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1) Distance between stations $D = 1.5km$

$= 1.5 \times 1000 = 1500m$

Schedule speed $= 36 km/h$

$= 36 \times \frac{1000}{3600} = 10m/s$

Duration of stops = 25 seconds

retardation $\beta = 3 km/h/s = 3 \times \frac{1000}{3600}$

$= \frac{5}{6} m/s^2$

schedule time of run $= \frac{\text{Distance}}{\text{schedule speed}} = \frac{1500}{10} = 150s$

Actual time of run $= 150 - 25 = 125s$

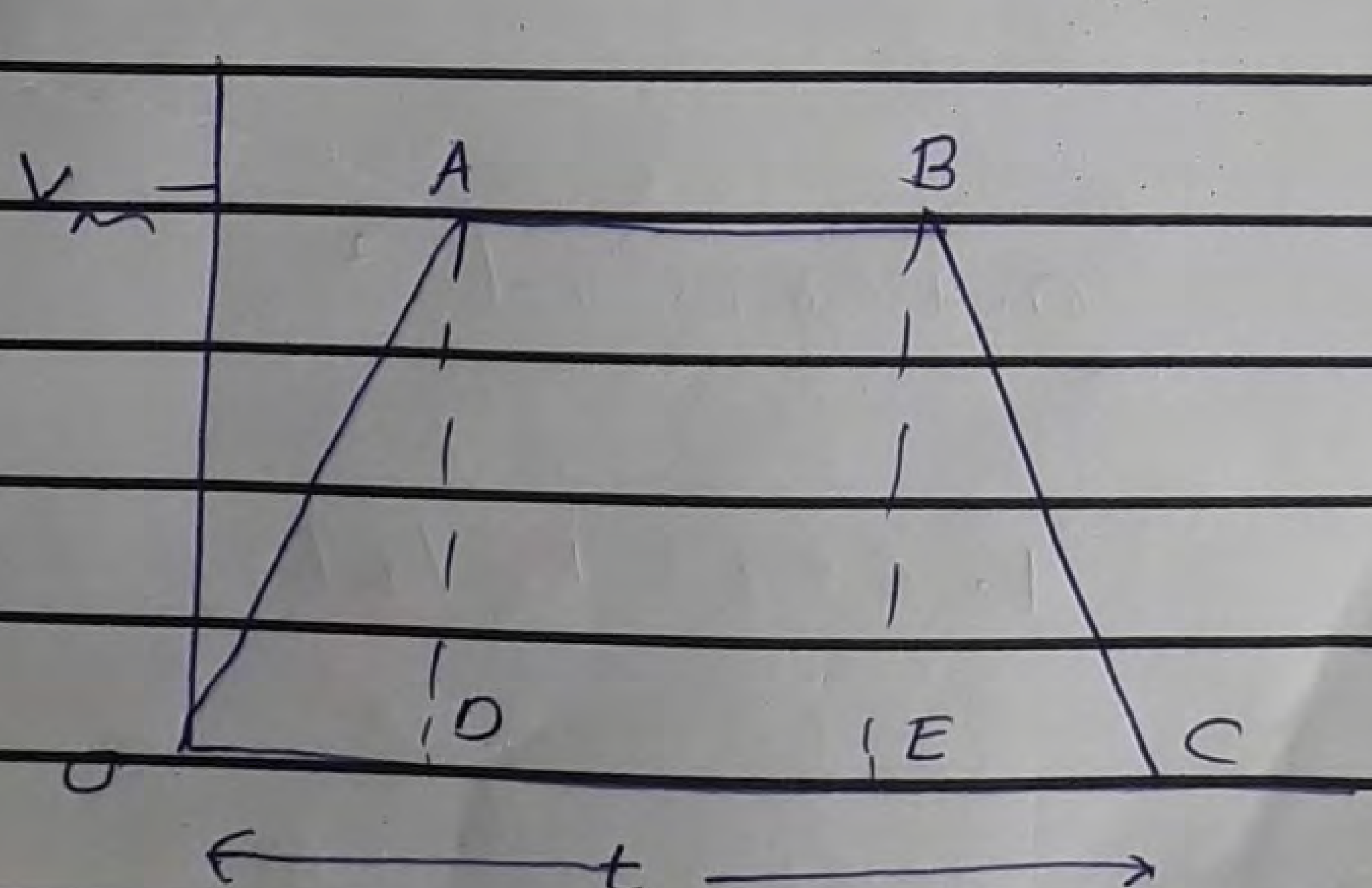
Average speed $V_a = \frac{\text{Distance}}{\text{Actual time of run}} = \frac{1500}{125} = 12m/s$

