

Modsim
Var 19

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1a)

$$C_r^i = \begin{bmatrix} \cos\theta \\ \sin\theta \\ 0 \end{bmatrix} \quad C_o^i = \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix} \quad C_z^i = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$C_r^i \cdot C_o^i = \cos\theta \sin\theta - \cos\theta \sin\theta = 0$$

$$C_r^i \cdot C_z^i = 0 + 0 + 0 = 0$$

$$C_o^i \cdot C_z^i = 0 + 0 + 0 = 0$$

$$C_z^i \times C_F^i = \begin{bmatrix} i & 0 & \cos\theta \\ j & 0 & \sin\theta \\ k & 1 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix} = C_o^i \rightarrow \text{right hand}$$

$$\begin{vmatrix} \cos\theta \\ \sin\theta \\ 0 \end{vmatrix} = \cos^2\theta + \sin^2\theta = 1$$

$$|C_o^i| = \cos^2\theta + \sin^2\theta = 1$$

$$(C_z^i)^2 = 1 = 1$$

$$1(a) \quad S_r^i = \begin{bmatrix} \sin\phi \cos\theta \\ \sin\phi \sin\theta \\ \cos\phi \end{bmatrix}$$

$$S_\theta^i = \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix}$$

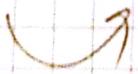
$$S_\phi^i = \begin{bmatrix} \cos\phi \cos\theta \\ \cos\phi \sin\theta \\ -\sin\phi \end{bmatrix}$$

$$S_r^i S_\theta^i = \sin\phi \cos\theta \sin\theta - \sin\phi \cos\theta \sin\theta \\ = \underline{\underline{0}}$$

$$S_\theta^i S_\phi^i = \cos\phi \cos\theta \sin\theta - \cos\phi \cos\theta \sin\theta \\ = \underline{\underline{0}}$$

$$S_r^i S_\phi^i = \sin\phi \cos\phi \cos^2\theta + \sin\phi \cos\phi \sin^2\theta \\ - \cos\phi \sin\phi = \underline{\underline{0}}$$

8)



1b)

$$\begin{aligned}\vec{c}_r &= \begin{bmatrix} -\dot{\theta} \cos \theta \\ -\dot{\theta} \sin \theta \\ 0 \end{bmatrix} \quad \vec{c}_i = \begin{bmatrix} 0 \\ 0 \\ r \end{bmatrix} \\ \vec{c}_\theta &= \begin{bmatrix} \dot{\theta} \cos \theta \\ -\dot{\theta} \sin \theta \\ 0 \end{bmatrix}\end{aligned}$$

$$\dot{v}_i^a = R_b^a \left[\dot{u}^b + (a^b_{ab})^T u^b \right]$$
$$R_i^c = R_c^i = [e_r^i, e_\theta^i, e_z^i]^T$$

$$\dot{v}_i^i = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

[

$$1b) \quad C_r^i = \begin{bmatrix} -\dot{\theta} \sin \theta \\ \dot{\theta} \cos \theta \\ 0 \end{bmatrix} \quad C_\theta^i = \begin{bmatrix} \dot{\theta} \cos \theta \\ \dot{\theta} \sin \theta \\ 0 \end{bmatrix}$$

$$\dot{C}_z^i = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$R^q \quad R_i^c = \begin{bmatrix} -\cos \theta & -\sin \theta & 0 \\ \sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R_i^c = \begin{bmatrix} -\dot{\theta} \sin \theta & -\dot{\theta} \cos \theta & 0 \\ \dot{\theta} \cos \theta & \dot{\theta} \sin \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$(\omega_i^c)^k = \dot{R}_i^c (\dot{r}_i^c)^T$$

$$= \begin{bmatrix} -\dot{\theta} \sin \theta & \dot{\theta} \cos \theta & 0 \\ \dot{\theta} \cos \theta & \dot{\theta} \sin \theta & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -\dot{\theta} \sin^2 \theta - \dot{\theta} \cos^2 \theta & 0 \\ \dot{\theta} & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \dot{\theta} \end{bmatrix}$$

$$1c) \quad \dot{\varsigma}_r^i = \begin{bmatrix} \dot{\phi} \cos\phi \cos\theta - \dot{\theta} \sin\phi \sin\theta \\ \dot{\phi} \cos\phi \sin\theta + \dot{\theta} \sin\phi \cos\theta \\ -\dot{\phi} \sin\phi \end{bmatrix}$$

$$\dot{\varsigma}_\phi^i = \begin{bmatrix} -\dot{\phi} \sin\phi \cos\theta - \dot{\theta} \cos\phi \sin\theta \\ -\dot{\phi} \sin\phi \sin\theta + \dot{\theta} \cos\phi \cos\theta \\ -\dot{\phi} \cos\phi \end{bmatrix}$$

$$\dot{\varsigma}_\theta^i = \begin{bmatrix} -\dot{\theta} \cos\theta \\ -\dot{\theta} \sin\theta \\ 0 \end{bmatrix}$$

