CMR INSTITUTE OF TECHNOLOGY **Department of EEE**	

Solution of Question Bank of Module 2 &Module 3-Illumination & Electric Traction

S.No	**Sub:UTILIZATION OF ELECTRICAL POWER**	Code:	17EE742/18EE742	
	Sem:VII	Section:	A & B	
1.	A hall of 28x48m is illuminated by indirect lighting using inverter fitting the average illumination of 108lm/m2 is to be provided on horizontal plans parallel to the flow and 0.5m above it. Design a suitable lighting scheme using filament lamps by taking UF&DF as 0.4 and 0.85.*Assume luminous efficiency 20 Lumens/Watt for 300W Lamp	CO4		L3
2.	Write a neat diagram ,explain the construction and working of the sodium & mercury vapour lamp	CO4		L3

Given data :

A = 28m × 48m

E = 108 lm/m²

h_m = 0.75m

UF = 0.4

D.F = 0.85

Assume suitable luminous efficiency = 20 lumens/watt for 300w lamp

Solution

1) $\phi = \frac{E \times A}{UF \times MF} = \frac{E \times A \times DF}{UF} = \frac{28 \times 48 \times 108 \times 0.85}{0.4}$

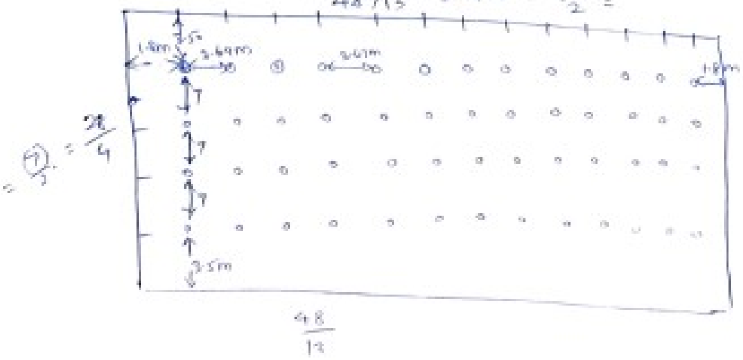
= 308448 lumens

2) Total W = $\phi/\eta = \frac{308448}{20}$ = 15422 W

3) Total no. of lamps = $\frac{15422}{300}$ = 52 (51.4)

4) No. of fittings = 52/2 = 26   4 × 13 = 52, 13 × 4 = 52

48/13 = 3.69m = 3.69/2 =

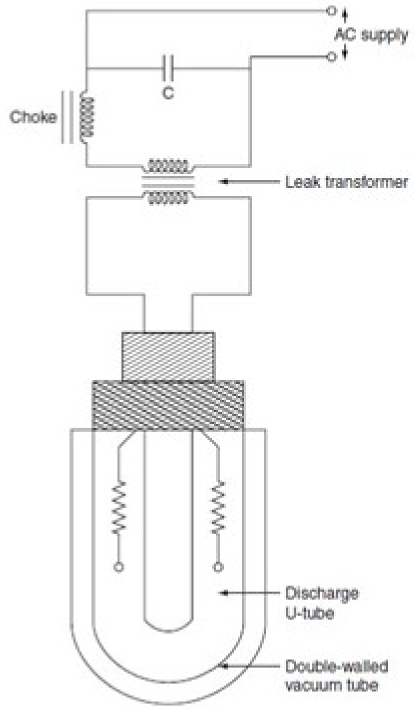


A sodium vapor lamp is a cold cathode and low-pressure lamp. A sodium vapor discharge lamp consists of a *U*-shaped tube enclosed in a double-walled vacuum flask, to keep the temperature of the tube within the working region. The inner *U*-tube consists of two oxide-coated electrodes, which are sealed with the ends. These electrodes are connected to a pin type base construction of sodium vapor lamp is shown in Fig..

This sodium vapor lamp is low luminosity lamp, so that the length of the lamp should be more. In order to get the desired length, it is made in the form of a *U*-shaped tube. This long*U*-tube consists of a small amount of neon gas and metallic sodium. At the time of start, the neon gas vaporizes and develops sufficient heat to vaporize metallic sodium in the *U*-shaped tube.

Working

Initially, the sodium is in the form of a solid, deposited on the walls of inner tube. When sufficient voltage is impressed across the electrodes, the discharge starts in the inert gas, i.e., neon; it operates as a low-pressure neon lamp with pink color. The temperature of the lamp



increases gradually and the metallic sodium vaporizes and then ionizes thereby producing the monochromatic yellow light. This lamp takes 10–15 min to give its full light output. The yellowish output of the lamp makes the object appears gray.