=> maximum speed = average speed × 1.25

$V_m = 12 \times 1.25$

$= 15m/s$

for a trapezoidal speed-time curve



$$V_m = \frac{t \pm \sqrt{t^2 - 4XD}}{2X} \quad -(i)$$

where $X = \frac{1}{2}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) \quad -(ii)$

from (i) (neglecting + sign)

$$XV_m^2 - tV_m + D = 0$$

$$XV_m^2 = tV_m - D$$

$$X = \frac{tV_m}{V_m^2} - \frac{D}{V_m^2}$$

$$= \frac{t}{V_m} - \frac{D}{V_m^2}$$

$$X = \frac{125}{15} - \frac{1500}{(15)^2}$$

$$= \frac{25}{3} - \frac{20}{3} = \frac{5}{3}$$

equating to (ii)

$$\frac{5}{3} = \frac{1}{2}\left(\frac{1}{\alpha} + \frac{1}{\frac{5}{6}}\right)$$

$$\frac{5}{3} = \frac{1}{2\alpha} + \frac{3}{5}$$

$$\frac{16}{15} = \frac{1}{2\alpha}$$

$$\Rightarrow \alpha = \frac{15}{32} = 0.46875 \ m/s^2$$

$$= 1.6875 \ km/h/s$$

2) $V_a = 36km/h$

Distance between two station $s = 2km = 2000m$

acceleration $\alpha = 1.8 km/h/s$

retardation $\beta = 3.6 km/h/s$

$V_m = ?$ trapezoidal speed/time curve

$$V_a = 36 \times \frac{5}{18} m/s = 10 m/s$$

$$\alpha = 1.8 \times \frac{5}{18} m/s^2 = 0.5 m/s^2$$

$$\beta = 3.6 \times \frac{5}{18} m/s^2 = 1.0 m/s^2$$

$$\left(\frac{1000}{3600} x km/h = x m/s\right) \Rightarrow \left(\frac{5}{18} x\, km/h = x\, m/s\right)$$

Actual time duration $t = \frac{D}{V_a} = \frac{2000}{10} = 200s$

recall $V_m = \frac{t - \sqrt{t^2 - 4XD}}{2X}$

where $X = \frac{\alpha + \beta}{2\alpha\beta} = \frac{0.5 + 1}{2(0.5)(1)}$

$= 1.5$

$$V_m = \frac{200 - \sqrt{200^2 - 4(1.5)(2000)}}{2(1.5)}$$

$$V_m = \frac{200 - \sqrt{40000 - 12000}}{3}$$

$$V_m = \frac{32.66799}{3}$$

$V_m = 10.88933 m/s$

$= 39.2016 km/h$

3) Surface area = $6.0 m^2$ (Cubic water tank)
90 % capacity fill six time daily
$\Delta\theta$ of water = 65 - 20 = 45 °C
loss / m^2 / °C = 6.3 W
loading = ?
Efficiency = ?
specific heat of water = 4200 J/kg/°C
1 kwh = 3.6 MJ

for a cubic tank
surface area = $6l^2$
$$6l^2 = 6$$
$$l^2 = \frac{6}{6} = 1m^2$$
$$l = 1m$$
Volume of tank = $l^3 = 1m^3$
for 90% fill six times daily
volume of water to be heated daily = $6 \times (1 \times 0.9)$
= $5.4m^3$
$1m^3$ of water weighs 1000kg
=> mass of water heated daily = 5.4×1000
= 5400kg

