## Solution to Question 2: The Rail Gun

Proper Solution (taking induced emf into consideration):		
(a) Let I be the current supplied by the battery in the absence of back emf.		
Let i be the induced current by back emf $\mathcal{E}_b$ .		
Since $\varepsilon_b = d\phi / dt = d(BLx)/dt = BLv$ , $\therefore i = Blv / R$ .	1	
	1	
Net current, $I_N = I - i = I - BLv/R$ .	0.5	
Forces parallel to rail are:	~ <b>-</b>	
Force on rod due to current is $F_c = BLI_N = BL(I - BLv/R) = BLI - B^2 L^2 v/R$ . Net force on rod and young man combined is $F_N = F_c - mg\sin\theta$ . (1)	0.5	
Net force on rod and young man combined is $\Gamma_N - \Gamma_c - mg \sin \theta$ . (1)		
Newton's law: $F_N = ma = mdv/dt$ . (2)	0.5	
Equating (1) and (2), & substituting for $F_c$ & dividing by <i>m</i> , we obtain the acceleration		
$L/L$ where $L$ $DIL/$ $C and - D/D^2 I^2$	0.5	
$dv/dt = \alpha - v/\tau$ , where $\alpha = BIL/m - g\sin\theta$ and $\tau = mR/B^2L^2$ .		3

(b)(i) Since initial velocity of rod = 0, and let velocity of rod at time t be $v(t)$ , we have		
$v(t) = v_{\infty} \left( 1 - e^{-t/\tau} \right), \tag{3}$	0.5	
where $v_{\infty}(\theta) = \alpha \tau = \frac{IR}{BL} \left( 1 - \frac{mg}{BLI} \sin \theta \right).$		
Let $t_s$ be the total time he spent moving along the rail, and $v_s$ be his velocity when he the rail, i.e.		
$v_{s} = v(t_{s}) = v_{\infty} \left( 1 - e^{-t_{s}/\tau} \right). $ (4)	0.5	
$\therefore t_s = -\tau \ln(1 - v_s / v_\infty) $ (5)	0.5	1.5

(b) (ii)		
Let $t_f$ be the time in flight:		
$t_f = \frac{2v_s \sin \hat{e}}{\sigma} \tag{6}$	0.5	
g (C)	0.5	
He must travel a horizontal distance w during t		
He must travel a horizontal distance w during $t_f$ .		
$w = (v_s \cos \dot{e})t_f \tag{7}$		
$w = 2v \sin \theta$		
$t_f = \frac{w}{v_s \cos\theta} = \frac{2v_s \sin\theta}{g} $ (8) (from (6) & (7))	0.5	
$v_s \cos\theta$ g	0.5	
Errom $(\mathbf{Q})$ wig fixed by the angle $\mathbf{Q}$ and the width of the strait w		
From (8), $v_s$ is fixed by the angle $\theta$ and the width of the strait w		
$\boxed{g_W}$		
$v_s = \sqrt{\frac{gw}{\sin 2\theta}} . \tag{9}$		
$\sqrt{\sin 2\theta}$		
$\begin{pmatrix} 1 & \boxed{mv} \end{pmatrix}$		
$\therefore t_s = -\tau \ln \left[ 1 - \frac{1}{1 - \frac{g_W}{1 - 20}} \right], \qquad \text{(Substitute (9) in (5))}$		
$\therefore t_s = -\tau \ln \left( 1 - \frac{1}{v_{\infty}} \sqrt{\frac{gw}{\sin 2\theta}} \right), \qquad \text{(Substitute (9) in (5))}$		1.5
And $t_f = \frac{2\sin\theta}{1+e^2} \int \frac{gw}{1+e^2} = \int \frac{2w\tan\theta}{1+e^2}$ (Substitute (9) in (8))	0.5	
And $t_f = \frac{2\sin\theta}{g}\sqrt{\frac{gw}{\sin 2\theta}} = \sqrt{\frac{2w\tan\theta}{g}}$ (Substitute (9) in (8))	0.5	
0 10000 0		
		1

