<table>
<tr><th>Question</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>ONE
(a)</td><td>The ladder’s mass is to be considered as zero. The centre of mass of the man and ladder system is therefore where the man is. As he climbs the ladder the horizontal position of the centre of mass must stay in its original position (at the foot of the ladder) because, on the frictionless ice, no unbalanced horizontal force can be exerted on the ladder / man system to move the centre of mass to the left. As the man climbs, moving left relative to the ladder, the ladder will move, relative to the ice, to the right so that the position of the centre of mass doesn’t move (except upwards).As the man climbs there is a component of the force he exerts acting to the right which moves the ladder to the right.</td><td rowspan="5">Thorough understanding of these applications of physics.

OR

Partially correct mathematical solution to the given problems.

AND / OR

Partial understanding of these applications of physics.</td><td rowspan="5">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of these applications of physics.</td><td rowspan="5">Correct mathematical solution to the given problems.

AND

Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>$mg = R_1 + R_2$
Taking moments about the top of the ladder
Each side can be treated separately (both sides must individually have zero net torque acting).
$R_2 \times L \sin\theta = T \times (L\cos\theta - d)$
$R_1 \times L \sin\theta = T \times (L\cos\theta - d) + mg \times (L\cos\theta - h)\tan\theta$
Add both
$L \sin\theta\,(R_1 + R_2) = 2T(L\cos\theta - d) + mg(L\cos\theta - h)\tan\theta$
Sub for $R_1 + R_2$
Rearrange $mg(L\sin\theta - L\cos\theta\tan\theta + h\tan\theta) = 2T(L\cos\theta - d)$
$\cos\theta\tan\theta = \sin\theta$ so $T = \dfrac{mgh\tan\theta}{2(L\cos\theta - d)}$</td></tr>
<tr><td>(c)(i)</td><td>$T = \dfrac{70 \times 9.81 \times 3 \times \cos 30° \times \tan 30°}{2(3\cos 30° - 2\cos 30°)}$
$T = 594\text{ N}$</td></tr>
<tr><td>(c)(ii)</td><td>x = length of tie bar
$2(L\cos\theta - d)\tan\theta = x$
$L\cos\theta - \dfrac{x}{2\tan\theta} = d$
$T = \dfrac{mgh\tan\theta}{2\left(L\cos\theta - \left(L\cos\theta - \dfrac{x}{2\tan\theta}\right)\right)}$
$= \dfrac{mgh\tan\theta}{\dfrac{2x}{2\tan\theta}}$
$T = mgh\dfrac{\tan^2\theta}{x}$
The tension will increase as $\tan\theta$ is proportional to x.</td></tr>
<tr><td>(d)</td><td>To climb the ladder, the electrician must accelerate upwards. If this acceleration is large (so that they get to the top quickly), the reaction forces from the ground must be greater to supply the force needed for acceleration. The reaction forces will require an increased tension in the tie bar and a slow climb will keep the tension as low as possible, so hopefully the tie will not snap.</td></tr>
</table>