Heat required to raise water's temperature
from 20 - 65 = $m_w \times \Delta\theta \times c$
= $5400 \times 45 \times 4200$
= 10206×10^5
= 1020.6 MJ

To kwh

$$x \text{ kWh} = \frac{1020.6}{3.6}$$

$$= 283.5 \text{ kWh}$$

loss from surface of the tank ~~for~~ daily ~~fills~~

$$= \frac{6.3 \times 6 \times 45 \times 24}{1000}$$

$$= 40.824 \text{ kWh}$$

Energy supplied per day $= 283.5 + 40.824$

$$= 324.324 \text{ kWh}$$

loading in kW $= \frac{\text{Energy per day}}{24}$

$$= \frac{324.324}{24}$$

$$= 13.5135$$

Efficiency of the tank $= \frac{283.5}{324.324} \times 1000$

$$= 87.4126 \%$$

4) $V_s = 20V$

Power consumption $= 600 kW$ — heat th is full

Power factor $= 0.6$

I_s (secondary current)

$$= \frac{P}{V \cos \theta}$$

$$I = \frac{600 \times 1000}{20 \times 0.6}$$

$$= 50000 A$$

Calculating the voltage's vector quantity

$\bar{V}_s = V_s(\cos\theta + j\sin\theta)$

$= 20(0.6 + j\sin\theta)$

where $\sin\theta = 0.8$

$\bar{V}_s = 20(0.6 + j0.8)$

$= (12 + j16)\,V$

Impedance $Z_s = \frac{V_s}{I}$

$= \frac{12 + j16}{50000}$

$Z_s = (0.00024 + j0.00032)\,\Omega$

When the hearth is half full, resistance of secondary circuit is assumed to be double, reactance remains constant (2R)

