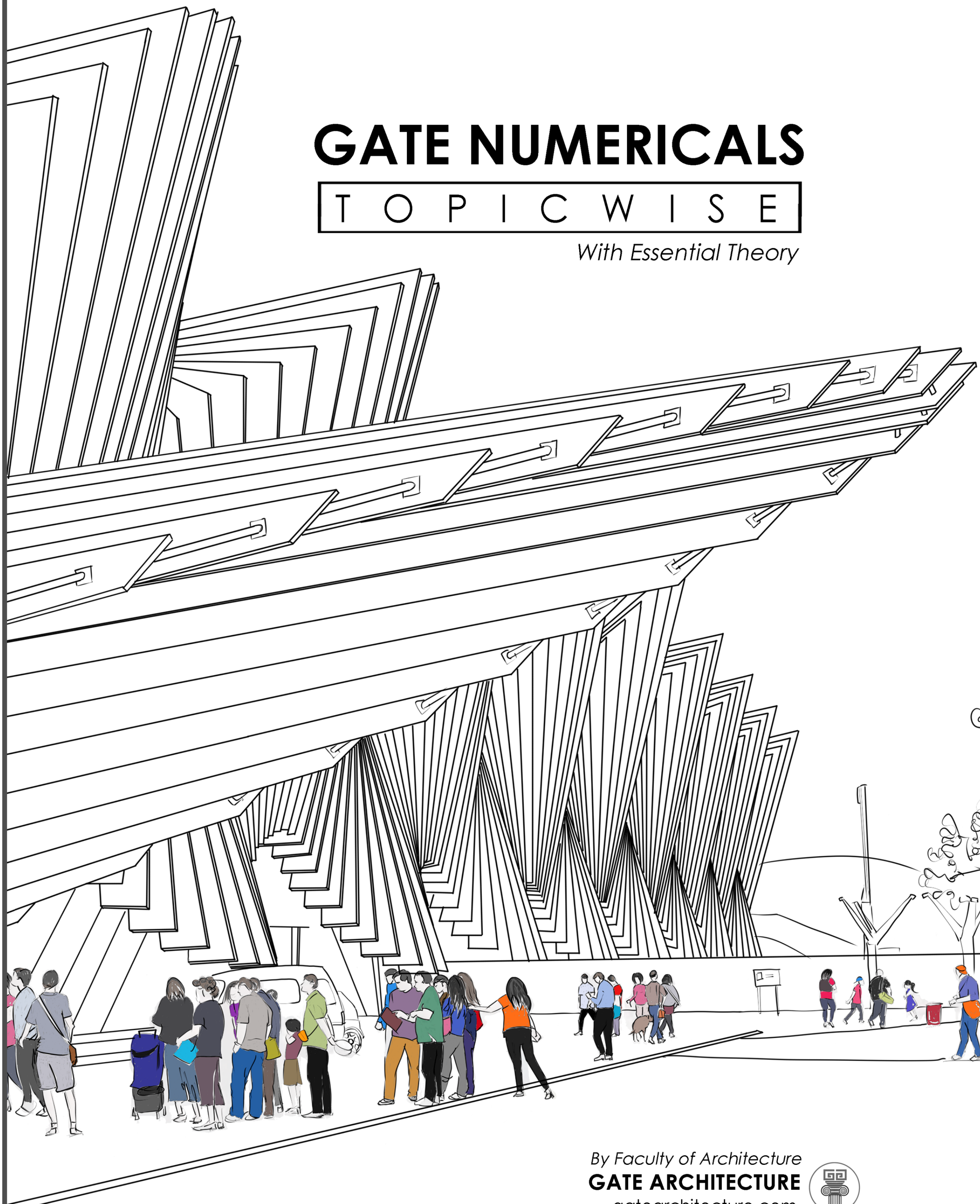
GATE NUMERICALS

TOPICWISE

With Essential Theory



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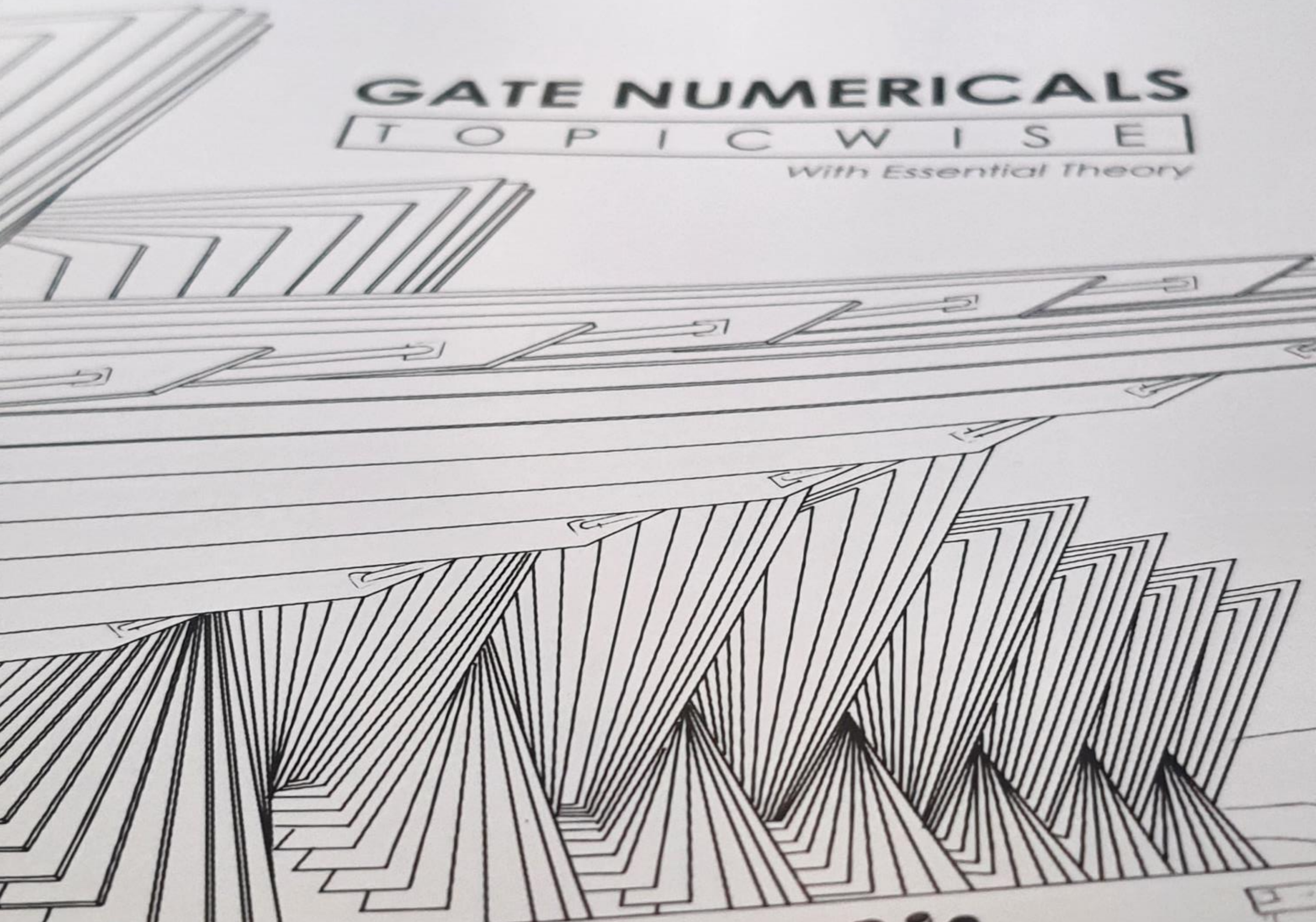