Question	Evidence	1-4 marks	5-6 marks	7-8 marks
2(a)(i)	If the system is stable the sum of turning forces on the system will be zero. Taking moments about O, there are only two torques, M g a (clockwise) and m g b (anticlockwise). These two must be equal if the system is to be stable. Taking external torques around the point of balance, $Mga - mgb = 0 \Rightarrow Ma = mb \Rightarrow M/m = b/a$	Partially correct mathematical solution to the given problems. AND / OR Partial understanding of this application of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of this application of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of this application of physics.
(ii)	$\cos\theta = \frac{b}{L}$ and $\cos\theta = \frac{(c-a)}{(L+d)}$ Therefore, $\frac{b}{L} = \frac{(c-a)}{(L+d)}$ $\Rightarrow \frac{\left(\frac{aM}{m}\right)}{L} = \frac{(c-a)}{(L+d)} \qquad \left[\text{from } \frac{M}{m} = \frac{b}{a}\right]$ $\Rightarrow \frac{a(L+d)M}{mL} = c - a$ $\Rightarrow c = \frac{a(mL+(L+d)M)}{mL}$ $\Rightarrow c = \left(\frac{\cos\theta}{M}\right)(mL+(L+d)M) \qquad \left[\text{from } \cos\theta = \frac{b}{L} = \frac{aM}{mL}\right]$ $\Rightarrow \cos\theta = \frac{Mc}{(mL+(L+d)M)}$ $\Rightarrow \cos\theta = \frac{Mc}{(m+M)L+Md}$			
(b)	If M is too large and / or c is too big, then $\cos\theta$ will be greater than 1. This cannot happen – the system will rotate so that the bottle hits the bench.			
(c)	$\cos\theta$ will drop as L is in the denominator and therefore θ will increase. Assuming constant mass as L increases, b increases so the anticlockwise torque increases. This is unstable; to return to equilibrium conditions θ must increase.			
(d)	When the wine is removed, M will decrease, so the clockwise torque will decrease. Moving the neck of the bottle to the right will increase the torque again by increasing the distance from the centre of mass over which the weight force acts.			

Question	Mark Allocation	Typical evidence
3(a)	2 marks for 40 N. 1 mark for no change to slow/bottom barge with appropriate explanation.	Fast barge must make the coal gain momentum. In 1 second 20 kg added which means to increase its velocity by 2 m s^{-1} requires $Ft = \Delta p = 20 \times 2 = 40$ kg m s^{-1} so in one second this is 40 N. The slow barge requires no extra force as friction is constant. (Total momentum will reduce but the mass reduces proportionally as well.)
2 (b)	2 marks for correct answer.	Force needed for constant velocity same as for at rest: $2T = mg$ ($2T$ as pulley effectively creates two ropes) The tension is therefore $\frac{mg}{2} = 564\,\text{N}$
2 (c)	1 mark for stating that the period depends on the position of the CoM. 1 mark for CoM “tracking” the movement of the water downwards therefore increasing the period. 1 mark for CoM ending up at CoM (bucket) which is closer to the original period.	The period for SHM of a pendulum is independent of mass, and so as the mass of the water / bucket decreases, there should be no change in the time period. However if the height of the bucket is not insignificant compared to the length of the rope, then the effective length of the pendulum will get longer as the centre of mass of the bucket / water gets lower. This increase in length will increase the time period slightly. When the bucket is completely empty, the centre of mass of the bucket will be back near the centre of the bucket, and therefore the length will decrease slightly and the time period will decrease slightly, coming closer to what it was originally.

4(a)	One mark for friction or right-hand wheel arguments.	The frictional force provides the centripetal force so it is towards the centre of the circle. The force on the right hand wheel is critical, as in the case of rolling the left hand wheel will lift off the road providing zero friction, and it is only the right hand wheel's frictional force that can keep the car on the road.	2
(b)		Anticlockwise torques = clockwise torques $\tau_a = N \times \frac{t}{2}$ and $\tau_c = f \times h$ $f = \frac{mv^2}{r}$ $mg\frac{t}{2} = \frac{mv^2}{r} \times h$ $\Rightarrow \frac{t}{2h} = \frac{v^2}{rg}$	2
(c)		If the centre of mass of the passengers is above C, then the more passengers there are the higher the total centre of mass will be and so the slower the car must be driven. Eg with a 50 m corner, v_{max} = 22.8 m/s unloaded, but if h increases by 20 cm, v_{max} = 20.4 m/s. If the gear is stowed in the back the effect on h will be much less than if it is stowed on the roof rack. The position of the passengers could be considered, eg moving around when cornering.	2
(d)		It is an inverse relationship between rate of rolling and SSF. However, even the worst case SUV has a 0.03% rolling rate. Is this significant? These vehicles may have more chance of rolling but may be safer in collisions. However, it can be said that the shape of the above curve means that a small change in the SSF in the region of 1.0 to 1.2 would mean a large change in the rolling rate. An SSF of about 1.2 or greater seems optimal.	2