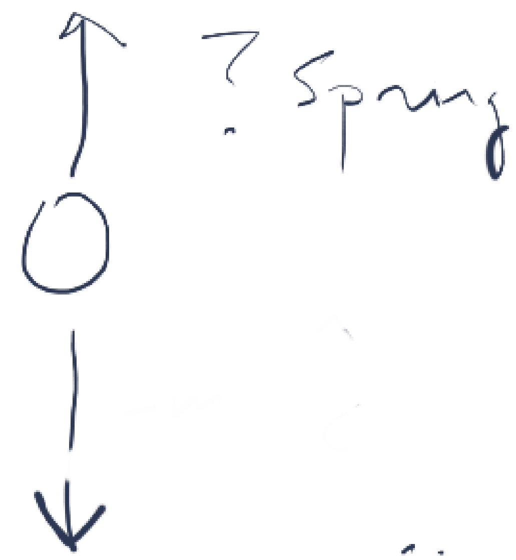
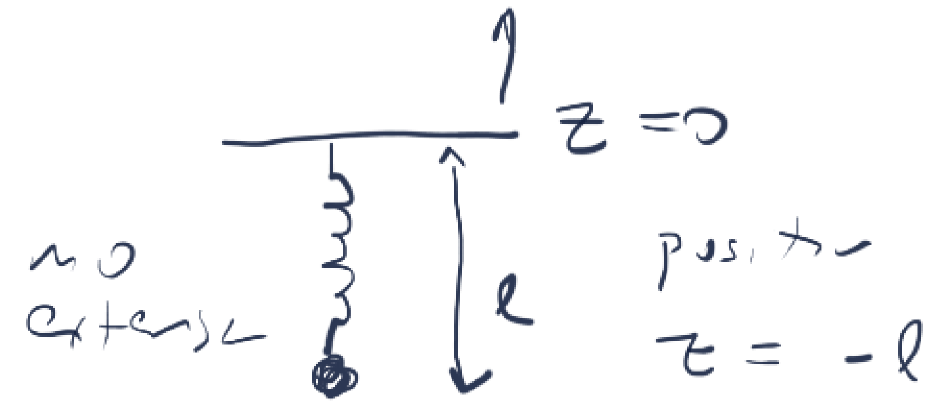
position = $\boxed{-(\ell + x(t))\hat{z} \equiv z(t)\hat{z}}$

