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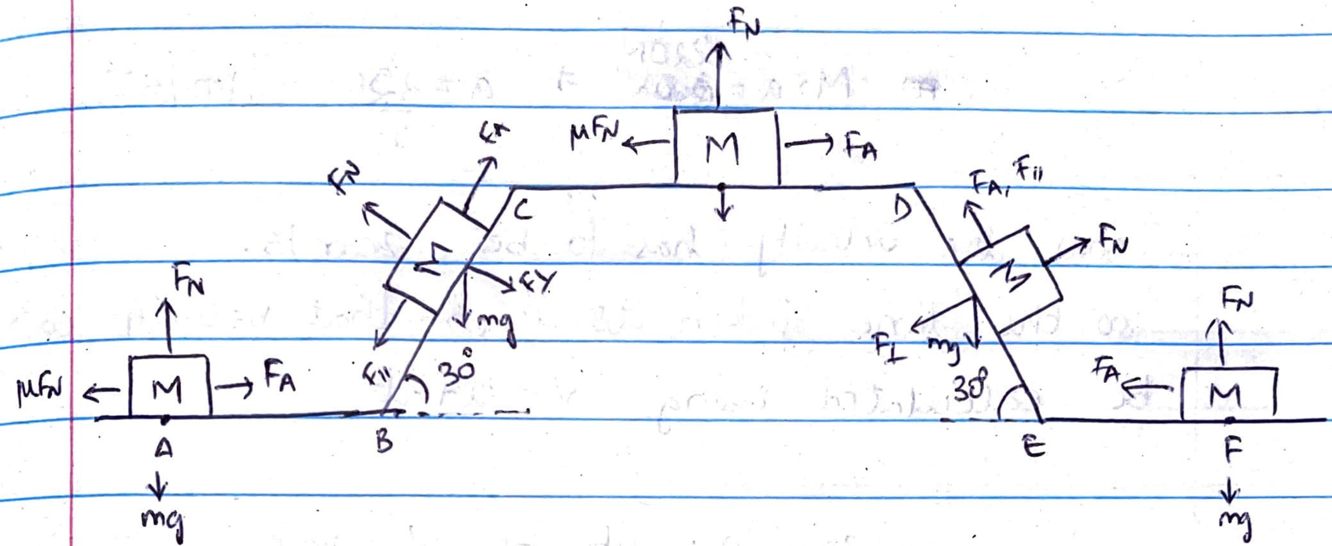
HOMEWORK-2

Problem 1:-



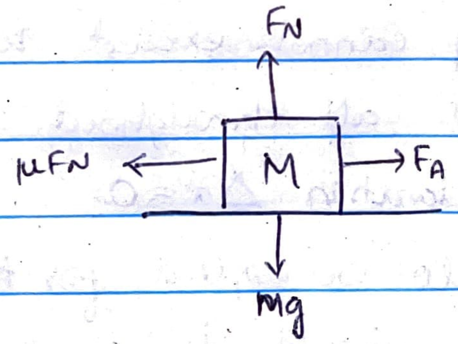
Assumptions & Data:-

$M = 20\,kg$ $g = 10\,m/s^2$ $AB = BC = CD = DE = EF = 250m$

μ_1 (M and ground) $= 0.4$ Force Limit $= 300N$

velocity max $= 20m/s$ $V_A = V_F = 0$.

1) $A \rightarrow B$



$F_{net} = F_A - (\mu F_N)$ friction

Condition:- The body has to reach 'F' in minimum possible time. so to accelerate the body to highest velocity, we have to apply max. force for 't' seconds.

$F_A = 300N$ $F_{net} = 300 - 0.4 \times (20 \times 10)$

$= \underline{220N}$

$M \times a = 220N \Rightarrow a = \frac{220}{20} = 11 m/s^2$.

now the velocity has to be 20m/s.
so the time taken to reach that velocity can be calculated using $V = u + at$

$$20 = 0 + 11t \Rightarrow t = \underline{\frac{20}{11} s}.$$

Now how much distance will the body cover in $\frac{20}{11} s$ can be determined using $S = ut + \frac{1}{2}at^2$.

$$S = 0 + \frac{1}{2} \times \cancel{11} \times \frac{\cancel{20}^{10}}{\cancel{11}} \times \frac{20}{11} = \underline{\frac{200}{11} m}$$

Now the velocity cannot exceed 20m/s so, it will remain constant all throughout. Hence the change in acceleration $\Delta a = 0$.