In order to start the lamp, 380 – 450 V of striking voltage required for 40- and 100-W lamps. These voltages can be obtained from a high reactance transformer or an auto transformer. The operating power factor of the lamp is very poor, so that a capacitor is placed to improve the power factor to above 0.8. More care should be taken while replacing the inner tube, if it is broken, then sodium comes in contact with the moisture; therefore, fire will result. The lamp must be operated horizontally or nearly so, to spread out the sodium well along the tube.

The efficiency of sodium vapor lamp is lies between 40 and 50 lumens/W. Normally, these lamps are manufactured in 45-, 60-, 85- and 140-W ratings. The normal operating temperatures of these lamps are 300°C. In general, the average life of the sodium vapor lamp is 3,000 hr and such bulbs are not affected by voltage variations.

- The cathode fails to emit the electrons.
- The filament breaks or burns out.
- All the particles of sodium are concentrated on one side of the inner tube.
- The life of the lamp increases due to aging.

The average light output of the lamp is reduced by 15% due to aging. These lamps are mainly used for highway and street lighting, parks, railway yards, general outdoor lighting, etc.

HIGH-PRESSURE MERCURY VAPOR LAMP

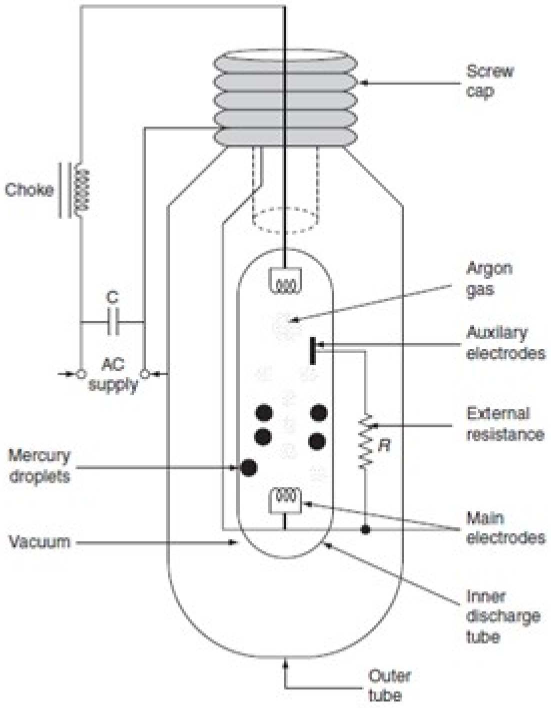
The working of the mercury vapor discharge lamp mainly depends upon the pressure, voltage, temperature, and other characteristics that influence the spectral quality and the efficiency of the lamp.

Generally used high-pressure mercury vapor lamps are of three types. They are:

1. MA type: Preferred for 250- and 400-W rating bulbs on 200–250-V AC supply.
2. MAT type: Preferred for 300- and 500-W rating bulbs on 200–250-V AC supply.
3. MB type: Preferred for 80- and 125-W rating bulbs and they are working at very high pressures.

MA type lamp

It is a high-pressure mercury vapor discharge lamp that is similar to the construction of sodium vapor lamp. The construction of MA type lamp is shown in Fig.



MA type lamp consists of a long discharge tube in '*U*' shape and is made up of hard glass or quartz. This discharge tube is enclosed in an outer tube of ordinary glass. To prevent the heat loss from the inner bulb, by convection, the gap between the two tubes is completely evacuated. The inner tube contains two main electrodes and an auxiliary starting electrode, which is connected through a high resistance of about 50 kΩ. It also contains a small quantity of argon gas and mercury. The two main electrodes are tungsten coils coated with electron emitting material (such as thorium metal).

Working

Initially, the tube is cold and hence the mercury is in condensed form. Initially, when supply is given to the lamp, argon gas present between the main and the auxiliary electrodes gets ionized, and an arc is established, and then discharge takes place through argon for few minutes between the main and the auxiliary electrodes. As a result, discharge takes place through argon for few minutes in between the main and the auxiliary electrodes. The discharge can be controlled by using high resistance that is inserted in-series with the auxiliary electrode. After few minutes, the argon gas, as a whole, gets ionized between the two main electrodes. Hence, the discharge shifts from the auxiliary electrode to the two main electrodes. During the discharge process, heat is produced and this heat is sufficient to vaporize the mercury. As a result, the pressure inside the discharge tube becomes high and the voltage drop across the two main electrodes will increases from 20 to 150 V. After 5–7 min, the lamp starts and gives its full output.