$$R_i^C = \begin{bmatrix} \sin\phi \cos\theta & \cos\phi \cos\theta & -\sin\theta \\ \sin\phi \sin\theta & \cos\phi \sin\theta & \cos\theta \\ \cos\phi & -\sin\phi & 0 \end{bmatrix}$$

$$(R_i^C)^T = \begin{bmatrix} \sin\phi \cos\theta & \sin\phi \sin\theta & \cos\phi \\ \cos\phi \cos\theta & \cos\phi \sin\theta & -\sin\phi \\ -\sin\theta & \cos\theta & 0 \end{bmatrix}$$

$$\dot{R}_i^C = \begin{bmatrix} \dot{\phi} \cos\phi \cos\theta - \dot{\theta} \sin\phi \sin\theta & -\dot{\phi} \sin\phi \cos\theta - \dot{\theta} \cos\phi \sin\theta & -\dot{\theta} \cos\theta \\ \dot{\phi} \cos\phi \sin\theta + \dot{\theta} \sin\phi \cos\theta & -\dot{\phi} \sin\phi \sin\theta + \dot{\theta} \cos\phi \cos\theta & -\dot{\theta} \sin\theta \\ -\dot{\phi} \sin\phi & -\dot{\phi} \cos\phi & 0 \end{bmatrix}$$

↙

$$7b) \quad \text{Given } \vec{r} = \langle -\theta \sin \phi, \theta \cos \phi, \phi \rangle$$

$$\vec{s}_\theta^i \times \vec{s}_r^i = \begin{vmatrix} i & j & k \\ -\sin \phi & \cos \phi & 0 \\ \sin \theta \cos \phi & \sin \theta \sin \phi & \cos \theta \end{vmatrix}$$

$$= \begin{pmatrix} \cos \phi \cos \theta \\ \cos \phi \sin \theta \\ -\sin \phi \end{pmatrix} = \vec{s}_\phi^i$$

$\boxed{\sin^2(x) = 1 - \cos^2(x)}$

$$|\vec{s}_\phi^i| = \sqrt{\sin^2 \phi \cos^2 \theta + \sin^2 \phi \sin^2 \theta + \cos^2 \phi}$$

$$= \sqrt{\cos^2 \theta - \cos^2 \theta \cos^2 \phi + (1 - \sin^2 \phi)(1 - \cos^2 \theta) + \cos^2 \phi}$$

$$= \sqrt{\cos^2 \theta - \cos^2 \theta \cos^2 \phi + \underbrace{\sin^2 \phi + \cos^2 \phi}_{1} - \sin^2 \phi \cos^2 \theta}$$

$$= \sqrt{\cos^2 \theta (1 - \cos^2 \phi - \sin^2 \phi) + 1} = \underline{\underline{1}}$$

$$|\vec{s}_\phi^i| = \sqrt{\cos^2 \phi \cos^2 \theta + \cos^2 \phi \sin^2 \theta + \sin^2 \phi}$$

$$= \sqrt{\cos^2 \phi (\underbrace{\cos^2 \theta + \sin^2 \theta}_{1}) + \sin^2 \phi} = \underline{\underline{1}}$$

$$|\vec{s}_r^i| = \sqrt{1 + \sin^2 \theta + \cos^2 \theta} = \underline{\underline{1}}$$

$$1c) (\omega_{ic}^c)^x = \dot{R}_i^c (R_i^c)^T = \begin{bmatrix} 0 & -a & b \\ a & 0 & c \\ b & -c & 0 \end{bmatrix}$$

$$\begin{aligned} a &= (\dot{\phi} \cos \phi \sin \theta + \dot{\theta} \sin \phi \cos \theta)(\sin \phi \cos \theta) \\ &+ (-\dot{\phi} \sin \phi \sin \theta + \dot{\theta} \cos \phi \cos \theta)(\cos \phi \cos \theta) \\ &+ (-\dot{\theta} \sin \theta)(-\sin \theta) \\ &= \dot{\phi} \cos \phi \sin \phi \cos \theta \sin \theta + \dot{\theta} \sin^2 \phi \cos^2 \theta \\ &+ \dot{\phi} \cos \phi \sin \phi \cos \theta \sin \theta + \dot{\theta} \cos^2 \phi \cos^2 \theta \\ &+ \dot{\theta} \sin^2 \theta \end{aligned}$$

$$= \dot{\theta} \sin^2 \phi \cos^2 \theta + \dot{\theta} \cos^2 \phi \cos^2 \theta = \underline{\underline{\dot{\theta} \cos^2 \theta}}$$

$$b = -\dot{\phi} \sin^2 \phi \cos \theta - \dot{\phi} \cos^2 \phi \cos \theta = \underline{\underline{\dot{\phi} \cos \theta}}$$

$$c = -\dot{\phi} \sin^2 \phi \sin \theta - \dot{\phi} \cos^2 \phi \sin \theta = \underline{\underline{\dot{\phi} \sin \theta}}$$

$$\Rightarrow \omega_{ic}^c = \begin{bmatrix} \dot{\theta} \cos^2 \theta \\ \dot{\phi} \cos \theta \\ \dot{\phi} \sin \theta \end{bmatrix}$$