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NUMERICAL

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31 YEARS

2021 - 1991

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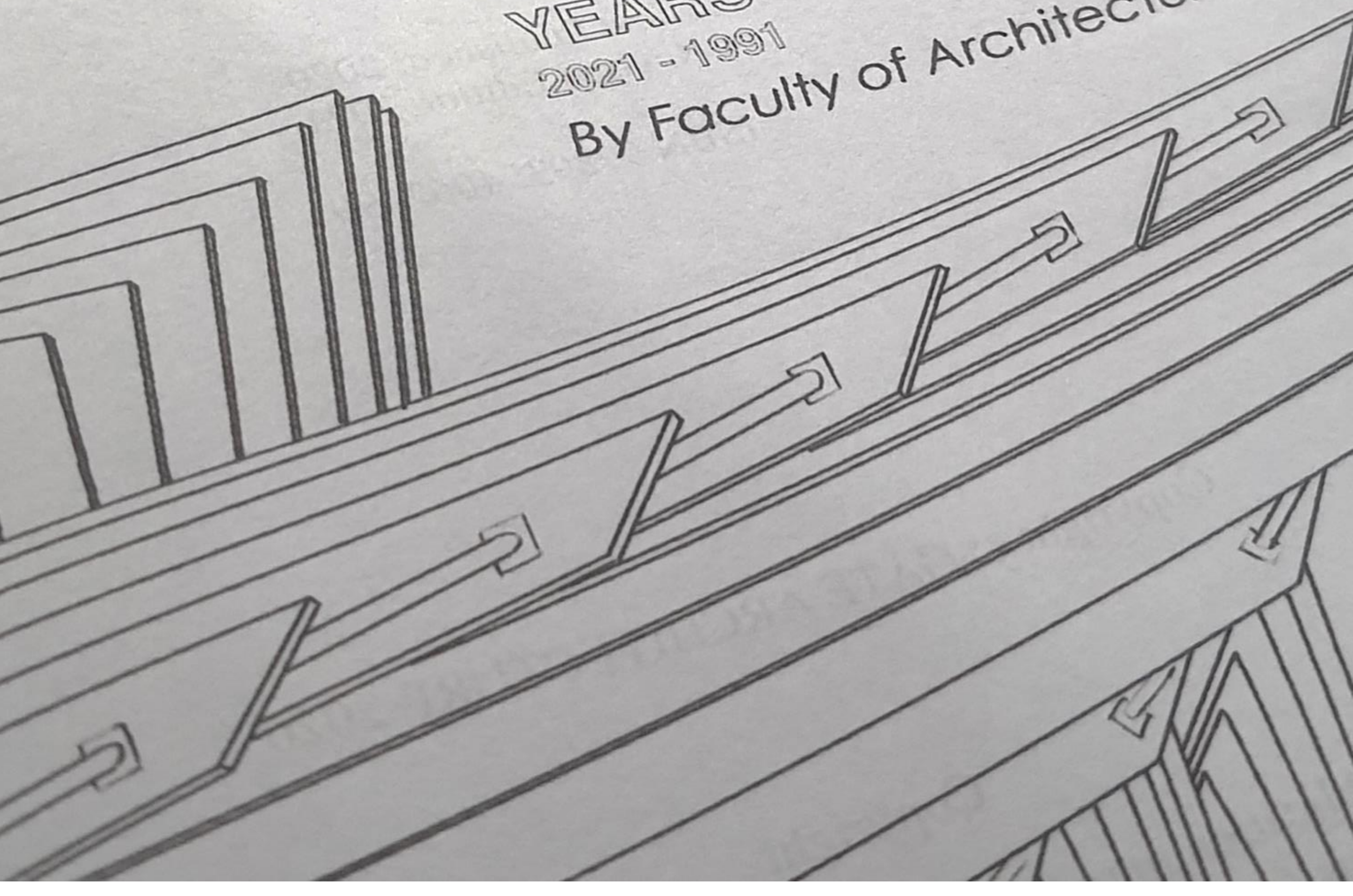
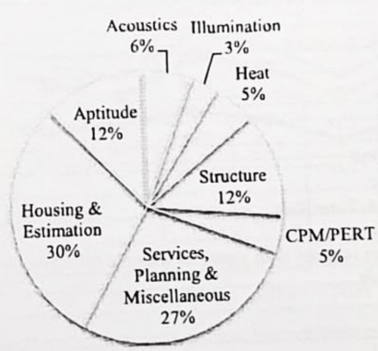


Short contents:



% 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. In GATE 2021, there were total 18 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!)

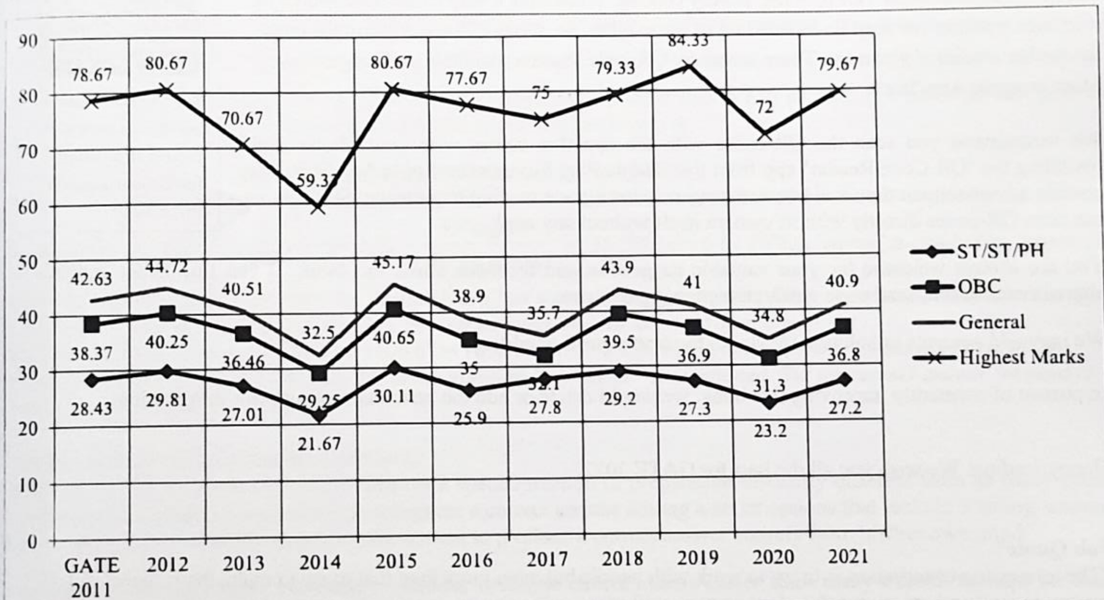
So, for such question pattern, you need through practice. We are hopeful that this book would meet the requirement.