Initially, the discharge through the argon is pale blue glow and the discharge through the mercury vapors is greenish blue light; here, choke is provided to limit high currents and capacitor is to improve the power factor of the lamp.

If the supply is interrupted, the lamp must cool down and the vapor pressure be reduced before it will start. It takes approximately 3 – 4 min. The operating temperature of the inner discharge tube is about 600°C. The efficiency of this type of lamp is 30–40 lumens/W. These lamps are manufactured in 250 and 400 W ratings for use on 200–250 V on AC supply.

Generally, the MA type lamps are used for general industrial lighting, ports, shopping centers, railway yards, etc.

3.	Assume the trapezoidal curve and derive the maximum speed for the speed –time curve	CO5	L2

SIMPLIFIED TRAPEZOIDAL SPEED TIME CURVES

Simplified speed–time curves gives the relationship between acceleration, retardation average speed, and the distance between the stop, which are needed to estimate the performance of a service at different schedule speeds. So that, the actual speed–time curves for the main line, urban, and suburban services are approximated to some from of the simplified curves. These curves may be of either trapezoidal or quadrilateral shape.

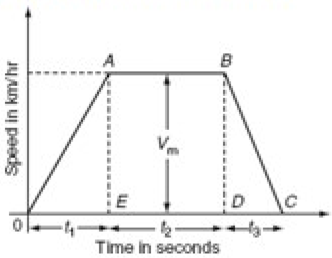


Fig. Trapezoidal speed–time curve

Calculations from the trapezoidal speed–time curve

Let D be the distance between the stops in km, T be the actual running time of train in second, α be the acceleration in km/h/sec, β be the retardation in km/h/sec, V_m be the maximum or the crest speed of train in km/h, and V_a be the average speed of train in km/h. From the Fig. 10.4:

Actual running time of train, $T = t_1 + t_2 + t_3$. (10.1)

Time for acceleration, $t_1 = \frac{V_m - 0}{\alpha} = \frac{V_m}{\alpha}$. (10.2)

Time for retardation, $t_3 = \frac{V_m - 0}{\beta} = \frac{V_m}{\beta}$. (10.3)

$= T - \left[\frac{V_m}{\alpha} + \frac{V_m}{\beta}\right]$. (10.4)

	Area under the trapezoidal speed–time curve gives the total distance between the two stops (D). $\therefore$ The distance between the stops (D) = area under triangle OAE + area of rectangle $ABDE$ + area of triangle DBC = The distance travelled during acceleration + distance travelled during free-running period + distance travelled during retardation. Now: The distance travelled during acceleration = average speed during accelerating period × time for acceleration $= \frac{0+V_m}{2} \times t_1$ km/h × sec $= \frac{0+V_m}{2} \times \frac{t_1}{3,600}$ km. The distance travelled during free-running period = average speed × time of free running $= V_m \times t_2$ km/h × sec $= V_m \times \frac{t_2}{3,600}$ km. The distance travelled during retardation period = average speed × time for retardation		

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$$= \frac{V_m + 0}{2} \times t_3 \text{ km/h} \times \text{sec}$$

$$= \frac{0+V_m}{2} \times \frac{t_3}{3,600} \text{ km.}$$

The distance between the two stops is:

$$D = \frac{V_m}{2}\times\frac{t_1}{3,600} + V_m \times \frac{t_2}{3,600} + \frac{V_m}{2}\times\frac{t_3}{3,600}$$

$$D = \frac{V_m t_1}{7,200} + \frac{V_m}{3,600}\left[T - V_m(t_1+t_2)\right] + \frac{V_m t_3}{7,200}$$

$$D = \frac{V_m^2}{7,200\alpha} + \frac{V_m}{3,600}\left[T - V_m\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)\right] + \frac{V_m^2}{7,200\beta}$$

$$3,600 \times D = \frac{V_m^2}{2\alpha} + \frac{V_m^2}{\beta} - V_m^2\left(\frac{1}{\alpha}+\frac{1}{\beta}\right) + V_m T$$

$$3,600\ D = V_m^2\left(\frac{1}{2\alpha}-\frac{1}{\alpha}\right) + V_m^2\left(\frac{1}{2\beta}-\frac{1}{\beta}\right) + V_m T$$

$$3,600\ D = \frac{-V_m^2}{2\alpha} - \frac{V_m^2}{2\beta} + V_m T$$

$$\therefore V_m^2\left[\frac{1}{2\alpha}+\frac{1}{2\beta}\right] - V_m T + 3,600D = 0.$$