1d)

$$\vec{r}_m = r \vec{c}_r + z \vec{c}_z$$

$$\vec{v}_m = \dot{r} = \dot{r} \vec{c}_r + r \dot{\theta} \vec{c}_\theta + \dot{z} \vec{c}_z + z \dot{\phi} \vec{c}_\phi$$

$$= \dot{r} \begin{pmatrix} \cos \theta \\ \sin \theta \\ 0 \end{pmatrix} + r \underbrace{\begin{pmatrix} -\dot{\theta} \sin \theta \\ \dot{\theta} \cos \theta \\ 0 \end{pmatrix}}_{\dot{\theta} \vec{c}_\theta^i} + \begin{pmatrix} 0 \\ 0 \\ \dot{z} \end{pmatrix}$$

$$= \dot{r} \vec{c}_r + r \dot{\theta} \vec{c}_\theta^i + \dot{z} \vec{c}_z$$

$$\vec{a}_m = \ddot{r} =$$

$$\ddot{r} \vec{c}_r + \dot{r} \vec{c}_r + \dot{r} \dot{\theta} \vec{c}_\theta^i + r \ddot{\theta} \vec{c}_\theta^i + r \dot{\theta} \vec{c}_\theta^i + \ddot{z} \vec{c}_z + \dot{z} \vec{c}_z$$

$$= \ddot{r} \vec{c}_r + \dot{r} \vec{c}_r + \dot{r} \dot{\theta} \vec{c}_\theta^i + r \ddot{\theta} \vec{c}_\theta^i + r \dot{\theta} \vec{c}_\theta^i + r \dot{\theta} \underbrace{\begin{pmatrix} \dot{\theta} \cos \theta \\ \dot{\theta} \sin \theta \\ 0 \end{pmatrix}}_{\dot{\theta} \vec{c}_r^i} + \ddot{z} \vec{c}_z + 0$$

$$= \ddot{r} (\vec{r} + r \dot{\theta}^2) + \vec{c}_\theta (r \dot{\theta}^2 \dot{\theta} + r \ddot{\theta}) + \ddot{z} \vec{c}_z$$

$$1e) \quad \vec{r}_m = r \vec{s}_r$$

$$\vec{v}_m = \dot{\vec{r}} = \dot{r} \vec{s}_r + r \dot{\vec{s}}_r = \dot{r} \vec{s}_r + r \begin{cases} \dot{\phi} \cos \theta \cos \phi - \dot{\theta} \sin \phi \sin \theta \\ \dot{\phi} \cos \theta \sin \phi + \dot{\theta} \sin \phi \cos \theta \\ -\dot{\phi} \sin \theta \end{cases}$$

$$= \dot{r} \vec{s}_r + \dot{\phi} s_\theta^i + \dot{\theta} \sin \phi s_\theta^i \iff \dot{\phi} s_\phi^i + \dot{\theta} \sin \phi s_\theta^i$$

$$\vec{a}_m = \ddot{\vec{r}}_m = \ddot{r} \vec{s}_r + \dot{r} \vec{s}_r^i + \dot{\phi} \vec{s}_\theta^i + \dot{\theta} \vec{s}_\theta^i + \ddot{\theta} \sin \phi \vec{s}_\theta^i + \dot{\phi} \dot{\phi} \cos \theta \vec{s}_\theta^i + \dot{\theta} \dot{\phi} \sin \phi \vec{s}_\theta^i$$

$$= \ddot{r} \vec{s}_r + \dot{r} \vec{s}_r^i + \dot{\phi} s_\theta^i + \dot{\theta} \sin \phi s_\theta^i + \dot{\phi} \vec{s}_\theta^i + \dot{\theta} \begin{bmatrix} -\dot{\phi} \sin \theta \cos \theta - \dot{\theta} \cos \phi \sin \theta \\ -\dot{\phi} \sin \theta \sin \theta + \dot{\theta} \cos \phi \cos \theta \\ -\dot{\phi} \cos \theta \end{bmatrix} r$$

$$+ \dot{\theta} \sin \phi \vec{s}_\theta^i + \dot{\phi} \dot{\phi} \cos \phi \vec{s}_\theta^i + \dot{\theta} \dot{\sin} \phi \begin{bmatrix} -\dot{\phi} \cos \theta \\ -\dot{\theta} \sin \theta \\ 0 \end{bmatrix} \left[-\dot{\phi} \vec{s}_r^i + \dot{\theta} \cos \phi \vec{s}_\theta^i \right]$$

$$= \vec{s}_r^i (\ddot{r} + \dot{r} \dot{\phi} \dot{\phi} - r \sin^2 \phi \dot{\theta}^2) + \vec{s}_r^i (\dot{r} \dot{\phi} + \dot{\theta} \sin \phi \cos \phi \dot{\theta}^2)$$

$$+ \vec{s}_\theta^i (\ddot{r} \dot{\phi} + 2 \dot{r} \dot{\phi} - r \sin \phi \cos \phi \dot{\theta}^2)$$