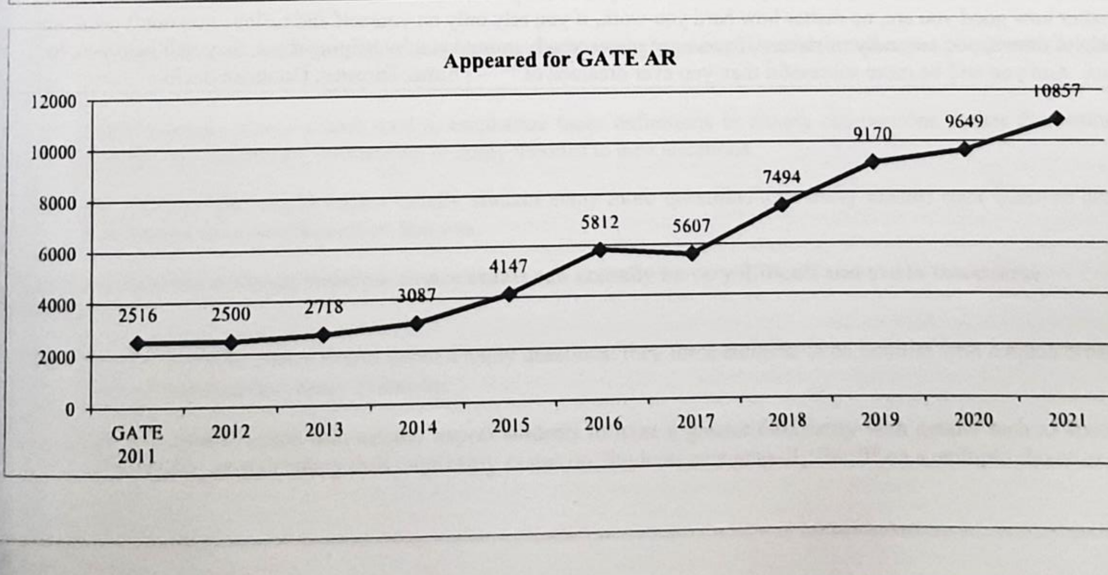
Answering an objective question has its own rule to follow when you have a doubt in choosing the right answer. For so, we have also attached expert opinion for handling objective question well.

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):

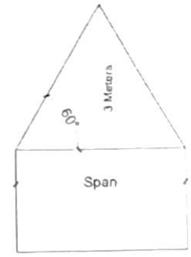




Tips & Tricks

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 the followings 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 60° and height of the roof is 3 m, span of the room, in m, would be ______
Solution: Span of the room = 2 * (3/tan60°) = 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 ($l= 0.5$m). 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 a diameter of 8mm*

So, total no. of rods spread in 1m of width = $\frac{335sqmm}{50.24sqmm}$ = 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 the 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.

Syllabus 2021

Part A: General

Section 1: Architecture, Planning and Design

Architectural Graphics; Visual composition in 2D and 3D; Computer application in Architecture and Planning; Anthropometrics; Organization of space; Circulation- horizontal and vertical; Space Standards; Universal design; Building byelaws; Codes and standards;

Section 2: Construction and Management

Project management techniques e.g. **PERT, CPM etc.; Estimation and Specification**; Professional practice and ethics; Form and Structure; Principles and design of disaster resistant structures; Temporary structures for rehabilitation;

Section 3: Environmental Planning and Design

Natural and man-made ecosystem; Ecological principles; Environmental considerations in Planning and design; Environmental pollution- types, causes, controls and abatement strategies; Sustainable development, goals and strategies; Climate change and built environment; Climate responsive design;

Section 4: Urban Design, landscape and Conservation

Historical and modern examples of urban design; Elements of urban built environment –urban form, spaces, structure, pattern, fabric, texture, grain etc.; Concepts and theories of urban design; Principles, tools and techniques of urban design; Public spaces, character, spatial qualities and Sense of Place; Urban design interventions for sustainable development and transportation; Development controls – **FAR**, densities and building byelaws.; Urban renewal and conservation; heritage conservation; historical public spaces and gardens; Landscape design; **Site planning;**

Section 5: Planning process

Salient concepts, theories and principles of urban planning; concepts of cities - Eco-City, Smart City; Concepts and theories by trendsetting planners and designers; Ekistics; Urban sociology; Social, Economic and environmental cost benefit analysis; Methods of non-spatial and spatial data analysis; Development guidelines such as URDPFI;

Section 6: Housing

Housing typologies; Concepts, principles and examples of neighbourhood; **Residential densities; Affordable Housing; Real estate valuation;**

Section 7: Services and Infrastructure

Firefighting Systems; Building Safety and Security systems; Building Management Systems; Water treatment; **Water supply and distribution system; Water harvesting systems**; Principles, Planning and Design of storm water drainage system; Sewage disposal methods; Methods of solid waste management - collection, transportation and disposal; Recycling and Reuse of solid waste; Land-use – transportation - urban form inter-relationships; Design of roads, intersections, grade separators and parking areas; Hierarchy of roads and level of service; Para-transits and other modes of transportation, Pedestrian and slow moving traffic planning;

Part B1: Architecture

Section B1.1: History and Contemporary Architecture

Principles of Art and Architecture; World History of Architecture: Egyptian, Greco-Roman classical period, Byzantine, Gothic, Renaissance, Baroque-Rococo, etc.; Recent trends in Contemporary Architecture: Art nouveau, Art Deco, Eclecticism, International styles, Post Modernism, Deconstruction in architecture, etc.; Influence of Modern art and Design in Architecture; Indian vernacular and traditional Architecture, Oriental Architecture; Works of renowned national and international architects;

Section B1.2: Building Construction and Structural systems

Building construction techniques, methods and details; Building systems and prefabrication of building elements; Principles of Modular Coordination; Construction planning and equipment; Building material characteristics and applications; **Principles of strength of materials**; Alternative building materials; Foundations; Design of structural elements with different materials; **Elastic and Limit State design; Structural systems;** Principles of Pre-stressing; High Rise and Long Span structures, gravity and lateral load resisting systems;

Section B1.3: Building Services and Sustainability

Solar architecture; Thermal, visual and acoustic comfort in built environments; Natural and Mechanical ventilation in buildings; **Air-Conditioning systems**; Sustainable building strategies; Building Performance Simulation and Evaluation; Intelligent Buildings; **Water supply; Sewerage and drainage systems**; Sanitary fittings and fixtures; Plumbing systems; Principles of internal and external drainage system; **Principles of electrification of buildings**; Elevators and Escalators - standards and uses;

Part B2: Planning

Section B2.1: Regional and Settlement Planning

Regional delineation; settlement hierarchy; Types and hierarchy of plans; Various schemes and programs of central government; Transit Oriented Development (TOD), SEZ, SRZ etc.; Public Perception and user behaviour; National Housing Policies, Programs and Schemes.; Slums, Squatters and informal housing; Standards for housing and community facilities; Housing for special areas and needs;

rchitectural Acoustics

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

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

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

ound

- 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 are 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.

Remember that sound-pressure level in air means that the reference pressure (p_{ref}) in the pressure ratio is 20 μPa. There are other reference quantities; some of the commonly used ones are listed in Table 2-3. The prefixes of Table 2-4 are often employed when dealing with very small and very large numbers. These prefixes are the Greek names for the power exponents of 10.

Prefix	Symbol	Multiple
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
mili	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Figure: Prefixes, Symbols and exponents

Acoustic Power

It doesn't take many watts of acoustic power to produce very loud sounds. A 100-W amplifier may be driving a loudspeaker, but loudspeaker efficiency (output for a given input) is very low, perhaps on the order of 10%. A typical loudspeaker might radiate 1 W of acoustic power. Increasing amplifier power to achieve higher acoustic levels can be frustrating. Doubling amplifier power from 1 to 2 W is a 3-dB increase in power level (10 log 2 = 3.01), yielding a very small increase in loudness. Similarly, an increase in power from 100 to 200 W or 1,000 to 2,000 W yields the same 3-dB increase in level.