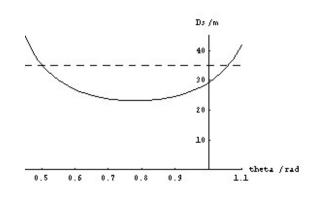
	1	-
$(c) \qquad \qquad$		
Therefore, total time is: $T = t_s + t_f = -\tau \ln\left(1 - \frac{1}{v_{\infty}}\sqrt{\frac{gw}{\sin 2\theta}}\right) + \sqrt{\frac{2w\tan\theta}{g}}$		
The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00 m, R=1.0 $\Omega$ , g=10 m/s <sup>2</sup> , m=80 kg, and w=1000 m.		
Then $\tau = \frac{mR}{B^2 L^2} = \frac{(80)(1.0)}{(10.0)^2 (2.00)^2} = 0.20 \text{ s.}$		
$v_{\infty}(\theta) = \frac{2424}{(10.0)(2.00)} \left( 1 - \frac{(80)(10)}{(10.0)(2.00)(2424)} \sin \theta \right)$		
$= 121(1 - 0.0165\sin\theta)$		
So, $T = t_s + t_f = -0.20 \ln \left( 1 - \frac{100}{v_{\infty}} \frac{1}{\sqrt{\sin 2\theta}} \right) + 14.14 \sqrt{\tan \theta}$	Labeling: 0.1 each axis	
By plotting T as a function of $\theta$ , we obtain the following graph:	Unit: 0.1 each axis	
Note that the lower bound for the range of $\theta$ to plot may be determined by the condition $v_s / v_{\infty} < 1$ (or the argument of ln is positive), and since mg/BLI is small (0.0165), $v_{\infty} \approx IR/BL$ (= 121 m/s), we have the condition $\sin(2\theta) > 0.68$ , i.e. $\theta > 0.37$ . So one may start plotting from $\theta = 0.38$ .	Proper Range in $\theta$ : 0.3 lower limit (more than 0.37, less than 0.5), 0.2 upper limit (more than 0.5 and less than 0.6) Proper shape of curve: 0.2 Accurate intersection at $\theta = 0.5$ : 0.4	1.5
From the graph, for $\theta$ within the range (~0.38, 0.505) radian the time <i>T</i> is within 11 s.		

## (d)

However, there is another constraint, i.e. the length of rail D. Let  $D_s$  be the distance travelled during the time interval  $t_s$ 

$$D_{s} = \int_{0}^{t_{s}} v(t) dt = v_{\infty} \int_{0}^{t_{s}} \left( 1 - e^{-t/\tau} \right) dt = v_{\infty} \left( t + \tau e^{-\beta t} \right)_{0}^{s} = v_{\infty} \left[ t_{s} - \tau \left( 1 - e^{-\beta t} \right) \right] = v_{\infty} t_{s} - v(t_{s}) \tau$$

$$D_{s} = -\tau \left[ v_{\infty}(\theta) \ln \left( 1 - \frac{1}{v_{\infty}(\theta)} \sqrt{\frac{gw}{\sin 2\theta}} \right) + \sqrt{\frac{gw}{\sin 2\theta}} \right]$$



It is necessary that  $D_s \leq D$ , which means  $\theta$  must range between .5 and 1.06 radians.

To 2 sig fig T = 11 s. Range is 0.50 to 0.51 (in degree: 28.6<sup>o</sup> to 29.2<sup>o</sup> or 29<sup>o</sup>)

i.e. $D_s = -\tau \left[ v_{\infty}(\theta) \ln \left( 1 - \frac{1}{v_{\infty}(\theta)} \sqrt{\frac{gw}{\sin 2\theta}} \right) + \sqrt{\frac{gw}{\sin 2\theta}} \right]$	0.5	
The graph below shows $D_s$ as a function of $\theta$ .	Labeling: 0.1 each axis	
Ds /m $40$ $20$ $10$ $10$ $0.5 0.6 0.7 0.8 0.9$ $1.1$ theta /rad	Unit: 0.1 each axis Proper Range in θ: 0.3 lower limit (more than 0.4, less than 0.49), 0.2 upper limit (more than 0.51	
It is necessary that $D_s \leq D$ , which means $\theta$ must range between .5 and 1.06 radians.	and less than 1.1) Proper shape of curve: 0.2	
	Accurate intersection at $\theta = 0.5$ : 0.4	
In order to satisfy both conditions, $\theta$ must range between 0.5 & 0.505 radians.		
(Remarks: Using the formula for $t_f$ , $t_s$ & D, we get		
At $\theta = 0.507$ , $t_f = 10.540$ , $t_s = 0.466$ , giving T = 11.01 s, & D = 34.3 m At $\theta = 0.506$ , $t_f = 10.527$ , $t_s = 0.467$ , giving T = 10.99 s, & D = 34.4 m At $\theta = 0.502$ , $t_f = 10.478$ , $t_s = 0.472$ , giving T = 10.95 s, & D = 34.96 m At $\theta = 0.50$ , $t_f = 10.453$ , $t_s = 0.474$ , giving T = 10.93 s, & D = 35.2 m, So the more precise angle range is between 0.502 to 0.507, but students are not		
So the more precise angle range is between 0.502 to 0.507, but students are not expected to give such answers. To 2 sig fig T = 11 s. Parga is 0.50 to 0.51 (in degree) 28.6° to 20.2° or 20°)	0.5	2.5