$$+ \vec{s}_\theta^i (\ddot{\theta} \sin \phi + \dot{\theta} \cdot 2 \dot{\phi} \sin \phi + 2 \dot{r} \dot{\phi} \cos \phi) \vec{s}_\theta^i$$

$$\text{F) } \sum F = m\vec{a} = \vec{N} - \vec{G}$$

$$\Rightarrow \vec{N} = m\vec{a} + \vec{G}$$

$$= m \left((r\ddot{\phi}^2 - r\dot{\phi}^2\dot{\theta}^2 - r\sin^2\phi\dot{\theta}^2)\hat{s}_r + (\dot{\phi}\dot{\theta} + 2r\dot{\phi} + r\sin\phi\cos\phi\dot{\theta}^2)\hat{s}_\phi + (r\sin\phi\dot{\theta} + 2r\sin\phi\dot{\theta} + 2r\dot{\phi}\cos\phi\dot{\theta})\hat{s}_\theta - g e_3 \right)$$

$$19) E_k = \frac{1}{2}mv^2 = \frac{1}{2}m(r\dot{s}_r + r\dot{\phi}\dot{s}_\phi + r\sin\theta\dot{s}_\theta)$$

$$E_p = mgh = mg r \dot{s}_r$$

$$L = E_k - E_p = m((gr + i)\dot{s}_r + r\dot{\phi}\dot{s}_\phi + r\sin\theta\dot{s}_\theta)$$

$$= m \left((gr + i) \begin{bmatrix} \sin\theta\cos\phi \\ \sin\theta\sin\phi \\ \cos\theta \end{bmatrix} + \dot{\phi} \begin{bmatrix} \dot{r}\cos\theta\cos\phi \\ \dot{r}\cos\theta\sin\phi \\ -\dot{r}\sin\theta \end{bmatrix} + r \begin{bmatrix} -\theta\sin^2\phi \\ \theta\sin\theta\cos\phi \\ 0 \end{bmatrix} \right)$$

$$\frac{\partial L}{\partial r} = (\dot{g}\dot{s}_r + \dot{\phi}\dot{s}_\phi + \sin\theta\dot{\theta}\dot{s}_\theta)m$$

$$\cancel{\frac{\partial L}{\partial \phi}} = (gr + i) \begin{bmatrix} \cos\phi\cos\theta \\ \cos\phi\sin\theta \\ -\sin\phi \end{bmatrix} + r \begin{bmatrix} (\dot{\phi}\cos\theta - \dot{\phi}\sin\theta)\cos\theta \\ (\dot{\phi}\cos\theta - \dot{\phi}\sin\theta)\sin\theta \\ -(\dot{\phi}\sin\theta + \dot{\phi}\cos\theta) \end{bmatrix}$$

$$+ r \begin{bmatrix} -\theta\sin\theta\cos\phi \\ \theta\cos\theta\cos\phi \\ 0 \end{bmatrix} \cancel{\dot{\phi}s_\phi^i - \dot{\phi}s_r^i}$$

$$\theta\cos\theta s_\theta^i$$

$$= m((gr + i + \dot{\phi})s_\phi^i + r\theta\cos\theta s_\theta^i - \dot{\phi}s_r^i)$$

1 \rightarrow 1J)

$$\frac{\partial L}{\partial \theta} = m((gr + r) \begin{bmatrix} -\sin\phi \sin\theta \\ \sin\phi \cos\theta \\ 0 \end{bmatrix} - r\dot{\phi} \begin{bmatrix} -\cos\phi \sin\theta \\ \cos\phi \cos\theta \\ 0 \end{bmatrix} + r \begin{bmatrix} -\sin^2\phi \cos\theta \\ \sin\phi \cos\theta - \theta \sin\phi \sin\theta \\ 0 \end{bmatrix})$$

$$\frac{\partial L}{\partial \phi} = m ((gr + r) \begin{bmatrix} \cos\phi \cos\theta \\ \cos\phi \sin\theta \\ -\sin\phi \end{bmatrix} + r\dot{\phi} \begin{bmatrix} -\sin\phi \cos\theta \\ -\sin\phi \sin\theta \\ -\cos\theta \end{bmatrix} + r\theta \begin{bmatrix} 2\sin\phi \cos\phi \\ \theta \cos\phi \cos\theta \\ 0 \end{bmatrix})$$

$$\frac{\partial L}{\partial r} = \underline{m\ddot{r}}$$

$$\frac{\partial L}{\partial \dot{\phi}} = \underline{r\ddot{\phi}}$$

$$\frac{\partial L}{\partial \theta} = 0$$



1. \rightarrow $l g) \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{r}} \right)$ ~~min~~ \nwarrow R constant

$$\tau_r = \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{r}} \right) - \frac{\partial L}{\partial r} = m \ddot{s}_r -$$

$$m (\ddot{s}_r \cos \phi + \dot{s}_\theta \sin \phi \cos \theta) \rightarrow$$

$$= m ((g+1) \ddot{s}_r + \dot{\phi} \ddot{s}_\theta + \theta \sin \phi \ddot{s}_\theta)$$