The force to be applied for the body to continue at this velocity should be equal to the friction force in the opposite direction, so that the body can have unrestricted motion due to negation of forces.

now the remaining distance from A → B is

$$S = 250 - \frac{200}{11} = \frac{2750 - 200}{11} = \frac{2550}{11} m$$

the time taken to cover the distance.

$$\frac{S}{t} = V \Rightarrow \frac{\frac{2550}{11}}{20} = t$$

$$t = \frac{2550}{11 \times 20} = \frac{255}{22} s$$

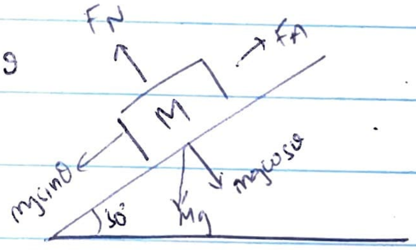
2) B → C

w.k.t $v = 20 m/s$ $\Delta a = 0$ $\therefore F_{N} = ma = 0$.

$F_N = f_n - \mu F_N - mg\sin\theta$

$F_A = \mu mg\cos\theta + mg\sin\theta$

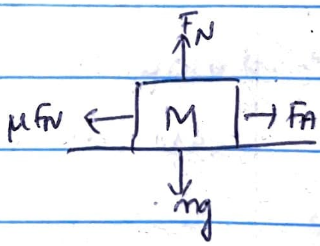
$= 169.282 N$



time taken will be $\frac{S}{t} = V \Rightarrow t = \frac{S}{V} = \frac{250}{20} = 12.5 s$

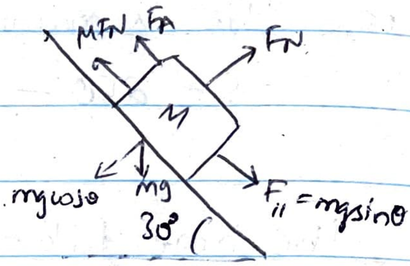
3) C-D

F_A will be $-(-\mu F_N) = 80N$



$S = 20 m/s \times t \Rightarrow t = \frac{250}{20} = 12.5 s$

D → E



$V = 20\,m/s$

$F_{net} = Mg\sin\theta - F_A - \mu F_N$

$\Rightarrow F_A + \mu F_N = Mg\sin\theta$

$\Rightarrow F_A = \frac{200}{2} - 0.4 \times \frac{200\sqrt{3}}{2}$

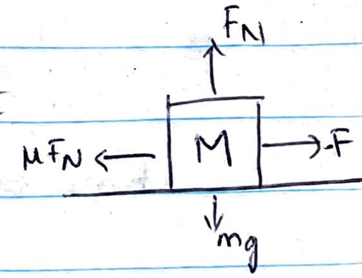
$= 30.7179\,N \simeq \underline{30.72\,N}$

The force Applied is in the negative direction

$\therefore F_A = \underline{-30.72\,N}$

$S = Vt \Rightarrow t = \underline{12.5s}$

E - F



Here the body has to stop, so the final velocity will be '0'.
To stop the body, F_A has to be applied till a certain point and then should change its direction.

$F_{net} = -(F_A + \mu F_N)$ $\quad F_{Net} = Ma$

$Ma = -(F_A + \mu F_N)$

$v = u + at$ $\quad$ $v = 0$ $\quad$ $u = 20\ m/s.$

$$0 = 20 + \frac{(-F_A - \mu F_N)}{M} t$$

$$20 = \frac{F_A + \mu F_N}{M} t$$

$$20 \times 20 = (F_A + 0.4 \times 20 \times 10)t$$

$$400 = (F_A + 80)t$$

If force applied is maximum how much time will it take to stop the block.

$$t = \frac{400}{380} = \frac{20}{19} s.$$

the distance it travels in that time duration of stopping. $S = ut + \frac{1}{2}at^2$

$$= 20 \times \frac{20}{19} + \frac{1}{\cancel{2}} \times \frac{\cancel{380}}{\cancel{20}} \times \frac{\cancel{20}}{\cancel{19}} \times \frac{20}{19}$$