If induced emf is not taken into account, there is no induced current, so the net force acting on the combined mass of the young man and rod is $F_{N} = BIL - mg \sin \theta .$ And we have instead $dv/dt = \alpha,$ where $\alpha = BIL/m - g \sin \theta .$ $\vdots v(t) = \alpha $ and $i v_{r} = v(t_{r}) = \alpha t_{r},$ $t_{r} = \frac{2v_{r} \sin \theta}{g} = \frac{2\alpha r_{s} \sin \theta}{g} .$ Therefore, $w = (v_{r} \cos \theta)t_{r} = \frac{\alpha^{2}t_{r}^{2} \sin 2\theta}{g} ,$ giving $t_{r} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\theta}} .$ $0.5$ Hence, $T = t_{r} + t_{r} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\theta}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[ 1 + 2\left(\frac{\alpha}{g}\right) \sin \theta \right]}{\alpha \sqrt{\sin 2\theta}} .$ $0.5$ Hence, $T = t_{o} + t_{r} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\theta}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[ 1 + 2\left(\frac{\alpha}{g}\right) \sin \theta \right]}{\sqrt{\sin 2\theta}} .$ $0.5$ $The values of the parameters are: B=10.0 T, I = 2424 A, L=2.00m, R=10 \Omega s^{2}, m=80 \text{ kg, and } w=1000 \text{ m. Then,}$ $T = \frac{100 \left[ 1 + 0.20\alpha \sin \theta \right]}{\sqrt{\sin 2\theta}} + 2\alpha (1 + 2\alpha + 1) (1 + 2$	Alternate Solution (Not taking induced emf into consideration):		
And we have instead $dv/dt = \alpha,$ where $a = BIL/m - g \sin \theta.$ $\therefore v(t) = \alpha t$ and $\therefore v_{s} = v(t_{s}) = \alpha t,$ $t_{f} = \frac{2v_{s} \sin \dot{\theta}}{g} = \frac{2\alpha t, \sin \dot{\theta}}{g}.$ Therefore, $w = (v_{s} \cos \dot{\theta})t_{f} = \frac{\alpha^{2}t_{s}^{2} \sin 2\dot{\theta}}{g},$ giving $t_{s} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{\theta}}}.$ $0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}}.$ $0.5$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{\theta}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[ 1 + 2\left(\frac{\alpha}{g}\right) \sin \theta \right]}{\alpha \sqrt{\sin 2\dot{\theta}}}.$ $where \alpha = BIL/m - g \sin \theta.$ The values of the parameters are: B=10.0 T, I = 2424 A, L=2.00m, R=1.0 \Omega, g=10 \text{ m/s}^{2}, m=80 \text{ kg, and } w=1000 \text{ m. Then,}. $T = \frac{100}{\alpha} \left[ \frac{1 + 0.20\alpha \sin \theta}{\sqrt{\sin 2\dot{\theta}}} \right]$ $0.3$ $2$			
where $\alpha = BIL/m - g \sin \theta$ . $\therefore v(t) = \alpha $ and $\therefore v_s = v(t_s) = \alpha t_s$ $t_f = \frac{2v_s \sin \hat{e}}{g} = \frac{2\alpha t_s \sin \hat{e}}{g}$ . Therefore, $w = (v_s \cos \hat{e})t_f = \frac{\alpha^2 t_s^2 \sin 2\hat{e}}{g}$ , giving $t_s = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}}$ $t_f = \sqrt{\frac{2w \tan \theta}{g}}$ . Hence, $T = t_s + t_f = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[ 1 + 2 \left( \frac{\alpha}{g} \right) \sin \theta \right]}{\sqrt{\sin 2\hat{e}}}$ . where $\alpha = BIL/m - g \sin \theta$ . The values of the parameters are: B=10.0 T, 1= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^2, m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{[1 + 0.20\alpha \sin \theta]}{\sqrt{\sin 2\hat{e}}}$ , 0.3	And we have instead		
and $\therefore v_{x} = v(t_{x}) = \alpha t_{x}$ $t_{f} = \frac{2v_{x} \sin \hat{e}}{g} = \frac{2\alpha_{x} \sin \hat{e}}{g}.$ Therefore, $w = (v_{x} \cos \hat{e})t_{f} = \frac{\alpha^{2}t_{x}^{2} \sin 2\hat{e}}{g},$ giving $t_{x} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} \qquad 0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}}.$ Hence, $T = t_{x} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[1 + 2\left(\frac{\alpha}{g}\right)\sin\theta\right]}{\sqrt{\sin 2\hat{e}}}.$ where $\alpha = BIL/m - g\sin\theta.$ The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100 \left[1 + 0.20\alpha \sin\theta\right]}{\alpha \sqrt{\sqrt{\sin 2\hat{e}}}} \qquad 0.3$	,		
and $i v_{s} = v(t_{s}) = \alpha t_{s}$ $t_{f} = \frac{2v_{s} \sin \dot{e}}{g} = \frac{2\alpha t_{s} \sin \dot{e}}{g}.$ Therefore, $w = (v_{s} \cos \dot{e})t_{f} = \frac{\alpha^{2}t_{s}^{2} \sin 2\dot{e}}{g},$ giving $t_{s} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} \qquad 0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}}.$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[1 + 2\left(\frac{\alpha}{g}\right)\sin \theta\right]}{\sqrt{\sin 2\dot{e}}}.$ where $\alpha = BIL/m - g \sin \theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{[1 + 0.20\alpha \sin \theta]}{\sqrt{\sin 2\dot{e}}}$ where $\alpha = 606 - 10 \sin \theta$ . 0.3	$\therefore v(t) = \alpha t$	0.1	
