1) When $s_A = 0.9\,m$

$$s_B = \frac{0.18}{0.12} s_A$$

$$= 1.35\,m$$

$$\theta = \frac{s_A}{0.12}$$

$$= 7.5\,rad$$

$$I_G = mk^2$$

$$= 6 \times 0.14^2$$

$$= 0.1176\,kgm^2$$

$$U_{1\to2} = -3g(0.9) + 3g(1.35) - 0.5(7.5)$$

$$= 9.4935$$

$$U_{1\to2} = E_{k2} - E_{k1}$$

$$= \frac{1}{2} I_G w^2 + \frac{1}{2} m_A v_A^2 + \frac{1}{2} m_B v_B^2$$

$$= 0.5(0.1176)w^2 + 0.5(3)(0.12^2)w^2$$

$$+ 0.5(3)(0.18^2)w^2$$

$$= 0.129\,w^2$$

$$9.4935 = 0.129 w^2$$

$$w = 8.578637611\,rads^{-1}$$

$$v_A = 0.12(8.578637611)$$

$$\approx 1.029\,ms^{-1}$$

2) Assuming cylinder C has speed v and acceleration a

$$\omega_A = \frac{v}{r_1} = \frac{v}{0.1} = 10v$$

$$\omega_A(0.15) = \omega_B(0.1)$$

$$\omega_B = 15v$$

$$\alpha_A = \frac{a}{r_1} = \frac{a}{0.1} = 10a$$

$$\alpha_A(0.15) = \alpha_B(0.1)$$

$$\alpha_B = 15a$$

a) $mgs = \frac{1}{2}mv^2 + \frac{1}{2}I_G\omega_A^2 + \frac{1}{2}I_G\omega_B^2$

$$10gs = \frac{1}{2}(10)v^2 + \frac{1}{2}(0.25)(10v)^2 + \frac{1}{2}(0.25)(15v)^2$$

$$10gs = 45.625v^2$$

$$\frac{16g}{73}s = v^2$$

$$2\left(\frac{8g}{73}\right)s = v^2$$

$$\therefore a = \frac{8 \times 9.81}{73}$$

$$= 1.07506893\,ms^{-2}$$

$$v = at = 1.075(3)$$

$$= 3.225205479 \simeq 3.225\,ms^{-1}$$

2b) $T_B(0.1) = I_G \alpha_B$

$$T_B = 10(0.25)(15)(1.075)$$

$$= 40.3150684\text{9N}$$

c) $T_A(0.1) - T_B(0.15) = I_G \alpha_B$

$$T_A(0.1) - \frac{8829}{1460} = 0.25(10)(1.075)$$

$$T_A = 87.34931507\,N$$

3) Making use of instantaneous centre C,

$$v_G = \frac{L}{2}\dot{\theta} = \frac{L}{2}w$$

So E_K of AB can be expressed as:

$$E_K = \frac{1}{2}mv_G^2 + \frac{1}{2}I_G w^2$$
$$= \frac{1}{2}mL^2w^2$$

The E_p of the system can be expressed as:

$$E_p = E_g + E_e$$
$$= mgy + \frac{1}{2}k\delta^2$$
$$= mg(-0.5L\sin\theta) + \frac{1}{2}k(L\sin\theta)^2$$

$$E_K + E_p = 0$$

$$\frac{1}{6}mL^2w^2 - \frac{1}{2}mgL\sin\theta + \frac{1}{2}kL^2\sin^2\theta = 0$$

$$w^2 = \frac{3}{mL^2}(mgL\sin\theta - kL^2\sin^2\theta)$$

$$w = \pm\sqrt{3\left(\frac{g}{L}\sin\theta - \frac{k}{m}\sin^2\theta\right)}$$

3) For point A, using instant centre C,

$$v_A = L\cos\theta\,\omega$$

$$= \pm L\cos\theta\sqrt{3\left(\frac{g}{L}\sin\theta - \frac{k}{m}\sin^2\theta\right)}$$

$$= \pm 0.75\cos\theta\sqrt{39.24\sin\theta - 30\sin^2\theta}$$

4) Using intant centre for rolling without slipping

$$v_A = v_B = 0.5 v_c$$
$$= 0.5 v$$

$$w_A = w_B = w$$
$$= \frac{0.5v}{r}$$

$$U = 10s$$

$$U = \frac{1}{2}(6)v^2 + 2\left[\frac{1}{2}(4)(0.5v)^2 + \frac{1}{2} I_G w^2\right]$$
$$= 3v^2 + 2\left[\frac{2}{4}v^2 + \frac{1}{2}\left(\frac{1}{2}\right)(4)(\cancel{0.075^2})\left(\frac{0.5}{\cancel{0.075}}\right)^2\right]$$
$$= 3v^2 + v^2 + \frac{1}{2}v^2$$
$$= 4.5v^2$$

$$\therefore 10s = 4.5v^2$$
$$\frac{20}{9}s = v^2$$
$$2\left(\frac{10}{9}\right)s = v^2$$
$$\therefore a = \frac{10}{9}\ ms^{-2}$$

$$v = at$$
$$= \frac{10}{9}(2.5)$$
$$= \frac{25}{9}\ ms^{-1}$$

5) Let D be a point on the belt,

$$2s_A - s_D = \text{constant}$$

$$v_D = 2v_A = 2v$$

$$a_D = 2a = 2a$$

$$\omega_B = \frac{v_D}{r} = \frac{2v}{r}$$

$$\omega_A = \frac{v_A}{r} = \frac{v}{r}$$

$$\alpha_B = \frac{a_D}{r} = \frac{2a}{r}$$

$$\alpha_A = \frac{a_A}{r} = \frac{a}{r}$$

a) $$mgs = \frac{1}{2}mv_A^2 + \frac{1}{2}I_G\omega_A^2 + \frac{1}{2}I_G\omega_B^2$$

$$10gs = \frac{1}{2}(10)v^2 + \frac{1}{4}(10)\cancel{(0.125)^2}\left(\frac{v}{\cancel{0.125}}\right)^2 + \frac{5}{4}(10)\cancel{(0.125)^2}\left(\frac{2v}{\cancel{0.125}}\right)^2$$

$$10gs = 17.5v^2$$

$$gs = \frac{7}{4}v^2$$

$$2\left(\frac{2}{7}g\right)s = v^2$$

5a) $\therefore a = \frac{2}{7} g$

$= \frac{981}{350} \approx 2.803 ms^{-2}$

$v = at$

$= 2.5 \times \frac{981}{350}$

$= \frac{981}{140} \approx 7.01 ms^{-1}$

b) Considering disk B,

$M_B = Tr$

$= I_G \alpha_B$

$= \frac{1}{2} mr^2 \left(\frac{2a}{r}\right)$

$T\cancel{r} = \cancel{\frac{1}{2}} m\cancel{r}\cancel{^2} \left(\frac{\cancel{2}a}{\cancel{r}}\right)$

$T = ma$

$= 10\left(\frac{981}{350}\right)$

$= \frac{981}{35}$

$\approx 28.03 N$