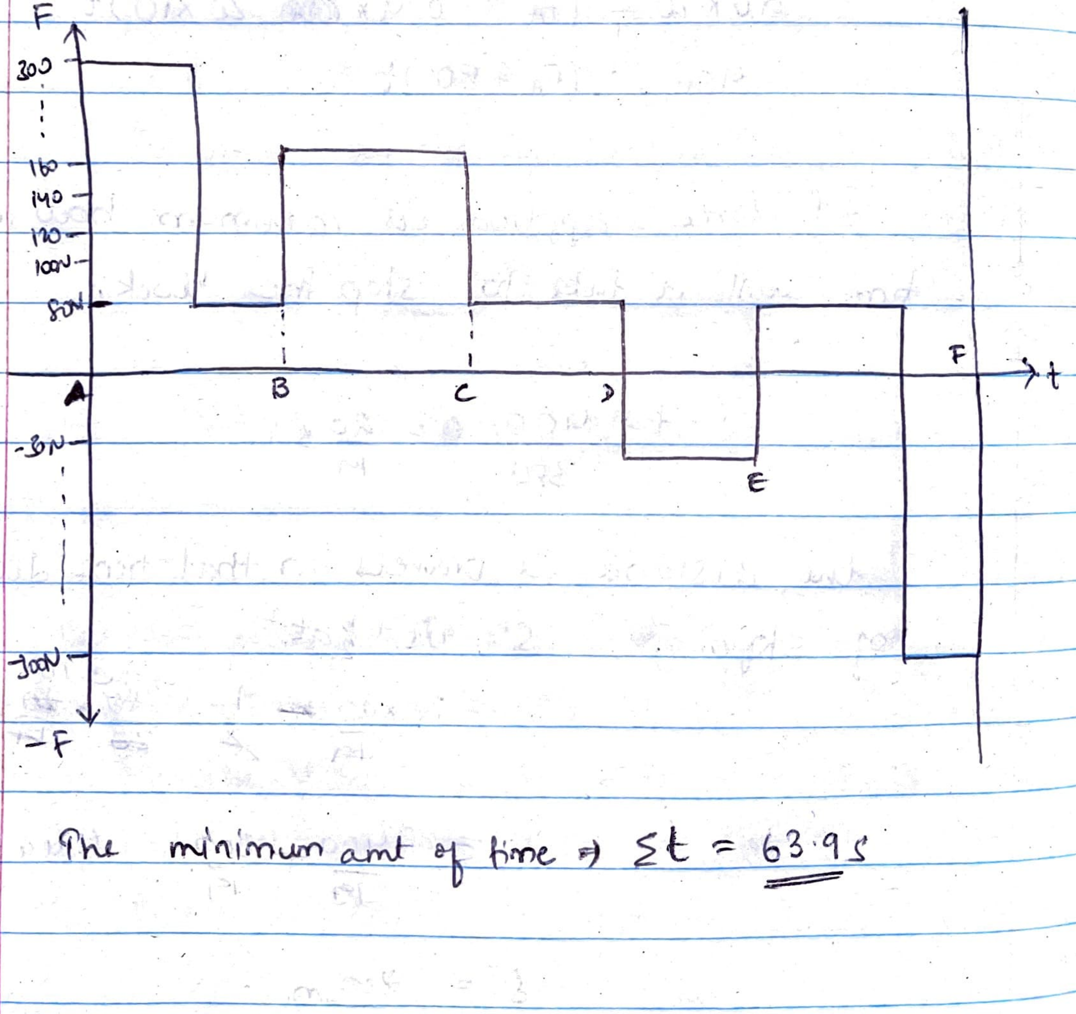
$$= \frac{400}{19} + \frac{200}{19} \quad \text{(decelaration)}$$

$$S = \frac{200}{19} m$$

So the block can travel at 20 m/s for a distance of $s = 250m - \frac{200}{19}m = \underline{\underline{239.473\ m}}$.