Let $\frac{1}{2\alpha}+\frac{1}{2\beta} = X = \frac{\alpha+\beta}{2\alpha\beta}$

$$\therefore V_m^2 X - V_m T + 3,600D = 0. \qquad \textbf{(10.5)}$$

Solving quadratic Equation (10.5), we get:

$$V_m = \frac{T+\sqrt{T^2-4\times X\times 3,600D}}{2\times X.}$$

$$= \frac{T}{2X} \pm \sqrt{\frac{T^2}{4X^2} - \frac{3,600D}{X}}.$$

By considering positive sign, we will get high values of crest speed, which is practically not possible, so negative sign should be considered:

$$V_m = \frac{T}{2X} - \sqrt{\frac{T^2}{4X^2} - \frac{3,600D}{X}} \qquad \textbf{(10.6)}$$

Or, $V_m = \frac{\alpha\beta}{\alpha+\beta}T - \sqrt{\left(\frac{\alpha\beta}{\alpha+\beta}\right)^2 T^2 - 7,200\left(\frac{\alpha\beta}{\alpha+\beta}\right)D}.$

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<tr><td>4.</td><td>A lamp giving 400 candle powers in all direction below the horizontal is suspended 3m above the centre of a square table of 1.5m side. Calculate the maximum and minimum illumination on the table
Answer: F= 11.42 Lux</td><td>CO4</td><td>L3</td></tr>
<tr><td>5.</td><td>State and explain the laws of Illumination</td><td>CO4</td><td>L2</td></tr>
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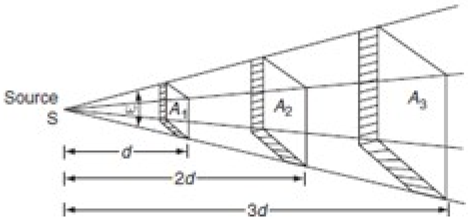
	Inverse square law This law states that 'the illumination of a surface is inversely proportional to the square of distance between the surface and a point source'. ***Proof:*** Let, '*S*' be a point source of luminous intensity '*I*' candela, the luminous flux emitting from source crossing the three parallel plates having areas $A_1 A_2$, and A_3 square meters, which are separated by a distances of *d*, 2*d*, and 3*d* from the point source respectively as shown in Fig. 6.10.  **Fig. 6.10** Inverse square law For area A_1, solid angle $\omega = \frac{A_1}{d^2}$. Luminous flux reaching the area A_1 = luminous intensity × solid angle $= I \times \omega = I \times \frac{A_1}{d^2}$. ∴ Illumination '$E_1$' on the surface area '$A_1$' is:		

$$E_1 = \frac{\text{flux}}{\text{area}} = \frac{IA_1}{d^2} \times \frac{1}{A_1}$$

$$\therefore E_1 = \frac{I}{d^2} \text{ lux.} \qquad (6.5)$$

Similarly, illumination 'E_2' on the surface *area* A_2 is:

$$E_2 = \frac{I}{(2d)^2} \text{ lux} \qquad (6.6)$$

and illumination 'E_3' on the surface area A_3 is:

$$E_3 = \frac{I}{(3d)^2} \text{ lux.} \qquad (6.7)$$

From Equations (6.5), (6.6), and (6.7)

$$E_1 : E_2 : E_3 = \frac{1}{d^2} : \frac{1}{(2d)^2} : \frac{1}{(3d)^2}. \qquad (6.8)$$

Hence, from Equation (6.8), illumination on any surface is inversely proportional to the square of distance between the surface and the source.

Lambert's cosine law

This law states that 'illumination, E at any point on a surface is directly proportional to the cosine of the angle between the normal at that point and the line of flux'.

Proof:

While discussing, the Lambert's cosine law, let us assume that the surface is inclined at an angle 'θ' to the lines of flux as shown in Fig. 6.11.

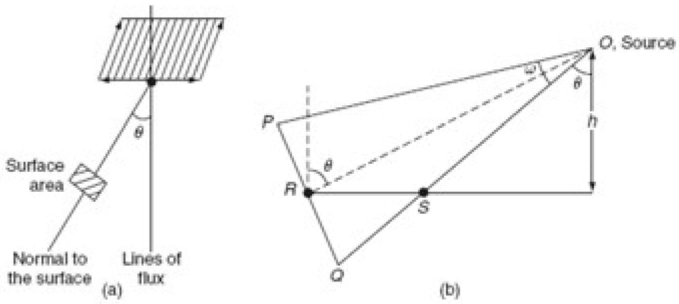


Fig. 6.11 Lambert's cosine law

Let

PQ = The surface area normal to the source and inclined at 'θ' to the vertical axis.

RS = The surface area normal to the vertical axis and inclined at an angle θ to the source 'O'.