$Z_s = (R + jX)\,\Omega$

$Z_s = [2(0.00024) + j0.00032]\,\Omega$

$Z_s = (0.00048 + j0.00032)\,\Omega$

Secondary voltage is kept constant

I_s with half full hearth

$= \frac{V_s}{Z_s \text{ (half full hearth)}}$

$= \frac{20}{0.00048 + j0.00032}$

$= \frac{20}{(4.8 + j3.2) \times 10^{-4}}$

Converting Z_s to polar form

$[\sqrt{4.8^2 + 3.2^2} < \tan^{-1}\frac{3.2}{4.8}] \times 10^{-4}$

$Z_s = (5.7688 \angle 33.69) \times 10^{-4}\ \Omega$

$I_s = (3.4669 \angle -33.69) \times 10^{4}\ A$

Power factor $= \cos\theta$ where $\theta = -33.69$

$\cos(-33.69)$

$= 0.832$

Power absorbed $= IV\cos\theta$

$= 3.4669 \times 20 \times 0.832 \times 10^{4}$

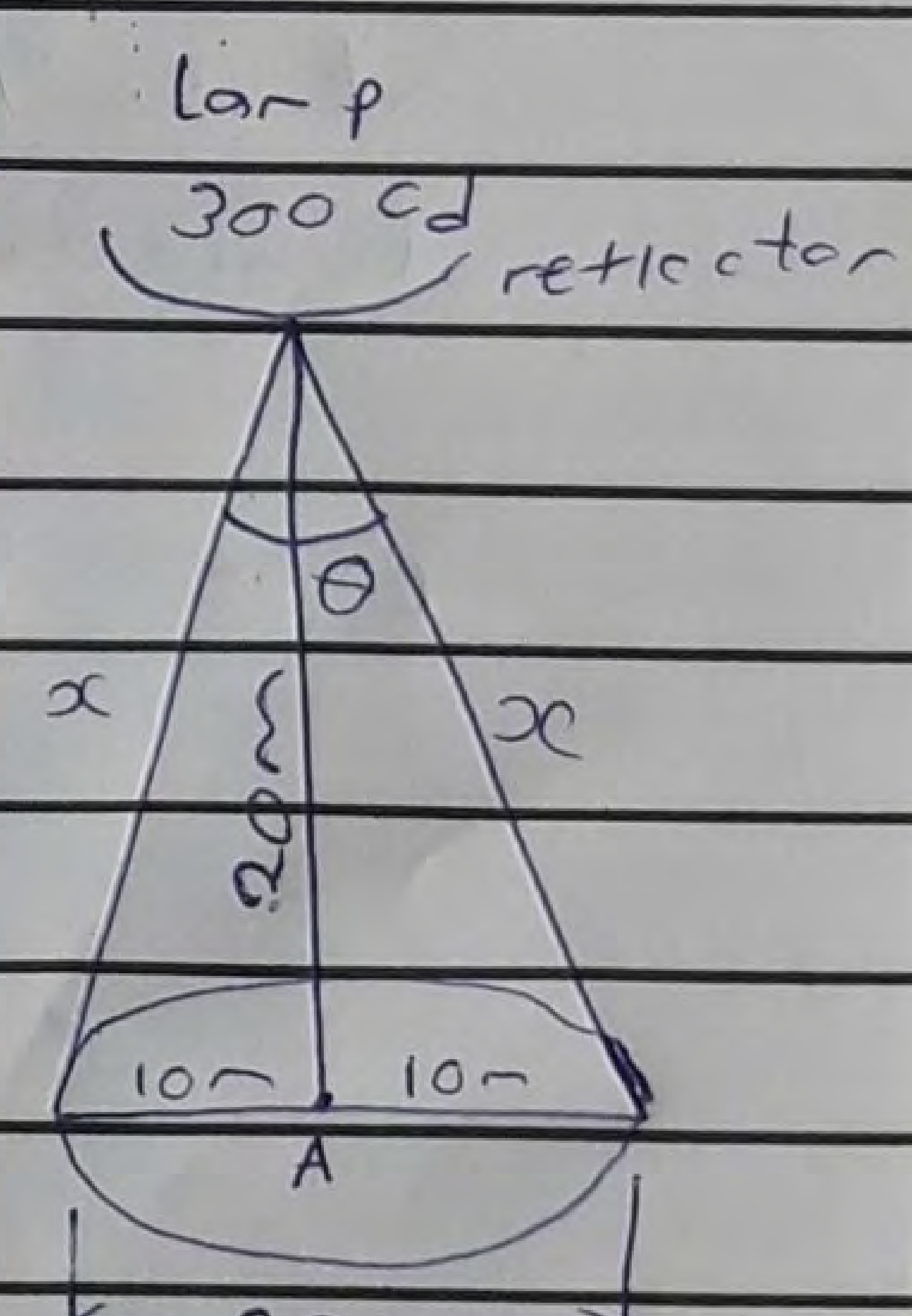
$= 576892.16\ W$

$= 576.892\ kW$

5) $I = 300\ cp$ in all directions

reflector directs 50 % of total emitted light uniformly on to a flat circular disc of 20m diameter 20m vertically below the lamp

without the reflector



a) Illumination $E = \frac{I}{r^2}$

$= \frac{300}{20^2}$

$= 0.75\ lumen/m^2$

b)

$x^2 = 10^2 + 20^2$

$= 500$

$\tan\theta = \frac{10}{20}$

$\theta = \tan^{-1}\left(\frac{10}{20}\right)$

$= 26.5651^{\circ}$

$\cos\theta = \cos 26.5651$

$= 0.8944$

$E = \frac{I\cos\theta}{x^2}$

$E = \frac{300 \times 0.8944}{500}$

$E = 0.53664$ lumen/m^2

with reflector (uniform emission)

Luminous flux $= \omega I$

$\omega = 4\pi$

$= 300 \times 4\pi$

$= 1200\pi$ lumen

at 50% emission

luminous flux $= 0.5 \times 1200\pi$ lumen

$= 600\pi$ lumen

$E = \frac{600\pi}{100\pi}$

$E = 6$ lumen/m^2 at the centre and the edge