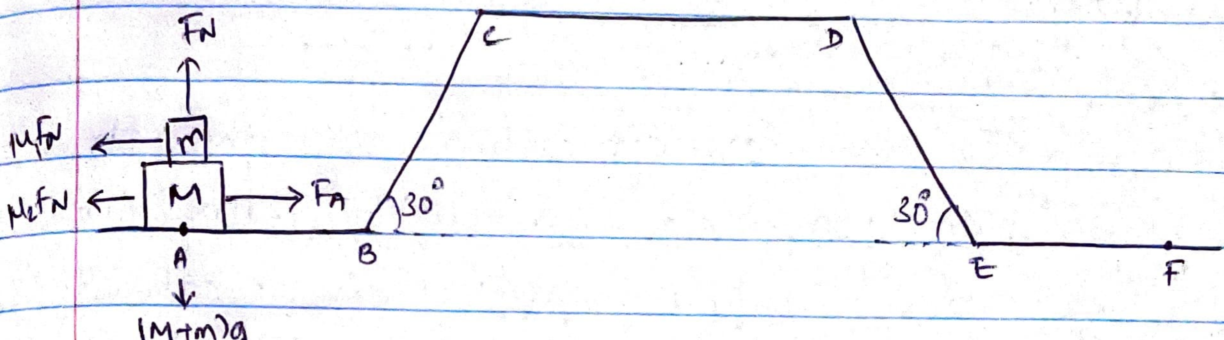
time taken to travel is $\frac{239.47}{20} = \underline{\underline{11.97s}}$

Force time graph :-



The minimum amt of time $\Rightarrow \Sigma t = \underline{\underline{63.9s}}$

Problem 2:



Assumptions & Data:-

$M = 20kg$ $m = 10kg$ $g = 10m/s^2$

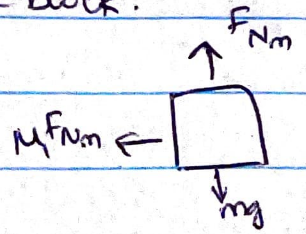
μ_1 (M & ground) = 0.4 μ_2 (m & M) = 0.7

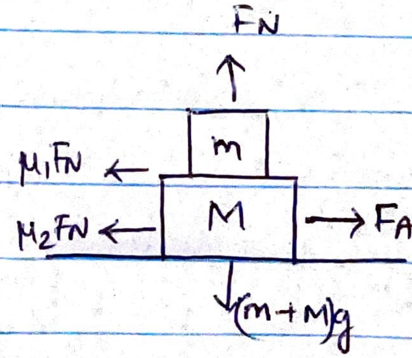
AB = BC = CD = EF = DE = 250m

Force limit cap = 300N velocity max = 20m/s.

A → B

small block.





condition:- Now for small block to not fall we have to apply a force less than the slipping force.

$\mu_1 F_{Nm} = 0.7 \times 10 \times 10 = 70N$

$\mu_2 F_{NM} = 0.4 \times (30) \times 10 = 120N$

Now the max accelaration with which the body can move to max velocity without the upper block slipping down can be calculated using:

$ma = \mu_1 F_{Nm}$

$10 \times a = 70$

$a = 7 m/s^2$

$F_{Applied} = F_{net} + \mu_1 F_{Nm} + \mu_2 F_{NM}$

$= Ma + 70 + 120$

$= 240 + 120 + 70$

$= \cancel{330N}\ 400N$

Maximum force that can be applied is 330N.

we have a limit to extend upto 300N. So we can use that with no restrictions

$F_A = (M+m)a + \mu_1 F_{Nm}$

$300 - (0.4)(30)(10) = 30a$

$a = 6 m/s^2$

$F_{A_2} = \mu_1 F_{NM+m} = 0.4 \cdot (30) \times 10 = 120N$

To achieve max velocity with 2000N force and $6 m/s^2$ acceleration, we have to find that time

$v = u + at \Rightarrow 20 = 0 + 6t \rightarrow t = \frac{20}{6} s = \frac{10}{3} s$

Now the distance moved in that amt of time will be

$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 6 \times \left(\frac{10}{3}\right)^2$

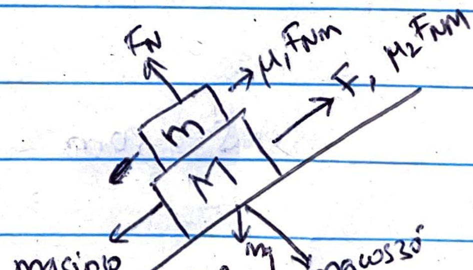
$= \frac{100}{3} m$

the distance remaining will be $S = 250 - \frac{100}{3} = \frac{650}{3} m$

the time taken to travel $\frac{650}{3} m$ at $20 m/s$ is

$vt = s \Rightarrow t = \frac{650}{3 \times 20} = \frac{65}{6} s$

B → C



for small block

$\mu_1 F_{Nm} = 0.7 \times 10 \times 10 \times \cos 30°$
$= 35\sqrt{3} N$

$mg \sin 30°$ (slipping due to reverse pull) $= 10 \times 10 \times \frac{1}{2} = 50 N$