Sound Source	Sound Pressure (Pascal, Pa)	Sound Pressure Level (dB)
Saturn rocket	100,000	194
Ram jet	2,000	160
Propeller aircraft	200	140
Riveter	20	120
Heavy truck	2	100
Noisy office or heavy traffic	0.2	80
Conversational speech	0.02	60
Quiet residence	0.002	40
Leaves rustling	0.0002	20
Hearing threshold, excellent ears at frequency maximum response	0.00002	0

Figure: Examples of sound pressure and Sound Pressure Level

Example: Sound-Pressure Level

A sound-pressure level (SPL) is 78 dB. What is the sound pressure?

$$78\text{ dB} = 20\log p/(20\times10^{-6})$$

$$\log p/(20\times10^{-6}) = 78/20$$

$$p/(20\times10^{-6}) = 10^{3.9}$$

$$p = (20\times10^{-6})\,(7{,}943.3)$$

$$p = 0.159\text{ Pa}$$

Remember that the reference level in SPL measurements is 20 μPa.

Example: Loudspeaker SPL

An input of 1 W produces a SPL of 115 dB at 1 m. What is the SPL at 6.1 m (20 ft)?

$$SPL = 115 - 20\log(6.1/1)$$
$$= 115 - 15.7$$
$$= 99.3\ \text{dB}$$

The assumption made in the 20 log 6.1 factor is that the loudspeaker is operating in a free field and that the inverse square law is valid in this case. This is a reasonable assumption for a 20-ft distance if the loudspeaker is remote from reflecting surfaces.

A loudspeaker is rated at a sound-pressure level of 115 dB on axis at 1 m with 1 W into 8 Ω. If the input were decreased from 1 to 0.22 W, what would be the sound-pressure level at 1-m distance?

$$SPL = 115 - 10\log(0.22/1)$$
$$= 115 - 6.6$$
$$= 108.4\ \text{dB}$$

Note that 10 log is used because two powers are being compared.

Example: Microphone Specifications

An omnidirectional dynamic microphone open-circuit voltage is specified as −80 dB for the 150-Ω case. It is also specified that 0 dB = 1 V/μbar. What would be the open-circuit voltage n in volts?

$$-80\ \text{dB} = 20\log v/1$$
$$\log v/1 = -80/20$$
$$v = 0.0001\ \text{V}$$
$$= 0.1\ \text{mV}$$

Example: Line Amplifier

A line amplifier (600 Ω in, 600 Ω out) has a gain of 37 dB. With an input of 0.2 V, what is the output voltage?

$$37\ \text{dB} = 20\log(v/0.2)$$
$$\log(v/02) = 37/20$$
$$= 1.85$$
$$v/0.2 = 10^{1.85}$$
$$v = (0.2)(70.79)$$
$$v = 14.16\ \text{V}$$

Example: General-Purpose Amplifier

An amplifier has a bridging input impedance of 10,000 Ω and an output impedance of 600 Ω. With a 50-mV input, an output of 1.5 V is observed. What is the gain of the amplifier? The voltage gain is:

$$\text{Voltage gain} = 20\log(1.5/0.05)$$
$$= 29.5\ \text{dB}$$

It must be emphasized that this is not a power level gain because of the differences in impedance. However, voltage gain may serve a practical purpose in certain cases.

Example: Concert Hall

A seat in a concert hall is 84 ft from the tympani. The tympanist strikes a single note. The sound-pressure level of the direct sound of the note at the seat is measured to be 55 dB. The first reflection from the nearest sidewall arrives at the seat 105 msec after the arrival of the direct sound. (A) How far does the reflection travel to reach the seat? (B) What is the SPL of the reflection at the seat, assuming perfect reflection at the wall? (C) How long will the reflection be delayed after arrival of the direct sound at the seat?

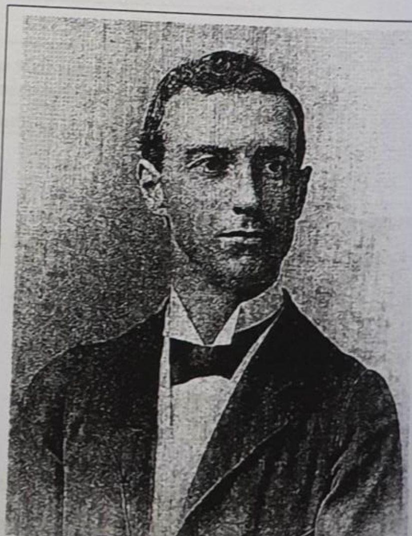


Figure: Wallace Clement Sabine, Physicist, Harvard Professor, and the Founder of Architectural Acoustics (Photo: Sabine Memorial).

$$L_2 - L_1 = 10\left[\log\left(\frac{I_2}{I_0}\right) - \log\left(\frac{I_1}{I_0}\right)\right]$$

$$= 10\left[\log\left(\frac{I_2}{I_1}\right)\right]$$

but $\frac{I_2}{I_1} = 2$ (given)

$$\therefore L_2 - L_1 = 10 \log 2$$

$$= 10\,(0.3010)$$

$$\therefore L_2 - L_1 = 3.01 \text{ dB}$$ **Answer.**

Example: An air conditioner unit operates at a sound intensity level of 70 dB. If it is operated in room with an existing sound intensity level of 80 dB, what will be the resultant intensity level.

Solution : Here for case – 1

Intensity level is 70 dB

$$\therefore 70 = 10 \log L_1 = 10 \log\left(\frac{I_1}{I_0}\right)$$

$$\therefore \frac{I_1}{I_0} = \text{Antilog } 7.0$$

or $I_1 = 10^7\, I_0 \text{ watts/m}^2$ …(1)

Similarly for Case – 2, intensity level is 80 dB.

$$\therefore 80 = 10 \log L_2 = 10 \log\left(\frac{I_2}{I_0}\right)$$

$$\therefore \frac{I_2}{I_0} = \text{Antilog } 8.0$$

$$\therefore I_2 = 1 \times 10^8\, I_0 \text{ watts/m}^2 \quad \ldots(2)$$

∴ Resultant intensity

$$I = I_1 + I_2$$

$$= 10^7\, I_0 + 10^8\, I_0$$

$$= I_0(1.1 \times 10^8)$$

∴ Resultant intensity level in dB

$$L = 10 \log\left(\frac{I}{I_0}\right)$$

$$= 10 \log\left(\frac{1.1 \times 10^8\, I_0}{I_0}\right) = 10 \log(1.1 \times 10^8)$$

$$= 80.41 \text{ dB}$$

∴ Resultant intensity level (in dB) is 80.41 **Answer.**

Example: The noise form an aeroplane engine 100 m from an observer is 40 dB in intensity. What will be the intensity when the aeroplane flies overhead at an altitude of 2 km?

Solution. : Intensity of sound is given by formula

$$I = \frac{P}{4\pi R^2}$$

Where P = Acoustic pressure level

R = Radial distance

Here, for case – 1

$$I_1 = \frac{P}{4\pi R_1^2}$$

And for case – 2

$$I_2 = \frac{P}{4\pi R_2^2}$$

$$\therefore \frac{I_2}{I_1} = \frac{R_1^2}{R_2^2}$$

Now $R_1 = 100$ m, $R_2 = 2000$ m (given)

$$\therefore \frac{I_2}{I_1} = \frac{100^2}{2000^2} = \frac{1}{400}$$

or $\frac{I_1}{I_2} = 400$ …(1)

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.

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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.

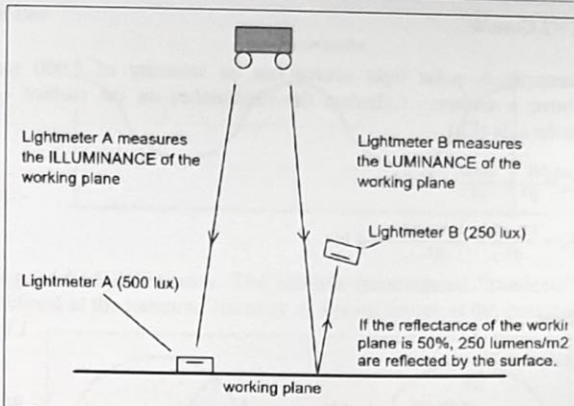


Figure: Experiment to illustrate the difference between Illuminance and Luminance

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.