Therefore, from Fig. 6.11:

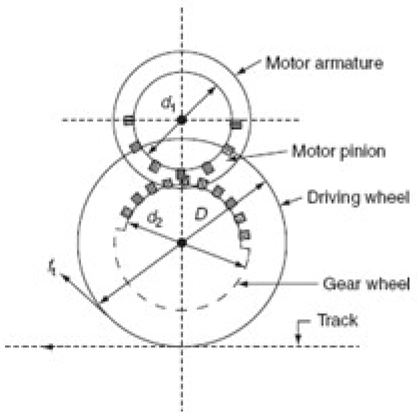
$$PQ = RS\cos\theta.$$

$\therefore$ The illumination of the surface $PQ, E_{PQ} = \dfrac{\text{flux}}{\text{area of } PQ}$

$$= \frac{I \times \omega}{\text{area of } PQ} = \frac{I}{\text{area of } PQ} \times \frac{\text{area of } PQ}{d^2} \quad \left[\therefore \omega = \text{area}/(\text{radius})^2\right]$$

$$= \frac{I}{d^2}. \qquad (6.9)$$

	∴ The illumination of the surface $RS, E_{RS} = \dfrac{\text{flux}}{\text{area of } RS} = \dfrac{\text{flux}}{\text{area of } PQ/\cos\theta}$ $[\therefore PQ = RS\cos\theta]$ $= \dfrac{I}{d^2}\cos\theta.$ **(6.10)** From Fig. 6.11(b): $\cos\theta = \dfrac{h}{d}$ or $d = \dfrac{h}{\cos\theta}$. Substituting 'd' from the above equation in Equation (6.10): $\therefore E_{RS} = \dfrac{I}{(h/\cos\theta)^2} \times \cos\theta = \dfrac{I}{h^2}\cos^3\theta$ **(6.11)** $\therefore E_{RS} = \dfrac{I}{d^2}\cos\theta = \dfrac{I}{h^2}\cos^3\theta$ **(6.12)** where d is the distance between the source and the surface in m, h is the height of source from the surface in m, and I is the luminous intensity in candela. Hence, Equation (6.11) is also known as 'cosine cube' law. This law states that the 'illumination at any point on a surface is dependent on the cube of cosine of the angle between line of flux and normal at that point'.		
6.	Define the following terms of Luminous Flux, Luminous Intensity ,Illumination, Mean Horizontal Power and Mean Spherical Candle Power **Luminous flux:** it is defined as the total quantity of light energy emitted per second form a luminous body. It is represented by symbol F and is measured in lumens. The concept of luminous flux helps us to specify the output and efficiency of a given light source. **Luminous intensity:** luminous intensity in any given direction is the luminous flux emitted by the source per unit solid angle, measured in the direction in which the intensity is required. It is denoted by symbol I and is measured in candela(cd) or lumens/steradian. If **F** is the luminous flux radiated out by source within a solid angle of ω steradian in any particular direction then I =F/ ω lumens/steradian or candela (cd). **Lumen:** The lumen is the unit of luminous flux and is defined as the amount of luminous flux given out in a space represented by one unit of solid angle by a source having an intensity of one candle power in all directions. ***Lumens = candle power X solid angle = cp X ω*** Total lumens given out by source of one candela are 4π lumens. **Candle power:** Candle power is the light radiating capacity of a source in a given direction and is defined as the number of lumens given out by the source in a unit solid angle in a given direction. It is denoted by a symbol **C.P.** ***C.P. = lumens/ω***	CO4	L1

	Mean horizontal candle power: (M.H.C.P) It is defined as the mean of candle powers in all directions in the horizontal plane containing the source of light. **Mean spherical candle power: (M.S.C.P)** It is defined as the mean of the candle powers in all directions and in all planes from the source of light. **Mean hemi-spherical candle power: (M.H.S.C.P)** It is defined as the mean of candle powers in all directions above or below the horizontal plane passing through the source of light. **Reduction factor:** Reduction factor of a source of light is the ratio of its mean spherical candle power to its mean horizontal candle power. ***reduction factor = M.S.C.P./M.H.C.P.***		
7.	Derive Tractive Efforts required for the propulsion of a train considering gradient and resistance to train movement It is the effective force acting on the wheel of locomotive, necessary to propel the train is known as '*tractive effort*'. It is denoted with the symbol F_t. The tractive effort is a vector quantity always acting tangential to the wheel of a locomotive. It is measured in newton. The net effective force or the total tractive effort (F_t) on the wheel of a locomotive or a train to run on the track is equals to the sum of tractive effort: 1. Required for linear and angular acceleration (F_a). 2. To overcome the effect of gravity (F_g). 3. To overcome the frictional resistance to the motion of the train (F_r). $\therefore F_t = F_a + F_g + F_r$ **(10.8)** Mechanics of train movement The essential driving mechanism of an electric locomotive is shown in Fig. 10.6. The electric locomotive consists of pinion and gear wheel meshed with the traction motor and the wheel of the locomotive. Here, the gear wheel transfers the tractive effort at the edge of the pinion to the driving wheel.  Fig. Driving mechanism of electric locomotives	CO5	L2