Therefore, $w = (v_{s} \cos \hat{e})t_{f} = \frac{\alpha^{2}t_{s}^{2} \sin 2\hat{e}}{g},$ giving $t_{s} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} \qquad 0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}}. \qquad 0.5$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[1 + 2\left(\frac{\alpha}{g}\right)\sin \theta\right]}{\sqrt{\sin 2\hat{e}}}.$ where $\alpha = BIL/m - g\sin \theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100 \left[1 + 0.20\alpha \sin \theta\right]}{\alpha \sqrt{\sin 2\hat{e}}}, \qquad 0.3 \qquad 2$	and $\therefore v_s = v(t_s) = \alpha t_s$	0.2	
$w = (v_{s} \cos \hat{e})t_{f} = \frac{\alpha^{2}t_{s}^{2} \sin 2\hat{e}}{g},$ giving $t_{s} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} \qquad 0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}}. \qquad 0.5$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\hat{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[1 + 2\left(\frac{\alpha}{g}\right)\sin\theta\right]}{\sqrt{\sin 2\hat{e}}}.$ where $\alpha = BIL/m - g\sin\theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100 \left[1 + 0.20\alpha \sin\theta\right]}{\alpha \sqrt{\sin 2\hat{e}}}, \qquad 0.3 \qquad 2$			
giving $t_{s} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} \qquad 0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}} \qquad 0.5$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg} \left[1 + 2\left(\frac{\alpha}{g}\right)\sin \theta\right]}{\sqrt{\sin 2\dot{e}}} \qquad 0.5$ Where $\alpha = BIL/m - g\sin \theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{[1 + 0.20\alpha \sin \theta]}{\sqrt{\sin 2\dot{e}}} \qquad 0.3$	Therefore,		
$t_{s} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} \qquad 0.5$ and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}} \qquad 0.5$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg}}{\alpha} \frac{\left[1 + 2\left(\frac{\alpha}{g}\right)\sin \theta\right]}{\sqrt{\sin 2\dot{e}}} \qquad 0.5$ Where $\alpha = BIL/m - g \sin \theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{\left[1 + 0.20\alpha \sin \theta\right]}{\sqrt{\sin 2\dot{e}}}$ where $\alpha = 606 - 10 \sin \theta$ . 0.3	$w = (v_s \cos \dot{e})t_f = \frac{\alpha^2 t_s^2 \sin 2\dot{e}}{g},$		
and $t_{f} = \sqrt{\frac{2w \tan \theta}{g}}.$ (0.5) Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg}}{\alpha} \frac{\left[1 + 2\left(\frac{\alpha}{g}\right)\sin \theta\right]}{\sqrt{\sin 2\dot{e}}}.$ where $\alpha = BIL/m - g\sin \theta$ . The values of the parameters are: B=10.0 T, 1= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s <sup>2</sup> , m=80 kg, and w=1000 m. Then, $T = \frac{100 \left[1 + 0.20\alpha \sin \theta\right]}{\alpha \sqrt{\sin 2\dot{e}}}$ where $\alpha = 606 - 10\sin \theta$ . 0.3	giving		
$t_{f} = \sqrt{\frac{2w \tan \theta}{g}}.$ $0.5$ Hence, $T = t_{s} + t_{f} = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w \tan \theta}{g}} = \frac{\sqrt{wg}}{\alpha} \frac{\left[1 + 2\left(\frac{\alpha}{g}\right)\sin \theta\right]}{\sqrt{\sin 2\dot{e}}}.$ where $\alpha = BIL/m - g\sin \theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 \Omega, g=10 m/s^{2}, m=80 kg, and w=1000 m. Then, $T = \frac{100 \left[1 + 0.20\alpha \sin \theta\right]}{\sqrt{\sin 2\dot{e}}}$ where $\alpha = 606 - 10\sin \theta$ . $0.3$	$t_s = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}}$	0.5	
$T = t_s + t_f = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w\tan\theta}{g}} = \frac{\sqrt{wg}}{\alpha} \frac{\left[1 + 2\left(\frac{\alpha}{g}\right)\sin\theta\right]}{\sqrt{\sin 2\dot{e}}}.$ where $\alpha = BIL/m - g\sin\theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 $\Omega$ , g=10 m/s <sup>2</sup> , m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{\left[1 + 0.20\alpha\sin\theta\right]}{\sqrt{\sin 2\dot{e}}}$ where $\alpha = 606 - 10\sin\theta$ .		0.5	
where $\alpha = BIL/m - g \sin \theta$ . The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 $\Omega$ , g=10 m/s <sup>2</sup> , m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{[1 + 0.20\alpha \sin \theta]}{\sqrt{\sin 2\hat{e}}}$ where $\alpha = 606 - 10 \sin \theta$ .	Hence,		
The values of the parameters are: B=10.0 T, I= 2424 A, L=2.00m, R=1.0 $\Omega$ , g=10 m/s <sup>2</sup> , m=80 kg, and w=1000 m. Then, $T = \frac{100 \left[1 + 0.20\alpha \sin \theta\right]}{\alpha \sqrt{\sin 2\dot{e}}}$ 0.3 0.3	$T = t_s + t_f = \frac{1}{\alpha} \sqrt{\frac{gw}{\sin 2\dot{e}}} + \sqrt{\frac{2w\tan\theta}{g}} = \frac{\sqrt{wg}}{\alpha} \frac{\left[1 + 2\left(\frac{\alpha}{g}\right)\sin\theta\right]}{\sqrt{\sin 2\dot{e}}}.$		
R=1.0 $\Omega$ , g=10 m/s <sup>2</sup> , m=80 kg, and w=1000 m. Then, $T = \frac{100}{\alpha} \frac{\left[1 + 0.20\alpha \sin\theta\right]}{\sqrt{\sin 2\dot{e}}}$ where $\alpha = 606 - 10\sin\theta$ .	where $\alpha = BIL / m - g \sin \theta$ .		
where $\alpha = 606 - 10\sin\theta$ .			
12		0.3	2
		12	