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

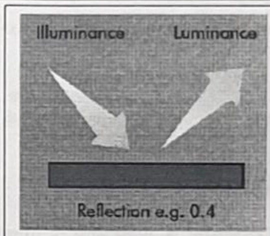


Figure: Illuminance onto a surface, Luminance off the surface.

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.

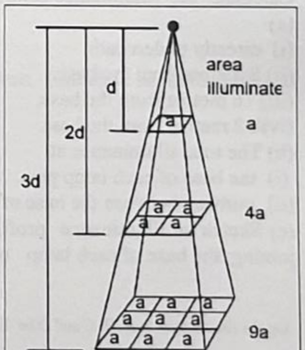


Figure: Inverse Square Law

In the example shown the illuminance reduces to a quarter of its original value when the distance is doubled. Similarly the illuminance reduces to one ninth of its original value when the distance away is tripled.

Cosine Law

When light does not fall normally on a surface, the area illuminated increases reducing the average illuminance by the same ratio. The figure shows light from a distant source striking surfaces AB and BC. The rays of incident light may be taken as parallel.

$$\frac{AB}{BC} = \cos\theta$$

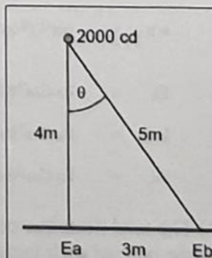


Figure: Cosine Law

Where θ = The angle between the incident light and the normal to the surface BC.

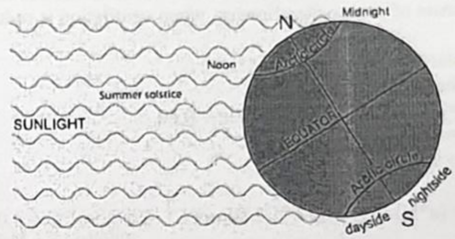
Therefore the average illuminance on a surface is given by the general formula:

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

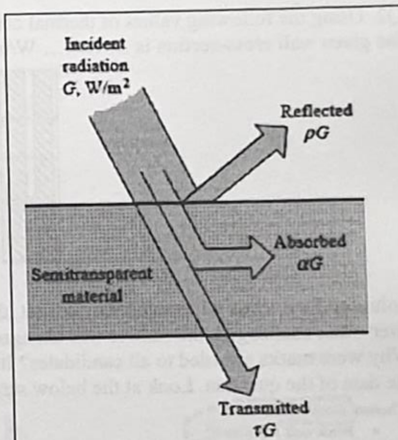
- Thus, you find that there are **days and nights and changes in the seasons because of the rotation and revolution of the earth respectively.**
- ***Rotation* ══ *Days and Nights.***
- ***Revolution* ══ *Seasons.***

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, and transmission of incident radiation by a semi-transparent material.

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

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

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

In the above equation, if the conductivity (k) is divided by length (L) then it is called conductance.
So, $\frac{k}{L}$ = conductance (C)

$$q = \frac{k A \Delta T}{L}$$

Now let's solve the question with amended data:

Thermal conductivity -
- Brick wall 1.2 W/m °C
- Plastering 0.5 W/m °C

Surface conductance -
- Internal surface 8.0 W/m² °C
- External surface 9.5 W/m² °C

Thermal resistance -
- 50 mm wall cavity 0.17 m² °C/W

U-value is similar to conductance in concept. So, $\frac{k}{L}$ = conductance (C) ≡ U-value

We know,

$$\frac{1}{Uo} = \frac{1}{U_1} + \frac{1}{U_2} + \frac{1}{U_3} + \ldots$$

$$\frac{1}{Uo} = \frac{1}{\text{External surface}} + \frac{1}{\text{Internal Surface}} + \frac{1}{\text{Cavity}} + \frac{1}{\text{Plaster}} + \frac{1}{\text{Brickwork}}$$

$$\Rightarrow \frac{1}{Uo} = \frac{1}{8.0\ W/m^2\,°C} + \frac{1}{9.5\ W/m^2\,°C} + \frac{1}{\frac{1}{0.17\ m^2\,°C/W}} + \frac{1}{\frac{0.5\ W/m\,°C}{20\ mm}} + \frac{1}{\frac{1.2\ W/m\,°C}{200\ mm}}$$

$$\Rightarrow \frac{1}{Uo} = \frac{1}{8.0\ W/m^2\,°C} + \frac{1}{9.5\ W/m^2\,°C} + \frac{1}{5.99\ W/m^2\,°C} + \frac{1}{\frac{0.5\ W/m\,°C}{0.02\ m}} + \frac{1}{\frac{1.2\ W/m\,°C}{0.2\ m}}$$

$$\Rightarrow \frac{1}{Uo} = \frac{1}{8.0\ W/m^2\,°C} + \frac{1}{9.5\ W/m^2\,°C} + \frac{1}{5.99\ W/m^2\,°C} + \frac{1}{25\ W/m^2\,°C} + \frac{1}{6\ W/m^2\,°C}$$

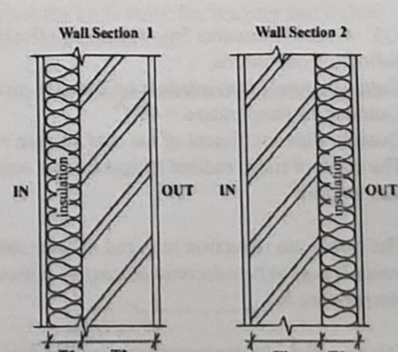
$$\Rightarrow \frac{1}{Uo} = 0.125\ (W/m^2\,°C)^{-1} + 0.105\ (W/m^2\,°C)^{-1} + 0.167\ (W/m^2\,°C)^{-1} + 0.040\ (W/m^2\,°C)^{-1} + 0.167\ (W/m^2\,°C)^{-1}$$

$$\Rightarrow \frac{1}{Uo} = 0.604\ (W/m^2\,°C)^{-1}$$

⇨ U = 1.65 W/m²°C Answer. This answer is in the range (that is *1.50 to 1.70*) of the official answer released for the first time!

GATE 2020

Q3. For the same thickness of material layers, relative position of insulation in the wall sections 1 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.

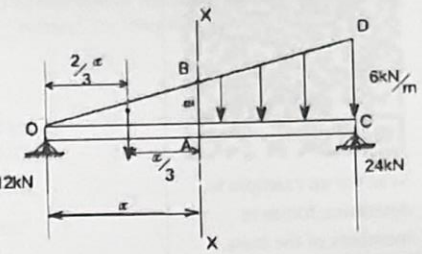
$= \dfrac{0 + \frac{x}{2}}{2}$

$= \dfrac{x}{4} \, k\dfrac{N}{m}$

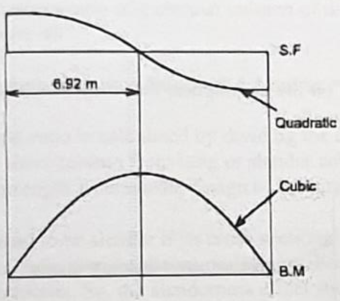
Therefore the total load over the length x would be