$$\tau_\phi = \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{\phi}} \right) - \frac{\partial L}{\partial \phi} = r \ddot{s}_\phi$$

$$= m ((g+r\dot{\theta}) \ddot{s}_\phi - r \dot{\phi} \begin{bmatrix} \sin \phi \cos \theta \\ \sin \phi \sin \theta \\ -\cos \phi \end{bmatrix})$$

$$+ r \dot{\theta} \begin{bmatrix} \ddot{s}_\phi \sin \phi \cos \theta \\ \ddot{s}_\phi \cos \phi \cos \theta \\ 0 \end{bmatrix}$$

$$\tau_\theta = \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{\theta}} \right) - \frac{\partial L}{\partial \theta} = \frac{\partial L}{\partial \theta}$$

Altereie
skrive denne.

$$7h) \quad (7a) = x = R \sin \phi \cos \theta$$

$$(8a) = X = \frac{R}{\sqrt{1+a^2 \theta^2}} \cos \theta$$

$$\Rightarrow \sin \phi = \frac{1}{\sqrt{1+a^2 \theta^2}} \quad (*)$$

$$(7c) = z = R \cos \phi$$

$$(8c) = z = \frac{R a \theta}{\sqrt{1+a^2 \theta^2}}$$

$$\Rightarrow \cos \phi = \frac{a \theta}{\sqrt{1+a^2 \theta^2}}$$

$$\Rightarrow \sqrt{1+a^2 \theta^2} = \frac{a \theta}{\cos \phi}$$

$$\Rightarrow (*) = \sin \phi = \frac{\cos \phi}{a \theta}$$

$$\Rightarrow a \theta = \tan^{-1}(a \theta)$$

$$7(i) \quad (6b) = \vec{V}_m = \dot{r} \vec{z} + r \dot{\phi} \vec{s}_\phi + r \sin \phi \dot{\theta} \vec{s}_\theta$$

$$r=R \Rightarrow \dot{r}=0$$

$$\Rightarrow \vec{V}_m = r \dot{\phi} \vec{s}_\phi + \sin \phi \dot{\theta} \vec{s}_\theta$$

$$\tan \phi = \tan^{-1}(a\theta) \Rightarrow s_\phi^i = \begin{bmatrix} \cos(\tan^{-1}(a\theta)) \cos \theta \\ \cos(\tan^{-1}(a\theta)) \sin \theta \\ -\sin(\tan^{-1}(a\theta)) \end{bmatrix}$$

$$s_\theta^i = \begin{bmatrix} -\sin \theta \\ \cos \theta \\ 0 \end{bmatrix}$$

$$E_k = \frac{1}{2} m v^2$$

$$\vec{V}_m^2 = r^2 \dot{\phi}^2 \vec{s}_\phi^2 + 2r \dot{\phi} \sin \phi \dot{\theta} \vec{s}_\phi \vec{s}_\theta + \sin^2 \phi \dot{\theta}^2 \vec{s}_\theta^2$$

$$E_k (6a) \cancel{= r^2} = \vec{r} \vec{s}_r = r \begin{bmatrix} \sin(\tan^{-1}(a\theta)) \cos \theta \\ \sin(\tan^{-1}(a\theta)) \sin \theta \\ -\cos(\tan^{-1}(a\theta)) \end{bmatrix}$$

$$E_p = mg \vec{r}_m$$

✓

$$\begin{aligned}
 1i) L = E_k - E_p &= r^2 \dot{\phi} \begin{bmatrix} \cos^2(\tan^{-1}(a\theta)) \cos^2\theta \\ \cos^2(\tan^{-1}(a\theta)) \sin^2\theta \\ -\sin^2(\tan^{-1}(a\theta)) \end{bmatrix} \\
 &+ 2r\dot{\phi}\sin\theta \begin{bmatrix} \cos(\tan^{-1}(a\theta)) \cos\theta \\ \cos(\tan^{-1}(a\theta)) \sin\theta \\ -\sin(\tan^{-1}(a\theta)) \end{bmatrix} \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix}^T \\
 &+ \sin^2\theta \dot{\phi}^2 \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix}
 \end{aligned}$$

this is
impossible, right? Wrong
dimensions.

