| Q | Evidence | 1–4<br>Below Schol | 5–6<br>Scholarship | 7–8<br>Outstanding |
|---|---|---|---|---|
| 1 (a)(i) | $mgL = \frac{1}{2}mv^2 \qquad v^2 = 2gL$<br>$T = mg + \frac{mv^2}{L} = mg + 2mg = 3mg$ | Thorough understanding of these applications of physics.<br>OR<br>Partially correct mathematical solution to the given problems.<br>AND / OR<br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br>AND / OR<br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br>AND<br>Thorough understanding of these applications of physics. |
| (ii) | The square of the speed reached increases as the length of the rope increases, and so the centripetal force (the tension) should also increase. But the centripetal force required is also reduced in direct proportion to the increase in radius of the motion. These factors exactly cancel each other, leading to a constant maximum tension. | | | |
| (b)(i) | $T = kx$<br>$T = mg + \frac{mv^2}{L+x}$<br>$T(L+x) - mg(L+x) = mv^2$<br>Energy<br>$mg(L+x) = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$<br>$2mg(L+x) = mv^2 + kx^2 = T(L+x) - mg(L+x) + Tx$<br>$3mg(L+x) = T(L+2x)$<br>$T = \frac{3mg(L+x)}{L+2x}$ | | | |
| (ii) | The maximum velocity reached is less for the rubber than for the rope because some of the transferred GPE is taken up as elastic PE in the stretched rubber. This reduces the required centripetal force, reducing the required tension. | | | |

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<tr><th>Q</th><th>Evidence</th><th>1–4 marks</th><th>5–6 marks</th><th>7–8 marks</th></tr>
<tr><td>TWO<br>(a)</td><td>At the top of the jump, Emma's centre of mass is 1 m above the platform. At the bottom of the jump, Emma's centre of mass is 1 m above the river. So Emma's centre of mass moves 25 m, from the platform to the bottom of the jump.<br>Loss of gravitational potential energy is $mgh$.<br>Extension of bungy spring is $x = (25 - 2) - L$.<br>Gain in potential energy of the spring is $0.5kx^2 = 0.5k(23 - L)^2$<br>Therefore, gravitational potential energy = spring potential energy so $mgh = 0.5\text{k}(23 - L)^2$</td><td rowspan="6">Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial understanding of these applications of physics.</td><td rowspan="6">(Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics.</td><td rowspan="6">Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>At equilibrium, downward force of gravity = upward force of spring $m\text{g} = \text{k}x = \text{k}(25 - 10 - L)$ ie, $m\text{g} = \text{k}(15 - L)$</td></tr>
<tr><td>(c)</td><td>From Two (a) and Two (b), equating expressions for $mgh$<br>$0.5\text{k}(23 - L)^2 = \text{k}(15 - L)h$ The "k"s cancel, and $h$ is 25 m.<br>So $0.5\,(23 - L)^2 = (15 - L)25$ therefore $(23 - L)^2 = (15 - L)50$<br>$529 + L^2 - 46L = 750 - 50L$<br>$L^2 + 4L - 221 = 0$<br>Solving this and taking the positive root gives $L = 13$ m.</td></tr>
<tr><td>(d)(i)</td><td>Maximum speed occurs at the point that Emma feels zero acceleration (before this the acceleration is downwards, and after this the acceleration is upwards, which slows the velocity). Zero acceleration when $m\text{g} = \text{k}x$<br>We know that $\frac{m\text{g}}{\text{k}} = 2$.<br>Therefore, zero acceleration at $x = 2$.<br>Loss of potential energy at $x = 2$ is $m\text{g}(L + 2 + 2)$<br>$= m\text{g}(L + 4)$<br>Gain of spring potential energy at $x = 2$ is $0.5\text{k}2^2 = 2\text{k}$<br>Therefore, KE $= m\text{g}(13 + 4) - 2\text{k} = 17\,m\text{g} - 2\text{k}$<br>$0.5\,mv^2 = 17\,m\text{g} - 2\text{k}$<br>$v^2 = 34\text{g} - 4\frac{\text{k}}{m} = 34\text{g} - 2\text{g}$ (from Two (b)) $= 32\text{g} = 32(9.81)$<br>$= 313.92$ therefore, $v = 17.7\text{ m s}^{-1}$</td></tr>
<tr><td>(ii)</td><td>Maximum acceleration downwards is $g$. But we know that the bungy counteracts this and actually turns around the motion.<br>Maximum acceleration due to bungy is $\frac{\text{k}x}{m}$ and is maximum when $x$ is a maximum. Maximum value of $x$ is 10 m, and $\frac{\text{k}}{m} = \frac{g}{2}$ (from Two (b)). So maximum acceleration due to bungy is 5g ($49.05\text{ m s}^{-2}$). Subtract the acceleration due to gravity, to get maximum of 4 g ($39.24\text{ m s}^{-2}$).</td></tr>
<tr><td>(e)</td><td>If force F is applied to the bungy, the change in length of the whole bungy will be $x$. If we imagine the bungy to be made of two parts, each part will extend by $\frac{x}{2}$ .Since the force is the same, the spring constant has doubled.</td></tr>