	Labeling:	
T/s	0.1 each axis	
12		
10	Unit:	
	0.1 each axis	
*	0.1 Cacil axis	
6	Dropor Dopgo in	
	Proper Range in $\theta$ :	
0.1 0.2 0.3 0.4 0.5 0.6 theta /rad		
P. C.	0.1 lower limit	
	(more than $0$ ,	
	less than 0.5),	
	0.2 upper limit	
For $\theta$ within the range (~0, 0.52) radian the time <i>T</i> is within 11 s.	(more than 0.52	
1 of 0 writing the range (30, 0.52) radian the time 1 is writing 11 s.	and less than $0.8$ )	
	Proper shape of	
	curve: 0.2	
	Accurate	
	intersection at	
	$\theta = 0.52: 0.4$	1.3
However, there is another constraint, i.e. the length of rail <i>D</i> .	Labeling:	
Let $D_s$ be the distance travelled during the time interval $t_s$	0.1 each axis	
$D_s = \frac{gw}{2\alpha\sin 2\theta} = \frac{5000}{\alpha\sin 2\theta}$	Unit:	
$2\alpha \sin 2\theta  \alpha \sin 2\theta$	0.1 each axis	
which is plotted below		
	Proper Range in	
Ds /m	θ:	
	0.1 lower limit	
40	(more than 0.08,	
20	less than 0.11),	
	0.1 upper limit	
20	(more than 0.52	
10	and less than 1.5)	
0.2 0.4 0.6 0.8 1 1.2 1.4 theta /rad	Proper shape of	
	curve: 0.2	
It is necessary that $D_s \leq D$ , which means $\theta$ must range between 0.11 and		
1.43 radians.	Accurate	
	intersection at	
	$\theta = 0.11: 0.4$	1.2
	0.11.0.7	
In order to satisfy both conditions, $\theta$ must range between 0.11 & 0.52		_
radians.		0.5
		1