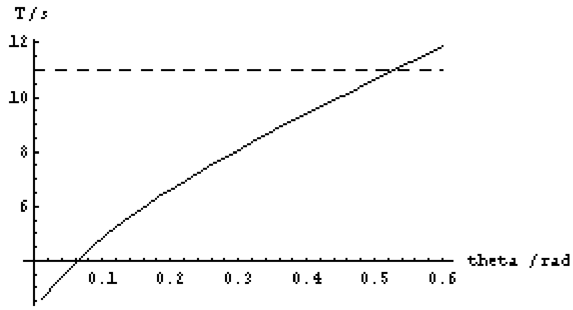
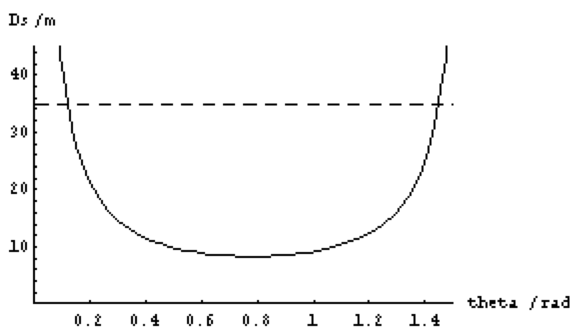

Alternate Solution (Not taking induced emf into consideration): If induced emf is not taken into account, there is no induced current, so the net force acting on the combined mass of the young man and rod is		
$F_N = BIL - mg\sin\theta$.	0.2 BIL 0.2 $mg\sin\theta$	
And we have instead $dv/dt = \alpha,$ where $\alpha = BIL/m - g\sin\theta$.		
$\therefore v(t) = \alpha t$	0.1	
and $\therefore v_s = v(t_s) = \alpha t_s$	0.2	
$t_f = \dfrac{2v_s \sin\theta}{g} = \dfrac{2\alpha t_s \sin\theta}{g}$. Therefore, $w = (v_s \cos\theta)t_f = \dfrac{\alpha^2 t_s^{\ 2} \sin 2\theta}{g}$, giving		
$t_s = \dfrac{1}{\alpha}\sqrt{\dfrac{gw}{\sin 2\theta}}$	0.5	
and $t_f = \sqrt{\dfrac{2w\tan\theta}{g}}$.	0.5	
Hence, $T = t_s + t_f = \dfrac{1}{\alpha}\sqrt{\dfrac{gw}{\sin 2\theta}} + \sqrt{\dfrac{2w\tan\theta}{g}} = \dfrac{\sqrt{wg}}{\alpha}\dfrac{\left[1 + 2\left(\dfrac{\alpha}{g}\right)\sin\theta\right]}{\sqrt{\sin 2\theta}}$. 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 Ω, g=10 m/s^2, m=80 kg, and w=1000 m. Then, $T = \dfrac{100}{\alpha}\dfrac{[1 + 0.20\alpha\sin\theta]}{\sqrt{\sin 2\theta}}$ where $\alpha = 606 - 10\sin\theta$.	0.3	2

 For θ within the range (~0, 0.52) radian the time T is within 11 s.	Labeling: 0.1 each axis Unit: 0.1 each axis Proper Range in θ: 0.1 lower limit (more than 0, less than 0.5), 0.2 upper limit (more than 0.52 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 D. Let D_s be the distance travelled during the time interval t_s $D_s = \dfrac{gw}{2\alpha \sin 2\theta} = \dfrac{5000}{\alpha \sin 2\theta}$ which is plotted below  It is necessary that $D_s \leq D$, which means θ must range between 0.11 and 1.43 radians.	Labeling: 0.1 each axis Unit: 0.1 each axis Proper Range in θ: 0.1 lower limit (more than 0.08, less than 0.11), 0.1 upper limit (more than 0.52 and less than 1.5) Proper shape of curve: 0.2 Accurate intersection at $\theta = 0.11$: 0.4	1.2
In order to satisfy both conditions, θ must range between 0.11 & 0.52 radians.		0.5

Question 3 - Marking Scheme

(a) Since $W(v) = 4\pi \left(\dfrac{M}{2\,\pi\, R\,T} \right)^{3/2} v^2\ e^{-M\,v^2/(2RT)}$,

$$\bar{v} = \int_0^\infty v\ W(v)\ dv =$$

$$= \int_0^\infty v\ 4\pi \left(\frac{M}{2\,\pi\, R\,T} \right)^{3/2} v^2\ e^{-M\,v^2/(2RT)}\ dv$$

$$= \int_0^\infty 4\pi \left(\frac{M}{2\,\pi\, R\,T} \right)^{3/2} v^3\ e^{-M\,v^2/(2RT)}\ dv$$

$$= 4\pi \left(\frac{M}{2\,\pi\, R\,T} \right)^{3/2} \int_0^\infty v^3\ e^{-M\,v^2/(2RT)}\ dv$$

$$= 4\pi \left(\frac{M}{2\,\pi\, R\,T} \right)^{3/2} \frac{4\,R^2\,T^2}{2\,M^2}$$

$$= \sqrt{\frac{8\,R\,T}{\pi\,M}}$$

Marking Scheme:

Performing the integration correctly:	1 mark
Simplifying	0.5 marks

Subtotal for the section 1.5 marks

(b) Assuming an ideal gas, $P V = N k T$, so that the concentration of the gas molecules, *n*, is given by

$$n = \frac{N}{V} = \frac{P}{k T}$$

the impingement rate is given by

$$J = \frac{1}{4} n \bar{v}$$

$$= \frac{1}{4} \frac{P}{k T} \sqrt{\frac{8 R T}{\pi M}}$$

$$= P \sqrt{\frac{8 R T}{16 k^2 T^2 \pi M}}$$

$$= P \sqrt{\frac{N_A k}{2 k^2 T \pi M}}$$

$$= P \sqrt{\frac{1}{2 k T \pi m}}$$

$$= \frac{P}{\sqrt{2 \pi m k T}}$$

where we have note that $R = N_A k$ and $m = \frac{M}{N_A}$ (N_A being Avogadro number).