$= \dfrac{x}{4} \times x \text{ kN}$

$= \dfrac{x^2}{4} \text{ kN}$

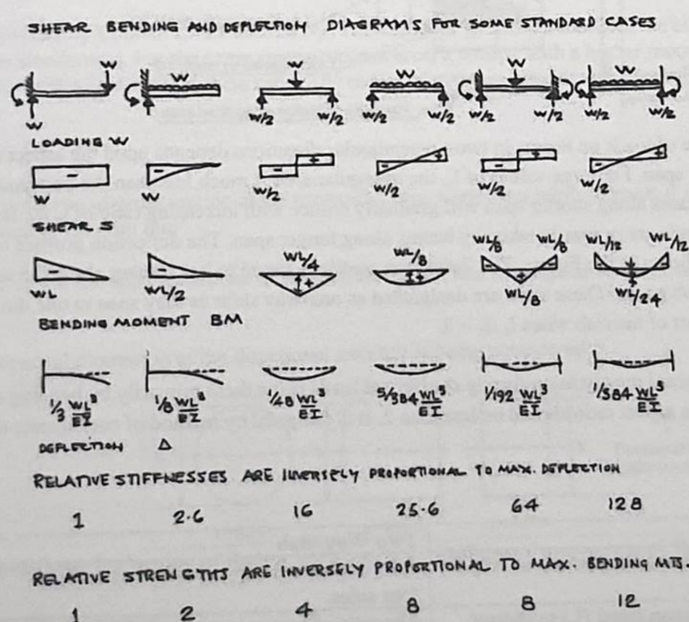


Now these loads will act through the centroid of the triangle OAB. i.e. at a distance 2/3 x from the left hand end.



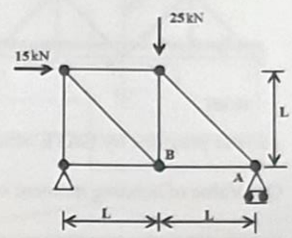
Common Relationships

Load	0	Constant	Linear
Shear	Constant	Linear	Parabolic
Moment	Linear	Parabolic	Cubic

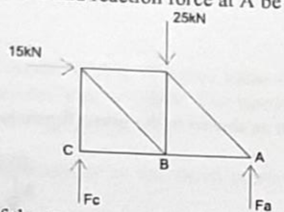


As per question, Bending Moment at x = 3 is 36kN-m
Therefore, (4W/7)*x = 36
Putting x = 3 in the above equation, gives us W = 21kN Answer

Q4. A simple truss is shown in the figure below. The truss is loaded with horizontal and vertical force 15 kN and 25 kN, respectively. The force in the member AB will be ___________ kN.



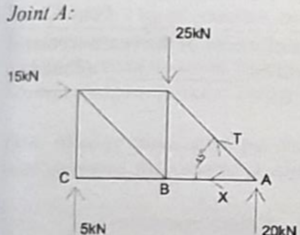
Solution: Our first aim should be to calculate reaction forces at support i.e. at A & C
Let the reaction force at C be Fc and reaction force at A be Fa



Sum of all vertical forces of the truss system must be zero.
So, Fa + Fc – 25kN = 0 ....(1)

Sum of moment at point C must be zero.
So, Fa*2L – 25kN*L – 15kN*L = 0
⇨ Fa = 20 kN

Joint A:



Sum of vertical forces at point A must be zero.
So, T*Sin45 + 20kN = 0
⇨ T = - 20kN/Sin45° ....(2)
Sum of horizontal force at point A must be zero.
Let the force in the member AB be X.
So, X – T*Cos45° = 0
⇨ X = 20 kN (Value of T is taken from equation (2)

So, the force in the member AB will be 20 kN Answer

GATE 2018

Q5. The compressive strength of M-25 concrete is
(A) 25 kg/sqm (B) 25 N/sqmm (C) 250 N/sqmm (D) 2.5 N/sqmm

Solution: Answer (B) 25 N/sqmm
According to Wikipedia, Compressive Strength of concrete is defined as the Characteristic strength of 150mm size concrete cubes tested at 28 days. But here in the question, the examiner is more interested whether you know the unit of the compressive strength a concrete or not. Option (A) and (B) may be a test for you. It is measured in Newton per square millimeter.

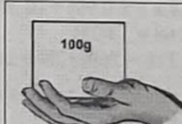


Figure: 100g in your hand is approximately equal to 1 Newton.

Q6. The live load and dead load in a three storeyed residential building, transferred through a single column, is 12 tons and 18 tons respectively. If the soil bearing capacity is 10 ton/sqm and the factor of safety is 1.5, the area of column footing is sqm (up to one decimal place).

Solution: Total load = (12+18)*1.5 = 45 ton

Bearing capacity = 10 ton/sqm
So, column footing area = (45 ton) / (10 ton/sqm) = 4.5 sqm Answer *(Official GATE answer varied from 4 to 5)*

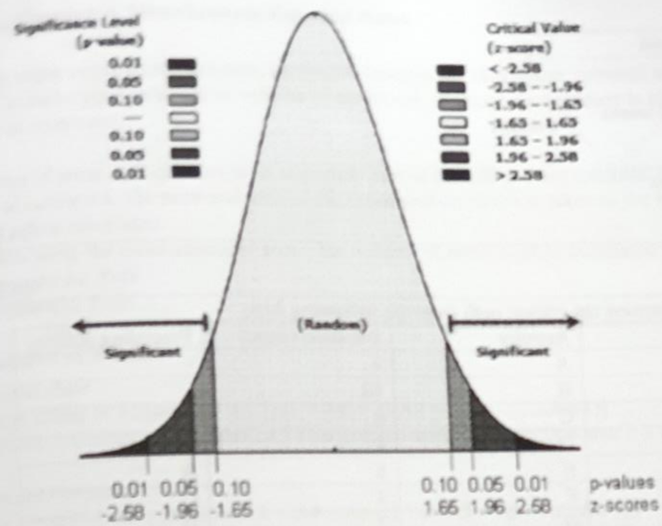


Figure: Z-score & P-value

GATE 1995

Q20. The optimistic (t_o) most likely (t_m) and permissible (t_p) times of activities on the critical path of a PERT network are given below.

Calculate the mean and the standard deviation of the path duration.

Activities on the critical path	t_o (days)	t_m (days)	t_p (days)
A	5	10	15
B	8	16	24

Solution: For an activity, mean = $(t_o + 4t_m + t_p)/6$ and standard deviation = $(t_p - t_o)/6$

Activities on the critical path	t_o (days)	t_m (days)	t_p (days)	Mean $(t_o + 4t_m + t_p)/6$	Standard Deviation, σ $(t_p - t_o)/6$	Variance, σ^2 Square of SD
A	5	10	15	10	1.67	2.79
B	8	16	24	16	2.27	5.15

We have already calculated σ for two activities – A & B. We now have to calculate standard deviation of the Critical Path. SD (standard deviation) of the Critical Path cannot be calculated by simply adding individual standard deviation σ. As per the Statistics, individual σ cannot be added together. In order to determine Critical Path SD, we have to first find Variance of the Critical Path.

Variance (Critical Path) = Variance(A) + Variance(B) = 2.79 + 5.15 = 7.94

As per the Statistics, σ can be determined by taking Square Root of Variance.

σ (Critical Path) = Square root of (Var(A) + Var(B)) = Square root of 7.94 = 2.82 Answer.

GATE 1994

Q21. The average completion time of the following construction activities are given below. As a construction manager for which activities you would like to maintain very strict schedule? Draw the network to justify your decision.

Activity	Average completion time (in weeks)
1-2	11
1-3	14
2-4	6
2-5	16
3-4	7
4-5	3

Q127. a) Explain the concept of relief displacement on aerial photography.

Illustration of deformation of an **aerial** image according to the distance from the nadir point, i.e. the centre of the image.