1i) not finished

1j) not done

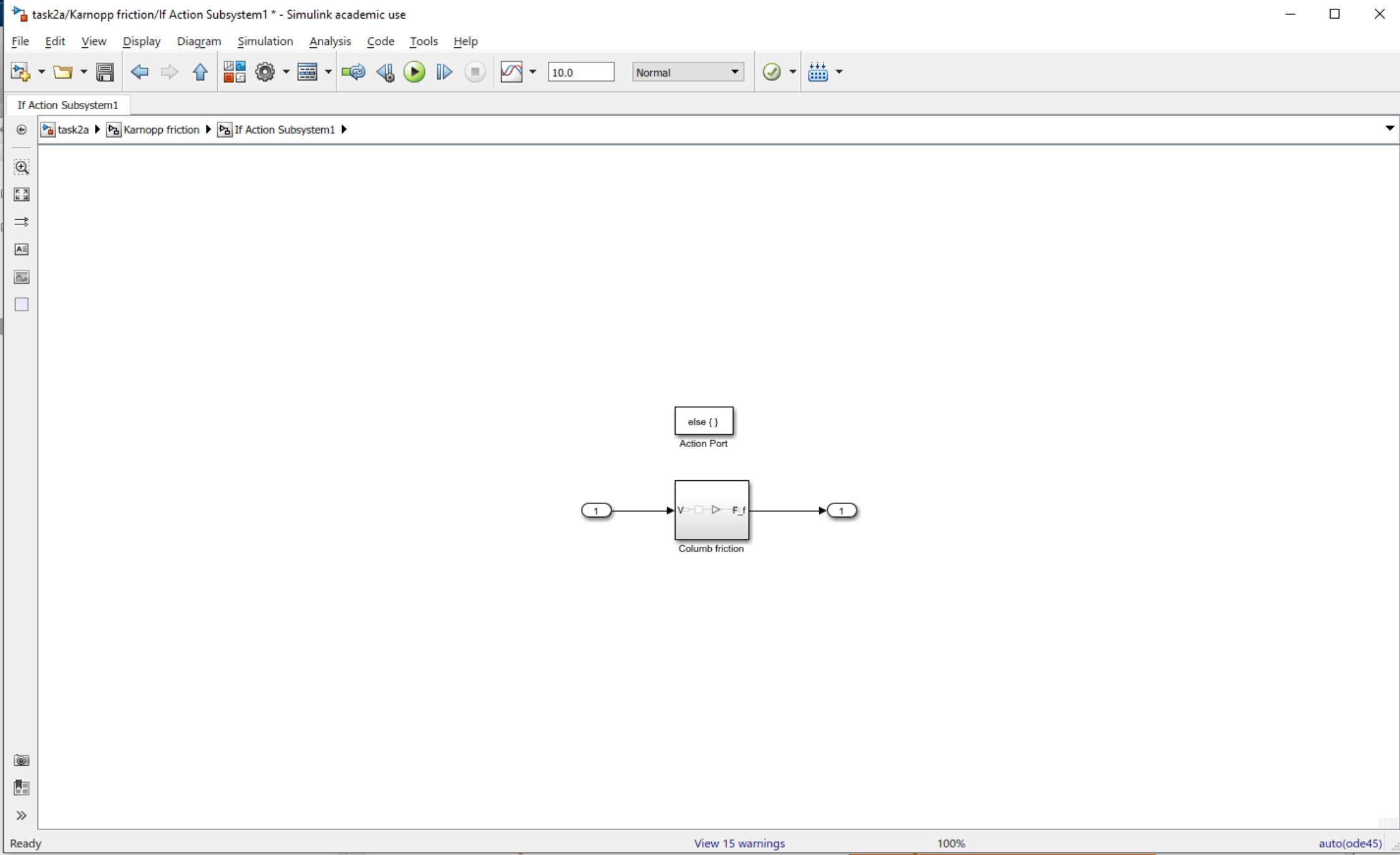
- 2 a) Variable time-step gives
zero-crossing detection stop.
Too many zero crossings.
- Fixed step works, we
can see that the friction
force zero crosses at the
start, but the detection
doesn't stop it. Cannot
burn off zero-crossing selection
when fixed step, so matlab
probably fixes our problem.
After ~1 second, the
force is normal, so
the block is moving, giving
an anded handle friction.
Probably wrong simulation,
but fixed-step doesn't
know that.