Marking Scheme:

Using ideal gas formula to estimate concentration of gas molecules: 0.7 marks
Simplifying expression: 0.4 marks
Using $R = N k$, and the formula for *m*; (0.2 mark each) 0.4 marks

Subtotal for the section 1.5 marks

(c) Assuming close packing, there are approximately 4 molecules in an area of 16 r^2 m^2. Thus, the number of molecules in 1 m^2 is given by

$$n_1 = \frac{4}{16\left(3.6 \times 10^{-10}\right)^2} = 1.9 \times 10^{18} \text{ m}^{-2}$$

However at (273 + 300) K and 133 Pa, the impingement rate for oxygen is

$$\begin{aligned} J &= \frac{P}{\sqrt{2\pi\, mkT}} \\ &= \frac{133}{\sqrt{2\pi\left(\frac{32 \times 10^{-3}}{6.02 \times 10^{23}}\right)(1.38 \times 10^{-23})\,573}} \\ &= 2.6 \times 10^{24} \text{ m}^{-2}\text{ s}^{-1} \end{aligned}$$

Therefore, the time needed for the deposition is $\frac{\boldsymbol{n}_1}{\boldsymbol{J}} = 0.7\ \mu\text{s}$

The calculated time is too short compared with the actual processing.

Marking Scheme:

Estimation of number of molecules in 1 m^2 :	0.4 marks
Calculation the impingement rate:	0.6 marks
Taking note of temperature in Kelvin	0.3 marks
Calculating the time	0.4 marks

Subtotal for the section 1.7 marks

(d) With activation energy of 1 eV and letting the velocity of the oxygen molecule at this energy is v_1, we have

$$\frac{1}{2} m v_1^2 = 1.6 \times 10^{-19} \text{ J}$$

$$\Rightarrow v_1 = 2453.57 \quad \text{ms}^{-1}$$

At a temperature of 573 K, the distribution of the gas molecules is

We can estimate the fraction of the molecules with speed greater than 2454 ms^{-1} using the trapezium rule (or any numerical techniques) with ordinates at 2453, 2453 + 500, 2453 +1000. The values are as follows:

Velocity, v	Probability, $W(v)$
2453	1.373×10^{-10}
2953	2.256×10^{-14}
3453	6.518×10^{-19}

Using trapezium rule, the fraction of molecules with speed greater than 2453 ms^{-1} is given by

$$\text{fraction of molecules} = \frac{500}{2}\left[\left(1.373 \times 10^{-10}\right) + \left(2 \times 2.256 \times 10^{-14}\right) + \left(6.518 \times 10^{-19}\right)\right]$$

$$f = 3.43 \times 10^{-8}$$

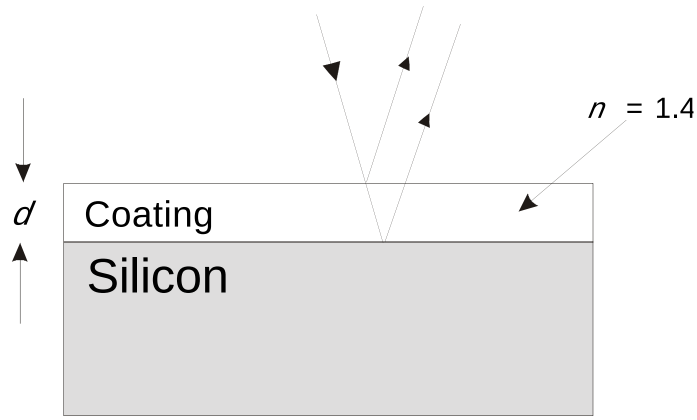
Thus the time needed for the deposition is given by 0.7 μs/(3.43×10^{-8}) that is 20.4 s

Marking Scheme

Computing the value of the cut-off energy or velocity: 0.6 marks
Estimating the fraction of molecules 1.2 marks
Correct method of final time 0.4 marks
Correct value of final time 0.6 marks

<u>Subtotal for the section 2.8 marks</u>

(e) For destructive interference, optical path difference $= 2\,d = \frac{\lambda'}{2}$ where $\lambda' = \frac{\lambda_{air}}{n}$ is the wavelength in the coating.



The relation is given by:

$$d = \frac{\lambda_{air}}{4\,n}$$

Plugging in the given values, one gets d = 105 or 105.2 nm.

Derive equation:

Finding the optical path length 0.2 marks
Knowing that there is a phase change at the reflection 0.5 marks
Putting everything together to get the final expression 0.6 marks
Subtotal: 1.3 marks

Computation of d: 0.6 marks
Getting the correct number of significant figures: 0.6 marks
Subtotal: 1.2 marks

Subtotal for Section **2.5 marks**

TOTAL **10 marks**