A vertical object (such as a building, for instance) will appear to be lying along a line radial to the image nadir point. This deformation is called **relief displacement**.

The image nadir point is the point located on the surface exactly below the perspective center.

This relief displacement underlie the following principles:

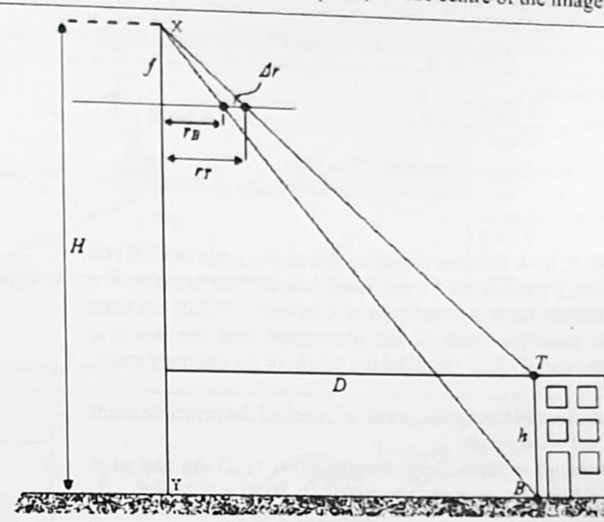


Figure: X is the perspective center, Y is the image nadir point

- Objects will tend to lean outward, i.e. be radially displaced.
- The taller the object, the greater the relief displacement.
- The further the object is from the principal point, the greater is the radial displacement.

Relief Displacement: Calculating Height

We can derive an expression for the relationship between object height and relief displacement using the geometry depicted in following picture.

We may write two expressions for distance D in this figure, in terms of radial image distances rB and rT.

$$\frac{r_B}{D} = \frac{f}{H} \quad , \quad D = \frac{H\, r_B}{f}$$

And

$$\frac{r_T}{D} = \frac{f}{H-h} \quad , \quad D = \frac{r_T\,(H-h)}{f}$$

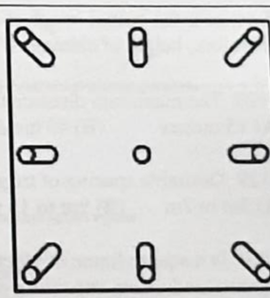


Figure: Illustration of deformation of an aerial image according to the distance from the nadir point, i.e. the centre of the image.

Source: Purdue Universitv

and set the two expressions for D equal to each other,

$$D = \frac{H\, r_B}{f} = \frac{r_T\,(H-h)}{f}$$

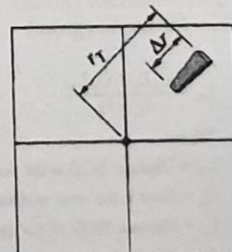
$$H\,r_T - h\,r_T - H\,r_B = 0$$

$$H(r_T - r_B) = h\, r_T$$

$$\frac{H \Delta r}{r_T} = h$$

The last equation tells us that the flying height above the base of the object (H) times the relief displacement in the photograph (Δr) divided by the radial distance from the principal point to the top of the object (rT) is equal to the height of the object (h).

Hence, if we know the flying height, we can calculate the height of any object in a photograph! The height of an object can be estimated from a single aerial photograph provided we have one auxiliary piece of information, the flying height.



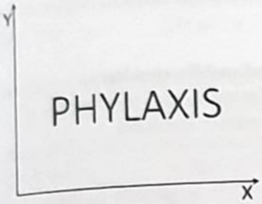
GATE Question Aptitude

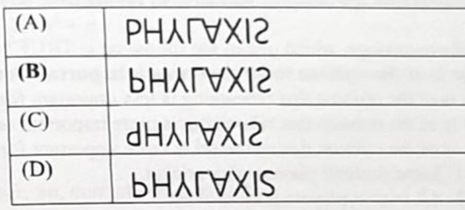
GATE 2021

Q1. (i) Arun and Aparna are here. (ii) Arun and Aparna is here.
(iii) Arun's families is here. (iv) Arun's family is here.

Which of the above sentences are grammatically CORRECT? (1 mark)
(A) (i) and (ii) **(B) (i) and (iv)** (C) (ii) and (iv) (D) (iii) and (iv)

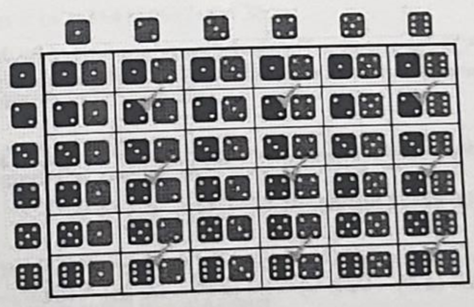
Q2. The mirror image of the below text about the x-axis is (1 mark)





Q3. Two identical cube shaped dice each with faces numbered 1 to 6 are rolled simultaneously. The probability that an even number is rolled out on each dice is: (A) 1/36 (B) 1/12 (C) 1/8 **(D) ¼** (1 mark)

Solution: Solution: Required probability = P(both are even) = P(first is even) * P(second is even) = (3/6)*(3/6) = (1/2)*(1/2) = **1/4 Answer**



Q4. ⊕and ⊙ are two operators on numbers p and q such that p ⊙ q = p − q, and p ⊕q = p x q.
Then, (9 ⊙ (6 ⊕ 7)) ⊙ (7 ⊕ (6 ⊙ 5)) =
(A) 40 (B) -26 (C) -33 **(D) -40** (1 mark)

Solution: [9-(6 X 7)] – [7 X 1] = - 33 – 7 = **- 40 Answer**

Q5. Four persons P, Q, R and S are to be seated in a row. R should not be seated at the second position from the left end of the row. The number of distinct seating arrangements possible is: (A) 6 (B) 9 **(C) 18** (D) 24 (1 mark)

So, required area = (Q) - (P) = 98/6 - 13/12 = 183/12 = **15.25**

Q46. The velocity V of a vehicle along a straight line is measured in m/s and plotted as shown with respect to time in seconds. At the end of the 7 seconds, how much will the odometer reading increase by (in m)? (2 marks)
(A) 0 (B) 3 (C) 4 (D) 5

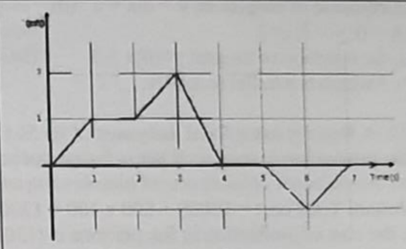


Figure: Odometer graph.