compression/extension

position $-\ell$

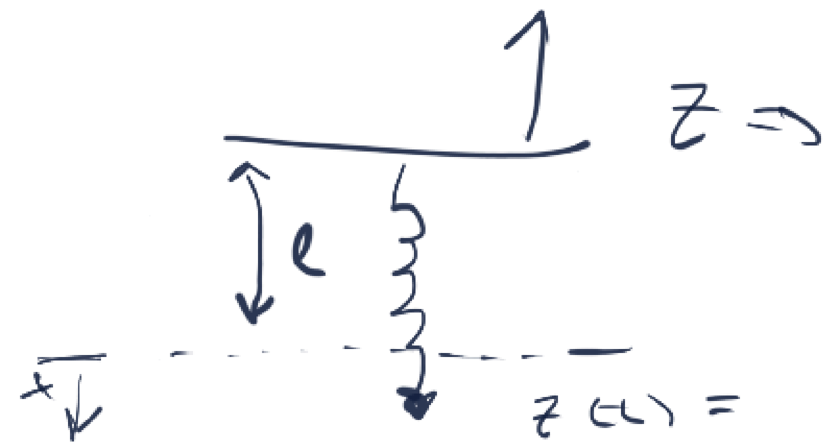


$$\boxed{\vec{F} = m\vec{a}}$$



$m\ddot{z}$ = net force

$= -mg + \gamma x$



extension is: $x(t)$

$-(\ell + x(t))$

$x(t) > 0$

$\gamma x(t)\hat{z}$

$z(t) = -(\ell + x(t))$

$\dot{z} = -\dot{x}(t)$

$\ddot{z} = -\ddot{x}(t)$

$$\boxed{-m\ddot{x} = \gamma x - mg} =$$

Retain $z(t) =$ thing defined on previous page

$$r(t) = \underbrace{ut\hat{z} + z(t)\hat{z}}_{\text{measured in space}}$$

as on previous page
measured from top of spring

$$\dot{r} = u\hat{z} + \dot{z}\hat{z}$$

$$\ddot{r} = \ddot{z}\hat{z}$$ so $\vec{F} = m\ddot{\vec{r}}$ unchanged

---

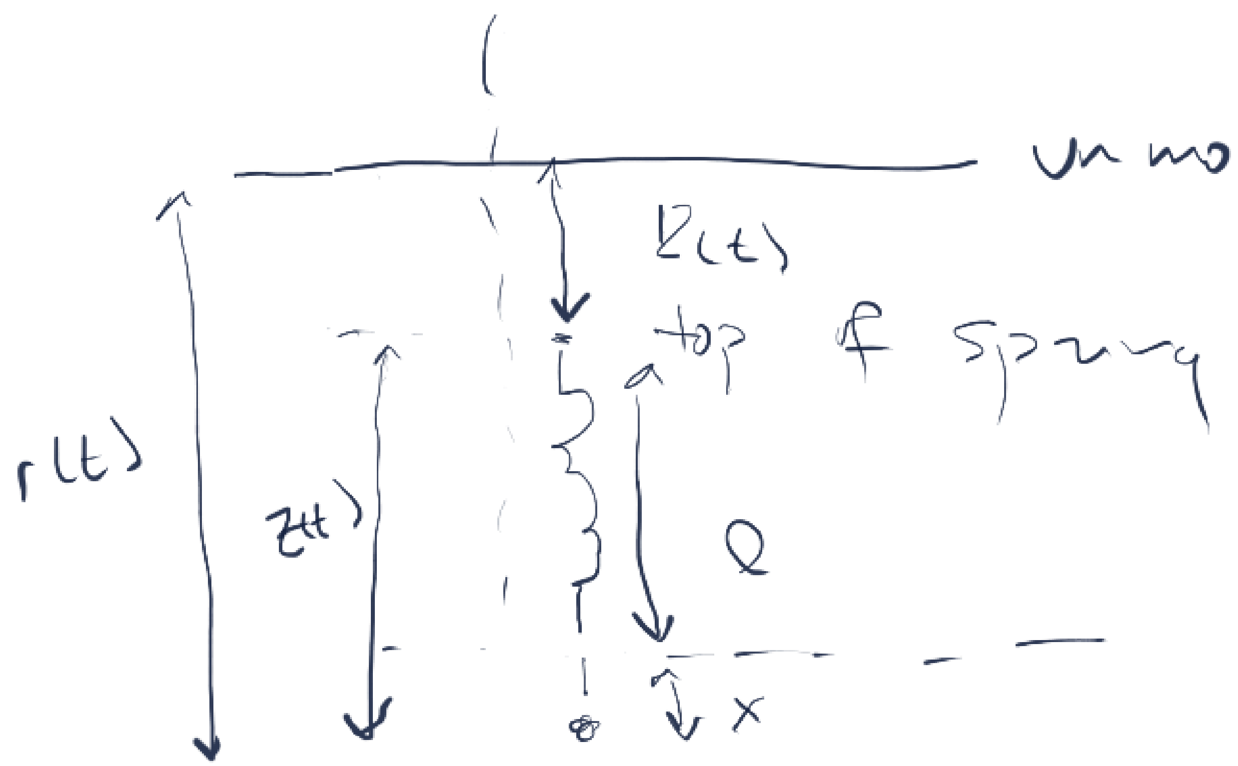
Finally let $R(t) = \cos(\omega t)\hat{z}$

$$r(t) = R(t)\hat{z} + z(t)\hat{z}$$

$$\ddot{r} = (\underbrace{-\omega^2\cos(\omega t)}_{\text{behaves like a modulation of gravity}} + \ddot{z})\hat{z}$$

(iii) (iv) (v)

unmoving origin $\vec{F} = m\vec{a}$ applies here



$z(t) = -(l + x(t))$

$\vec{r}(t) = R(t)\hat{i} + z(t)\hat{k}$

Newton's Law $\quad m\ddot{\underline{r}} = \underline{F}$