$F = \mu_1 F_{Nm} - mg\sin 30°$

$10a = 35\sqrt{3} - 50 \quad a \Rightarrow 1.062 m/s^2$

Now to calculate force that has to be applied.

$$F - 0.4\left(300\frac{\sqrt{3}}{2}\right) - (30)\times 10\times\frac{1}{2} = 0$$

$$\underline{F = 253.92N}$$

This force will maintain 20m/s velocity.

$S = 250m$ $\quad t = \frac{S}{v} = \frac{250}{20} = \underline{\underline{12.5S}}$

<u>C → D</u>

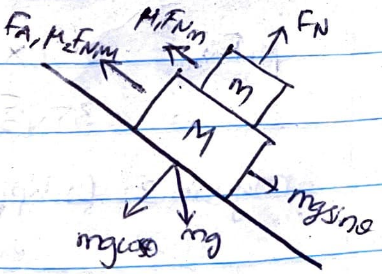
The surface is flat so all the parameters are already known, hence

$F_{net} = F_A - \mu_1 F_{N, M+m}$

$$F = (M+m)g \times 0.4$$
$$= (20+10)10\times 0.4$$
$$= \underline{120N}$$

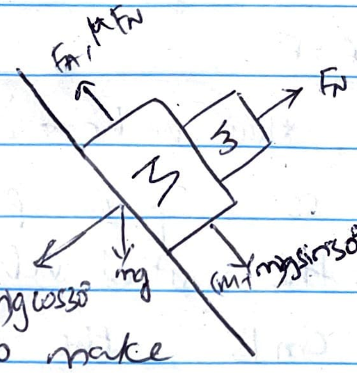
$S = 250m$ → $V = 20m/s$ → $t = S/v = \underline{\underline{12.5S}}$

<u>D → E</u>



when the system had an acceleration of $+1.062m/s^2$ while upwards inclination, when the net force is zero, it should have the same magnitude of deceleration while coming down.

Considering the case B→C to be the opposite case as the declining that we see here.



Before hand, we have to balance the forces so as to make sure that the body maintains the same velocity and the upper block doesn't slip.

$$\mu_1 F_{Nm} = 0.7 \times 10 \times 10 \times \cos 30°$$
$$= 35\sqrt{3}$$

$$\mu_2 F_{N(M+m)} = 0.4 \times 30 \times 10 \times \cos 30°$$
$$= 60\sqrt{3}$$

$$(M+m)g\sin 30° = 30 \times 10 \times 1/2$$
$$= 150.$$

The body has to maintain an accelaration of -1.062 while decelerating down the slope.

$$(M+m)a = 30 \times -1.062$$
$$= -31.86.$$

$$F + 35\sqrt{3} + 60\sqrt{3} - 150 = -31.86$$
$$F = -46.4\ N$$

$S = 250m$ $\quad$ $t = \frac{250}{20} = \underline{12.5\,s}$

<u>E-F</u>

Now we have to stop the body at force of 300N so if we put 200N to stop the body where the initial velocity is 20m/s, the final velocity is 0m/s, the acceleration will be found by $v=u+at$ and time will be t seconds, it will take S m to stop.

~~[illegible]~~

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w.k.t max acceleration of the body shouldn't exceed $7m/s^2$ for the block to be stable.

$$\mu_1 F_{Nm} - F_A - \mu_2 F_{N\,M+m} = (M)(-a)$$

$$70 - F_A - 120 = -190$$

$$\underline{F_A = 160N} \quad (-\text{ve direction})$$

~~[illegible]~~

~~[illegible]~~

The body is travelling with no change in acceleration but to decelerate it we have trace back to initial state where it accelerated from $0 \rightarrow 6m/s$ with 300 N force.