Solution: The odometer will read **5**. (The area shaded under the graph). Odometer is an instrument for measuring the distance travelled by a wheeled vehicle. So, you have to just count the no. of squares made by triangles of the graph. Answer: (D) 5

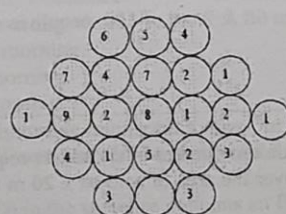
GATE 2015

Q47. Solve the following:
Operators □, ◊ and → are defined by: a □ b = $\frac{a-b}{a+b}$; a ◊ b = $\frac{a+b}{a-b}$; a → b = ab.
Find the value of (66 □ 6) → (66 ◊ 6)
(A) -2 (B) -1 (C) 1 (D) 2

Solution: 66□6 = 66-6/66+6 = 60/74
66◊6 = 66+6/66-6 = 74/60
Therefore, (66□6) →(66◊6) = (60/74)x(74/60) = 1

Q48. If $\log_x(5/7) = -1/3$, then the value of x is
(A) 343/125 (B) 125/343 (C) -25/49 (D) -49/25

Solution: As we know,
$\log 10^2 = 2$, $\log 10^3 = 3$, $\log 10^4 = 4$ and so on.
[Actually, $\log_{10}(10^2) = 2$]
So, $\log_x (5/7) = -1/3$
→ $x^{-1/3} = 5/7$
→ $x^{1/3} = 7/5$
→ $(x^{1/3})^3 = (7/5)^3$
→ $x = (7/5)^3 = 343/125$



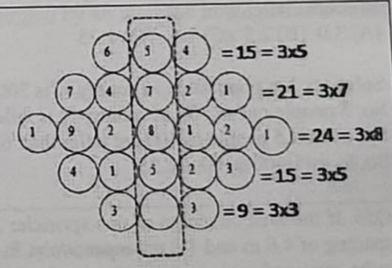


Figure: Solution of Q.No. 40

Q49. Fill in the missing value:

Solution: Missing value is 3

Q50. A cube of side 3 units is formed using a set of smaller cubes of side 1 unit. Find the proportion of the number of faces of the smaller cubes visible to those which are NOT visible.
(A) 1:4 (B) 1:3 (C) 1:2 (D) 2:3

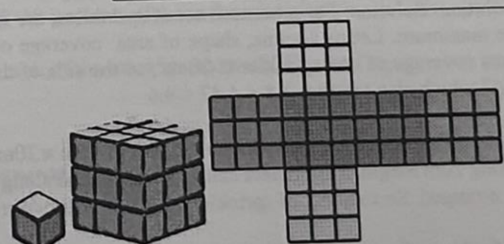


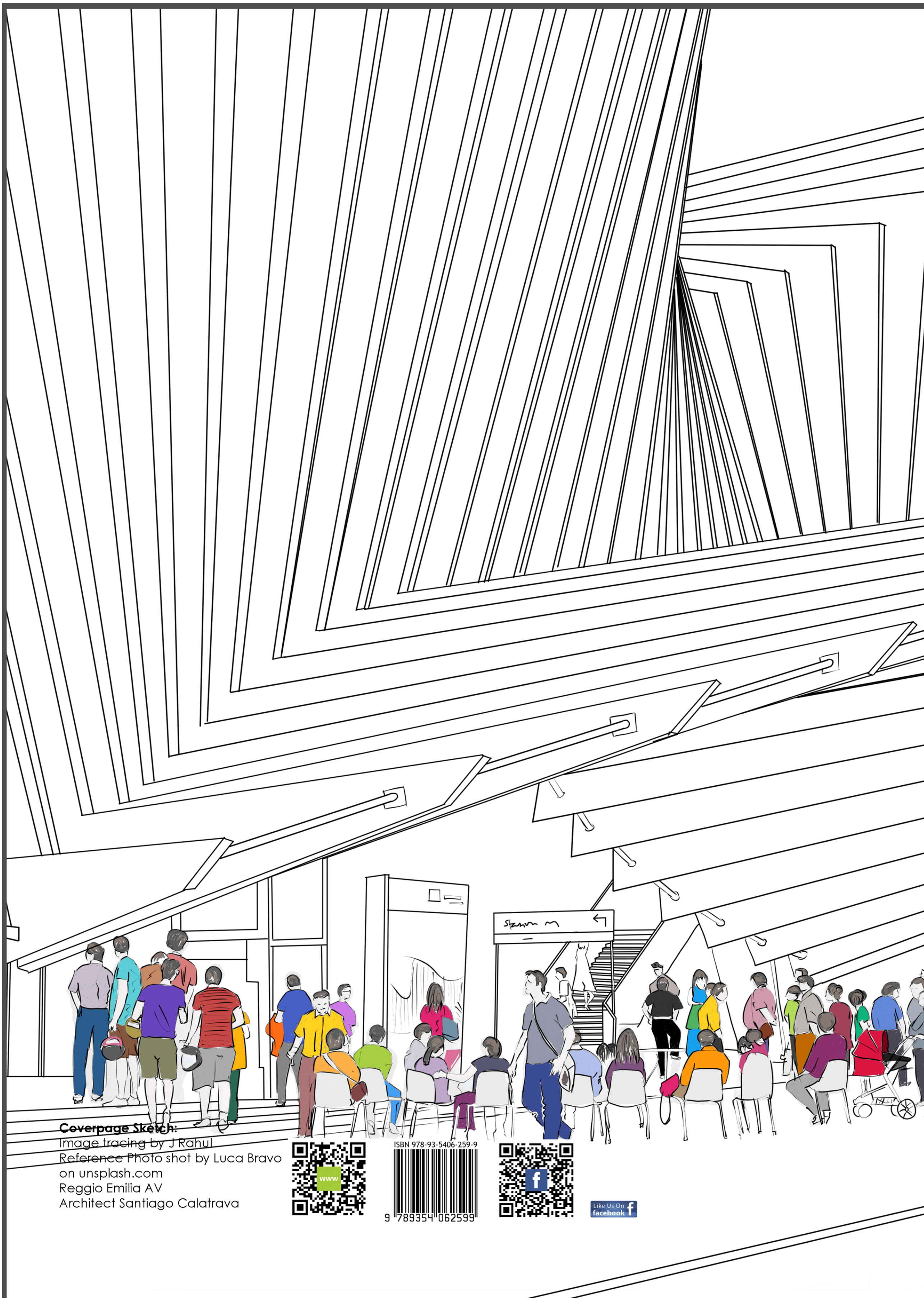
Figure: Rubik's Cube [Illustration for answer to Q. No.421

Solution: Answer (C) Let us take an example of a Rubik's cube assuming each side of 3 units. A Rubik's cube is made up of 27 small cubes assuming each side of 1 unit. A cube has 9 faces. So total no. of faces in 27 cubes are 27x6=162. Out of which 6x9=54 are visible.
So NOT visible faces will be = 162-54= 108
Therefore, required ratio = 54/108= ½=1:2

GATE 2014

Q51. If $y = 5x^2 + 3$, then the tangent at x = 0, y = 3
(A) passes through x = 0, y = 0
(B) has a slope of +1
(C) is parallel to the x-axis
(D) has a slope of −1

Solution: y'= 10x (slope)
So, at x=0, y'=0



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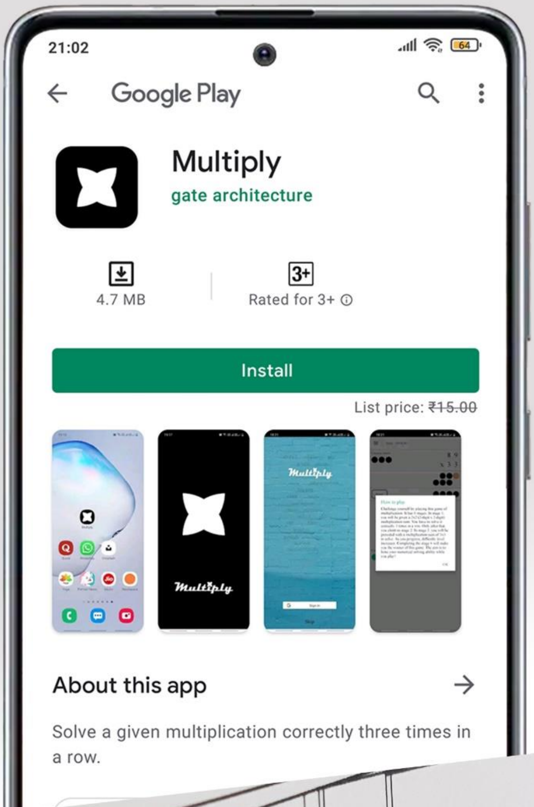

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