Let T is the torque exerted by the motor in N-m, F_p is tractive effort at the edge of the pinion in Newton, F_t is the tractive effort at the wheel, D is the diameter of the driving wheel, d_1 and d_2 are the diameter of pinion and gear wheel, respectively, and η is the efficiency of the power transmission for the motor to the driving axle.

Now, the torque developed by the motor $T = F_p \times \frac{d_1}{2}$ N-m.

$$\therefore F_p = \frac{2T}{d_1} \text{ N.} \qquad \textbf{(10.9)}$$

The tractive effort at the edge of the pinion transferred to the wheel of locomotive is:

$$F_t = F_p \times \frac{d_2}{D} \text{ N.} \qquad \textbf{(10.10)}$$

From Equations (10.9) and (10.10) $F_t = \eta \times \frac{2T}{d_1} \times \frac{d_2}{D}$

$$= \eta \cdot T \cdot \frac{2}{D}\left(\frac{d_2}{d_1}\right)$$

$$= \eta T \cdot \frac{2}{D} \cdot r,$$

where 'r'$= \left(\frac{d_2}{d_1}\right)$ is known as gear ratio.

$$\therefore F_t = 2\eta r \frac{T}{D} \text{ N.} \qquad \textbf{(10.11)}$$

10.7.2 Tractive effort required for propulsion of train

From Equation (10.8), the tractive effort required for train propulsion is:

$F_t = F_a + F_g + F_r$

From Equation (10.8), the tractive effort required for train propulsion is:

$$F_t = F_a + F_g + F_r$$

where F_a is the force required for linear and angular acceleration, F_g is the force required to overcome the gravity, and F_r is the force required to overcome the resistance to the motion.

Force required for linear and angular acceleration (Fa)

According to the fundamental law of acceleration, the force required to accelerate the motion of the body is given by:

Force = Mass × acceleration

$F = ma.$

Let the weight of train be 'W' tons being accelerated at 'α' kmphps:

∴ The mass of train $m = 1{,}000$ W kg.

And, the acceleration $= \alpha$ kmphps

$$= \alpha \times \frac{1{,}000}{3{,}600} \text{ m/s}^2$$

$$= 0.2788\alpha \text{ m/s}^2.$$

The tractive effort required for linear acceleration:

$$F_a = 1{,}000 \text{ W kg} \times 0.2778\alpha \text{ m/s}^2$$

$$= 27.88 \text{ W}\alpha \text{ kg} - \text{m/s}^2 \text{ (or) N.} \qquad \textbf{(10.12)}$$

Equation (10.12) holds good only if the accelerating body has no rotating parts. Owing to the fact that the train has rotating parts such as motor armature, wheels, axels, and gear system. The weight of the body being accelerated including the rotating parts is known as *effective weight* or *accelerating weight*. It is denoted with 'W_e'. The accelerating weight '(W_e)' is much higher (about 8–15%) than the dead weight (W) of the train. Hence, these parts need to be given angular acceleration at the same time as the whole train is accelerated in linear direction.

∴ The tractive effort required-for linear and angular acceleration is:

$$F_a = 27.88\, W_e \alpha \text{ N.} \qquad \textbf{(10.13)}$$

Tractive effort required to overcome the train resistance (Fr)

When the train is running at uniform speed on a level track, it has to overcome the opposing force due to the surface friction, i.e., the friction at various parts of the rolling stock, the fraction at the track, and also due to the wind resistance. The magnitude of the frictional resistance depends upon the shape, size, and condition of the track and the velocity of the train, etc.

Let '*r*' is the specific train resistance in N/ton of the dead weight and '*W*' is the dead weight in ton.

∴ The tractive effort required to overcome the train resistance $F_r = Wr$ N. **(10.14)**

Tractive effort required to overcome the effect of gravity (Fg)

When the train is moving on up gradient as shown in Fig. 10.7, the gravity component of the dead weight opposes the motion of the train in upward direction. In order to prevent this opposition, the tractive effort should be acting in upward direction.