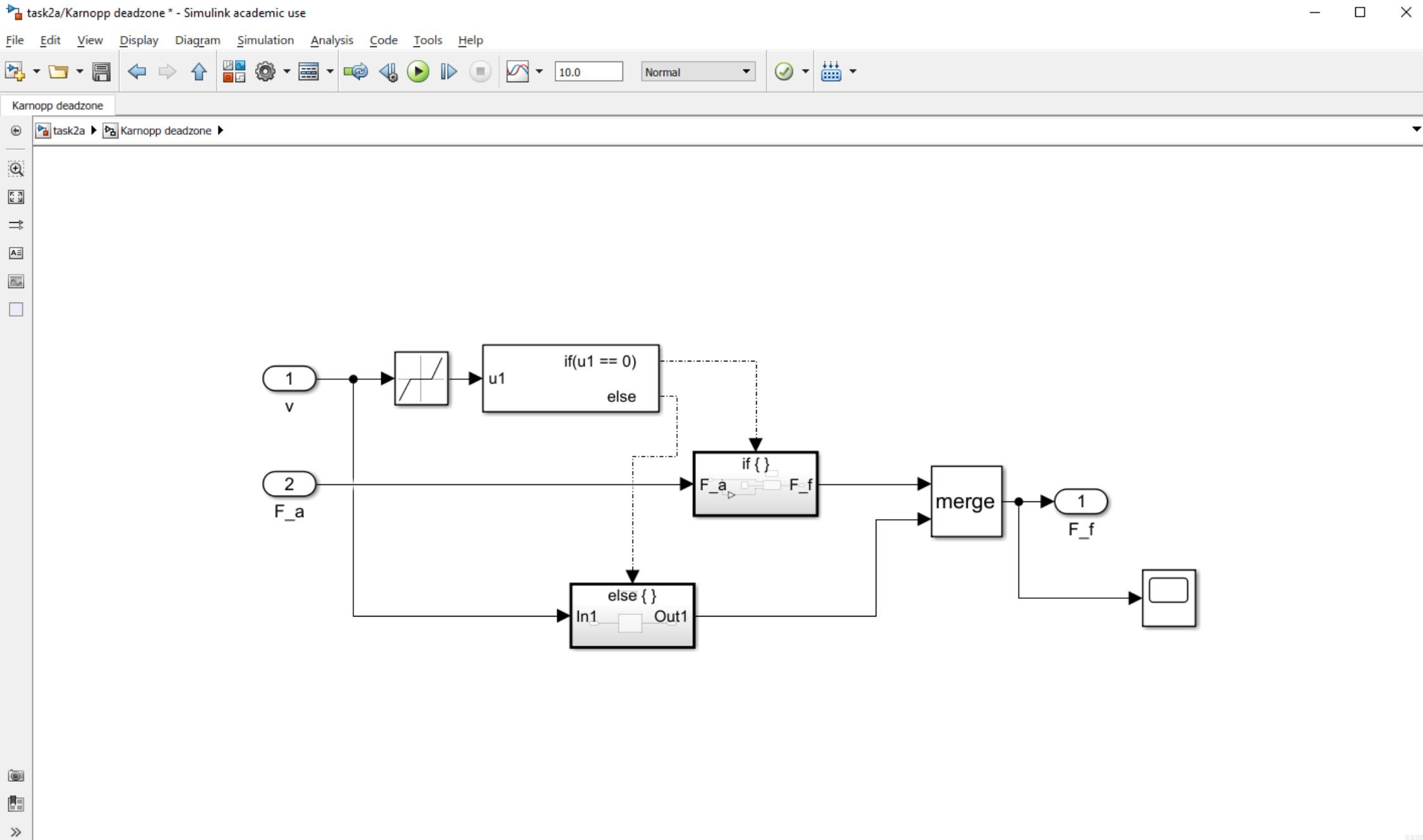
2b) When using Karnopp's, we first get friction when the force pushes harder than the friction would have time.

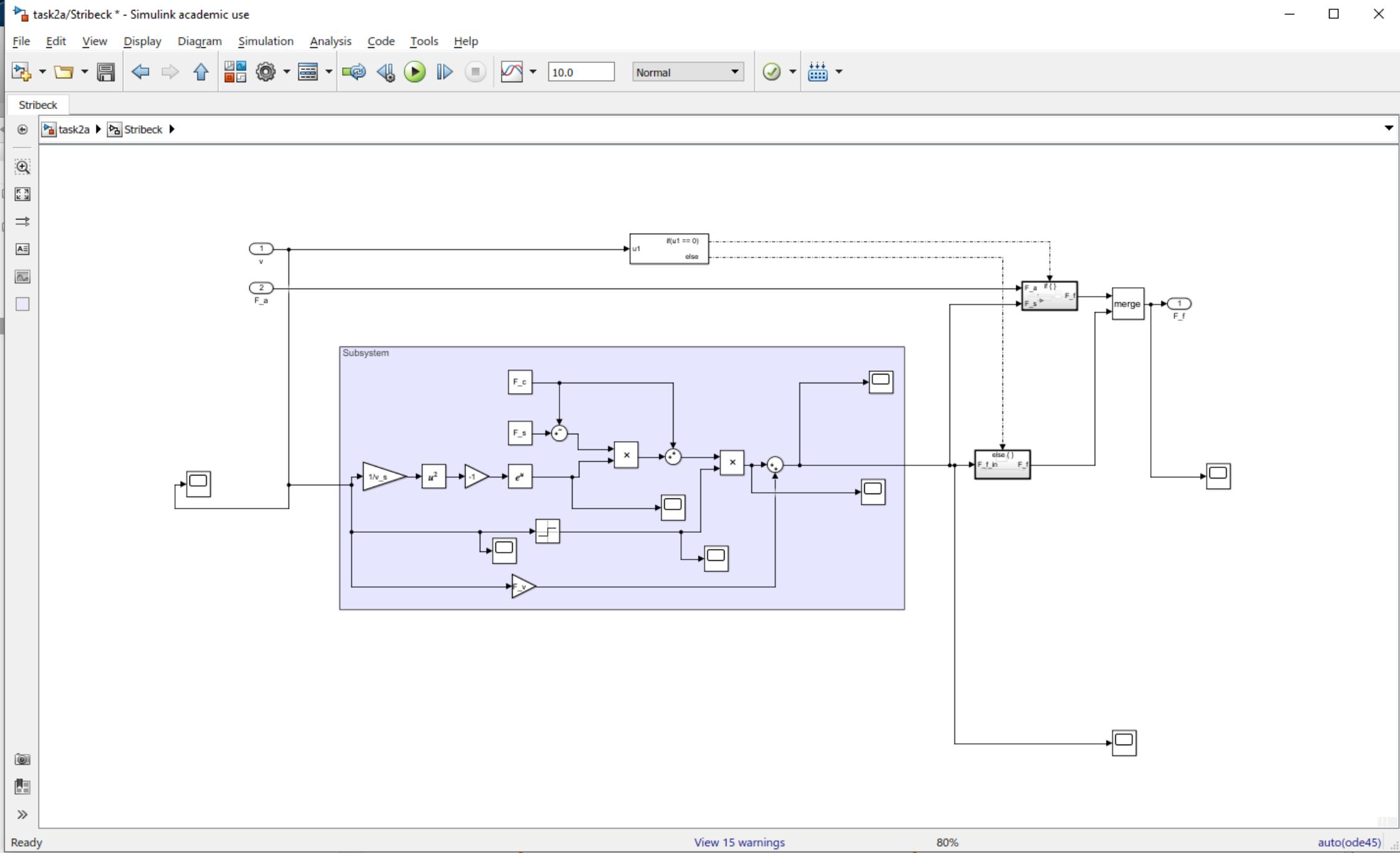
This is more correct than in 2a).