$$V = u + (-a)t$$

$$a = \frac{F_A + \mu F_{N(M+m)}}{M+m}$$

$$= \frac{90 + 0.4 \times 30 \times 10}{30}$$

$$a = 7$$

$$0 = 20 - 7t$$

$$t = \frac{20}{7} \text{ seconds.} = \underline{\underline{2.86s}}$$

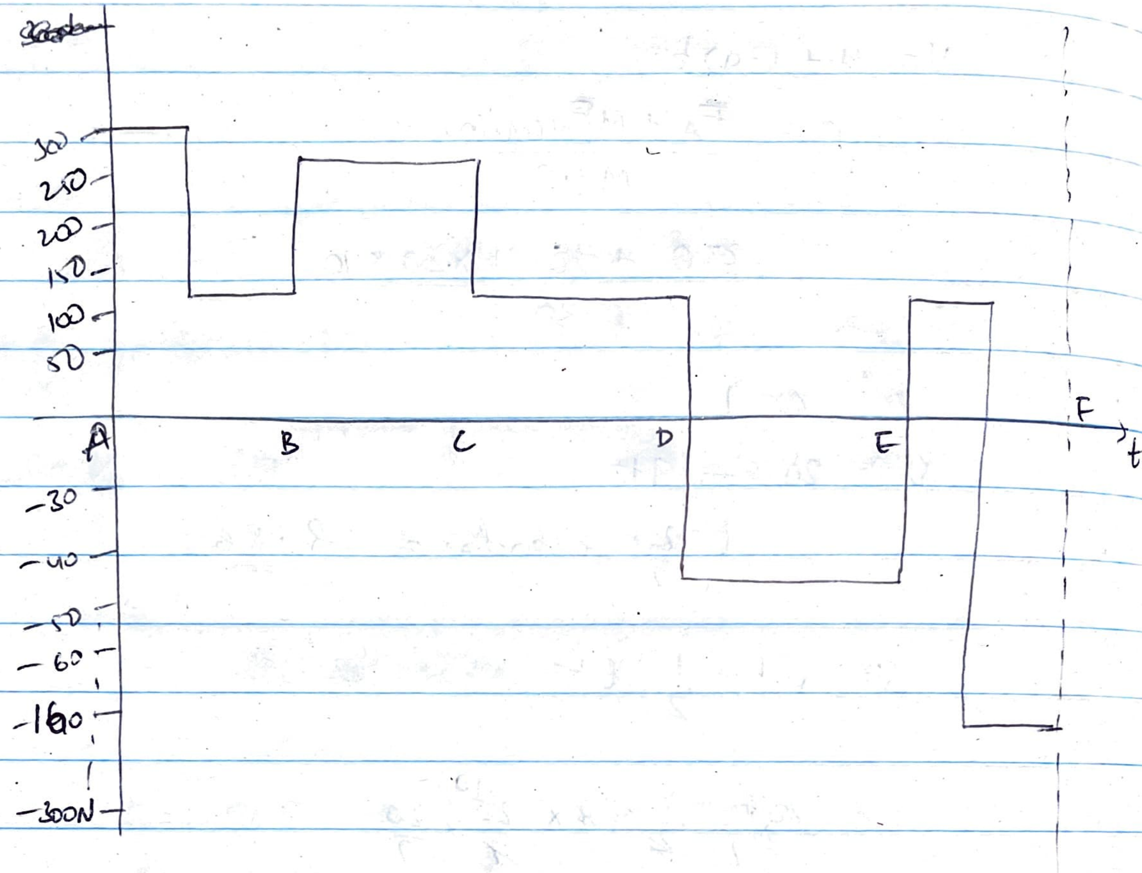
$$S = ut - \frac{1}{2}at^2$$

$$= 20 \times \frac{20}{7} - \frac{1}{\cancel{2}} \times \cancel{7} \times \frac{\cancel{20}^{10}}{\cancel{7}} \times \frac{20}{7}$$

$$= \frac{400}{7} - \frac{200}{7} = \underline{\frac{200}{7}\text{m.}}$$

Remaining distance $= 250 - \frac{200}{7}$ m $= \underline{\underline{221.43 \text{ m.}}}$

$S = 221.43$ $\quad V = 20$ m/s $\quad t = \frac{S}{V} = \underline{\underline{11.07s}}$



Minimum amt of time taken is $\Sigma t = \underline{\underline{65.6\,s}}$