∴ The tractive effort required to overcome the effect of gravity:

$$F_g = \pm \text{ mg } \sin\theta \text{ N}$$

$$= \pm 1{,}000 \text{ Wg } \sin\theta \quad [\because m = 1{,}000 \text{ Wkg}]. \qquad \textbf{(10.15)}$$

Now, from the Fig. 10.7:

$$\text{Gradient} = \sin\theta = \frac{BC}{AC} = \frac{\text{Elevation}}{\text{distance along the track}}$$

$$\% \text{ Gradient } G = \sin\theta \times 100. \qquad \textbf{(10.16)}$$

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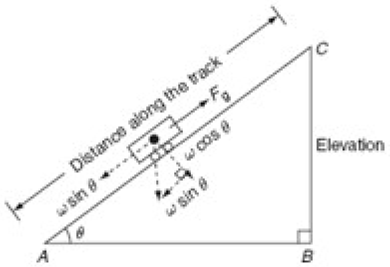

Fig. 10.7 Train moving on up gradient

From Equations (10.15) and (10.16):

$$\therefore F_g = \pm 1{,}000\ \mathrm{W}\,g \times \frac{G}{100}$$
$$= \pm\ 10 \times 9.81\ \mathrm{W}G$$
$$= \pm\ 98.1\ \mathrm{W}G\ \mathrm{N} \qquad [\text{since } g = 9.81\ \mathrm{m/s^2}]. \quad \mathbf{(10.17)}$$

+ve sign for the train is moving on up gradient.

−ve sign for the train is moving on down gradient.

This is due to when the train is moving on up a gradient, the tractive effort showing Equation (10.17) will be required to oppose the force due to gravitational force, but while going down the gradient, the same force will be added to the total tractive effort.

The total tractive effort required for the propulsion of train $F_t = F_a + F_r \pm F_g$:

$$F_t = 277.8\ W_e\alpha + Wr \pm 98.1\ \mathrm{W}G\ \mathrm{N}. \qquad \mathbf{(10.18)}$$
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<tr><td>8.</td><td>Define the terms of Crest Speed, Average Speed and Schedule Speed</td><td>CO5</td><td>L1</td></tr>
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	<u>Crest Speed</u> • The maximum speed attained by the vehicle during its running is called as crest speed. **<u>Average Speed</u>** • The mean or average speed of the vehicle during from start to stop is called as average speed. • It is distance covered between two stops divided by the actual time of run. Average speed = Distance between two stops / Average time of run **<u>Schedule Speed</u>** • It is defined as the ratio of the distance covered between two stops and total time of run include time of stop is called as schedule speed. Schedule speed = Distance between two stops / [Actual time of run + Stop time] • The schedule speed is smaller than the average speed.		
9.	The luminous intensity of a source is 600 candela is placed in the middle of a 10 × 6 × 2 m room. Calculate the illumination: 1. At each corner of the room. 2. At the middle of the 6-m wall.	CO4	L3

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Solution:

Given data:

Luminous intensity, (I) = 600 cd.

Room area = 10 × 6 × 2 m.

1. From the Fig. P.6.4:

$$OB = BD = \frac{\sqrt{10^2+6^2}}{2} = 5.83 \text{ m}$$

$$BS = d = \sqrt{2^2+(5.38)^2} = 6.163 \text{ m.}$$

∴ The illumination at the corner 'B':

$$E_B = E_A = E_C = E_D$$

$$\frac{I}{d^2}\cos\theta = \frac{600}{(6.163)^2}\times\frac{2}{(6.163)}$$

$$= 5.126 \text{ lux.}$$

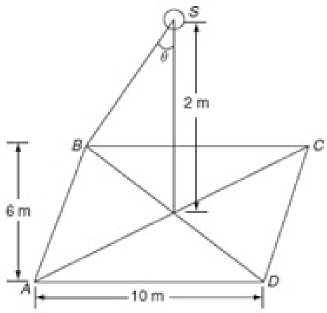

Fig. 1

2. From Fig. 1

$$PS = \sqrt{2^2+5^2}$$

$$= 5.385 \text{ m.}$$

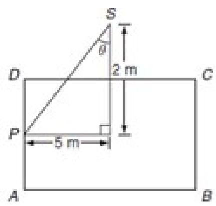

Fig. 2

The illumintaion at the point 'P

$$E_p = \frac{I}{d^2}\cos\theta = \frac{600}{(5.385)^2}\times\frac{2}{(5.385)} = 7.684 \text{ lux.}$$

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A lamp of 250 candela is placed 2 m below a plane mirror that reflects 60% of light falling on it. The lamp is hung at 6 m above ground. Find the illumination at point on the ground 8 m away from the point vertically below the lamp.