If/else changes when simulink detects event $u^1 = 0$, change friction mode!

2c) A deadzone works as in 2b), ~~or~~ cause you say there is no forces acting on the block when too little force tries to. But this doesn't work if we ~~start~~ in the ~~wrong~~ direct cross over the deadzone. Then we will glide on the deadzone, VTHD could be fixed by setting a small enough deadzone.









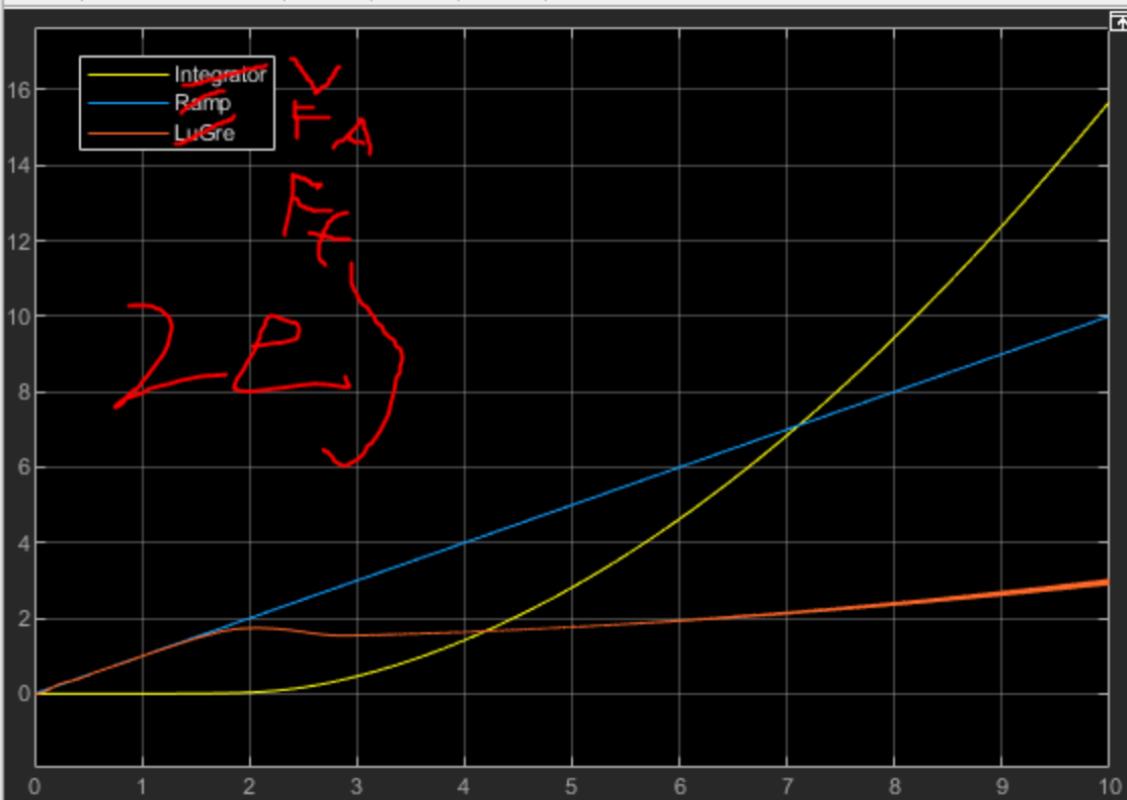
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2d) I did not manage to plot this. But it should output a graph of friction that goes slightly down when the velocity starts, and then starts to grow with the speed. This is the viscocity.|

Scope



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Ready

Sample based T=10.000



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2e) We see that the Lugre model is smoother than previous graphs.
This makes sense, as the speed modelled by an differential equation.