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| Question | Evidence | 1-4 marks | 5-6 marks | 7-8 marks |
|---|---|---|---|---|
| 3 (a ) | As the 2 g red puck approaches, electrostatic repulsion will cause it to slow down and the 4 g blue puck to start moving. The 4 g will accelerate in the original direction and the 2 g will stop and recoil in the opposite direction. | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND/OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics. |
| (b) | At closest approach, the relative velocity of the pucks must be zero. So both will have the same velocity with respect to the track.<br>Conservation of momentum<br><br>$m_{2g}v_{2g} = (m_{2g} + m_{4g})v_c$<br><br>$v_c = 42 / 6 = 7\text{ m s}^{-1}$ | | | |
| (c) | At 10 m, the electrostatic potential energy is<br>$\frac{kQQ}{r} = 9\times10^9\times\frac{(1.5\times10^{-6})^2}{10} = 2.02\times10^{-3}\text{ J}$<br>Kinetic energy is $\frac{1}{2}\times2\times10^{-3}\times21^2 = 441\times10^{-3}\text{ J}$ | | | |
| (d) | Total energy is conserved.<br><br>Original KE = $KE_{2g}$ at closest + $KE_{4g}$ at closest + electric potential energy<br>$\frac{1}{2}\times2\times10^{-3}\times21^2 = \left(\frac{1}{2}\times2\times10^{-3}\times7^2\right)$<br>$+\left(\frac{1}{2}\times4\times10^{-3}\times7^2\right)+\frac{1.5\times10^{-6}\times1.5\times10^{-6}\times9\times10^9}{d}$<br>$(441-49-98)\times10^{-3} = 0.294 = \frac{0.02025}{d}$<br>$d = 0.069\text{ m}$ | | | |
| (e) | The collision is elastic<br>$2\times21 = 2v_R + 4v_B$ (conservation of momentum )<br><br>$\frac{1}{2}\times2\times21^2 = \frac{1}{2}\times2\times v_R^2 + \frac{1}{2}\times4\times v_B^2$<br>(conservation of kinetic energy)<br>(and taking the original electric PE as zero)<br><br>From 1st equation:<br>$2v_R = 2\times21 - 4v_B \Rightarrow 4v_R^2 = (2\times21 - 4v_B)^2$<br><br>Using 2nd:<br>$2\times21^2 = \frac{(2\times21-4v_B)^2}{2} + 8v_B^2$<br>$2\times2\times21^2 = (2\times21)^2 - 336v_B + 16v_B^2 + 8v_B^2$<br>$336v_B = 24v_B^2$<br>$v_{Blue} = 14\text{ m s}^{-1}$<br>$v_{Red} = -7\text{ m s}^{-1}$ | | | |

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<td>4 (a)</td>
<td>$\frac{1}{2} mV^2 = \frac{1}{2} Mv^2$<br>$V = v\sqrt{\frac{M}{m}}$<br>Momentum small mass $= mv\sqrt{\frac{M}{m}}$<br>Momentum large mass $= Mv$<br>$v$s cancel in the comparison<br>$\sqrt{Mm} : M$<br>$\sqrt{m} : \sqrt{M}$<br>Large mass has the larger momentum by factor of $\sqrt{\frac{M}{m}}$</td>
<td rowspan="4">Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial discussion of the underlying physics of this application.</td>
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<td>(b)(i)</td>
<td>Centripetal force is supplied by tyre friction. It is static friction, because the tires are not moving into or away from the centre of the circle they are describing. If the car is going fast enough so that the static friction cannot supply the centripetal force needed to maintain a circular path, then the car will leave that path (move outwards relative to the road surface). (As soon as this happens, the available friction becomes kinetic friction and now the available centripetal force is far too low to maintain the circle. The car skids across the road.)<br>The statement “There is more force taking you off the road” is incorrect. There is no force “taking you off the road”. In the absence of a force, the car will continue in a straight line (Newton’s First Law). The statement “There is less force keeping you on it” is inaccurate. A more accurate statement would be “There is insufficient force to keep you going round the bend”.</td>
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<td>(b)(ii)</td>
<td>Energy absorbed / converted = ½ $.m$ . $50^2$ units<br><br>Energy started with = ½ . $m$ . $60^2$ units<br>Remaining energy = 1100 ½ m units<br><br>$V^2 = 1100$<br>$V = 33$ kph</td>
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<td>(c)</td>
<td>At constant velocity, the forces on the 10 kg must sum to zero. The 100 N gravity force must be balanced by a 100 N tension force.<br>The tension is constant throughout the belt.<br>The cylinder A is supported by two tensions = 200 N.<br>The gravity force on the cylinder must = 200 N<br>The mass that experiences a gravity force of 200 N would be 20 kg the mass of A.</td>
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