The candle power of the source, I = 200 candela.

Mounting height (h) = 6 m.

1. The illumination just below the lamp, i.e., at point 'A':

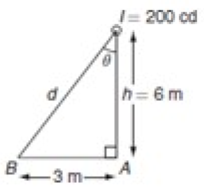
$$E_p = \frac{I}{d^2}\cos\theta$$

$$= \frac{600}{(5.385)^2}\times\frac{2}{(5.385)}$$

$$= 7.684 \text{ lux.}$$

2. From Fig. P.6.6:

$$d = \sqrt{3^2+6^2} = 6.708.$$



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<td>CO4</td>
<td>L3</td>
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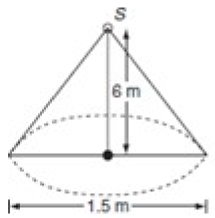
	$E_B = \frac{I}{d^2}\cos\theta$  **Fig. P.6.7** $= \frac{200}{(6.708)^2} \times \frac{6}{(6.708)}$ $= 3.975$ lux. 3. Surface area $= \frac{\pi}{4} d^2$ $= \frac{\pi}{4} \times (1.5)^2$ $= 1.767\ m^2$. The total flux reaching the area around the lamp: $= E_A \times$ surface area $= 5.55 \times 1.767$ $= 9.80$ lumens.		
11.	A drawing, with an area of 18 × 12 m, is to be illuminated with an average illumination of about 150 lux. The lamps are to be fitted at 6 m height. Find out the number and size of incandescent lamps required for an efficiency of 20 lumens/W. UF = 0.6, MF = 0.75. Given data: η = 120 lumens/W E = 150 lux $A = 18 \times 12 = 216\ m^2$ UF = 0.6	CO4	L3

MF = 0.75

The total gross lumens required $\phi = \frac{E \times A}{\text{UF} \times \text{MF}}$.

$$= \frac{150 \times 216}{0.6 \times 0.75} = 72,000 \text{ lumens.}$$

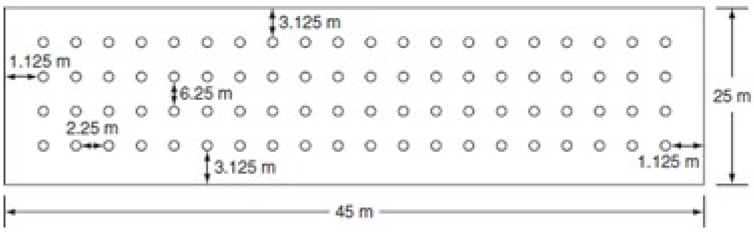
The total wattage required $= \frac{72,000}{\eta}$

$$= \frac{72,000}{20} = 3,600 \text{ W.}$$

Let, if 24 lamps are arranged to illuminate the desired area. For space to height ratio unity, i.e., 6 lamps are taken along the length with a space of 18/6 = 3m, and 4 lamps are along the width giving a space of 12/4 = 3 m.

$\therefore$ The wattage of each lamp $= \frac{3,600}{24} = 150$ W.

The arrangement of 24 lamps in a hall of 18 × 12 m is shown in Fig.



12.	A hall of 30 × 20 m area with a ceiling height of 6 m is to be provided with a general illumination of 200 lumens/m^2, taking a coefficient of utilization of 0.6 and depreciation factor of 1.6. Determine the number of fluorescent tubes required, their spacing, mounting height, and total wattage. Take luminous efficiency of fluorescent tube as 25 lumens/W for 300- W tube.	CO4	L3

Given data:

Area of hall (A) = 30 × 20 m = 600 m²

E = 200 lumens/m²

CU = 0.6

DF = 1.6

The wattage of fluorescent tube = 300 W

Efficiency η = 25 lumens/W

$$\therefore \text{Gross lumens required, } \phi = \frac{A \times E \times \text{DF}}{\text{UF}}$$

$$= \frac{600 \times 200 \times 1.6}{0.6} = 320{,}000 \text{ lux.}$$

$$\text{The total wattage required } = \frac{\phi}{\eta} = \frac{320{,}000}{25}.$$

$$\text{The number of tubes required } = \frac{\text{total wattage required}}{\text{wattage of each tube}}$$

$$= \frac{12{,}800}{300}$$

$$= 42.666 \cong 44.$$

Let us arrange 44 lamps in a 30 × 30 m hall, by taking 11 lamps along the length with spacing 30/11 = 2.727 m and 4 lamps along the width with spacing 20/4 = 5m. Here the space to height ratio with this arrangement is, 2.727/5 = 0.545. Disposition of lamps is shown in Fig.