### Walking & Running in Bipedal Robots: Control Theory and Experiments

#### EECS Department University of Michigan



### Jessy W. Grizzle



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## Acknowledgements



Gabriel Abba (Metz, France)

ROBEA

(French National Project)



Franck Plestan (Nantes, France)



Christine Chevallereau (Nantes, France)



Carlos Canudas-de-Wit (Grenoble, France)



Gabriel Buche (Grenoble, France)



Yannick Aoustin (Nantes, France)

## Acknowledgements



ROBEA

(A French National Project)



Christine Chevallereau (Nantes, France)

Carlos Canudas-de-Wit (Grenoble, France)

- Robotique et Entités Artificielles (1997)
- Links seven laboratories in France
- I was welcomed in Fall 1998 during a sabbatical in Strasbourg

## Two Further Introductions...



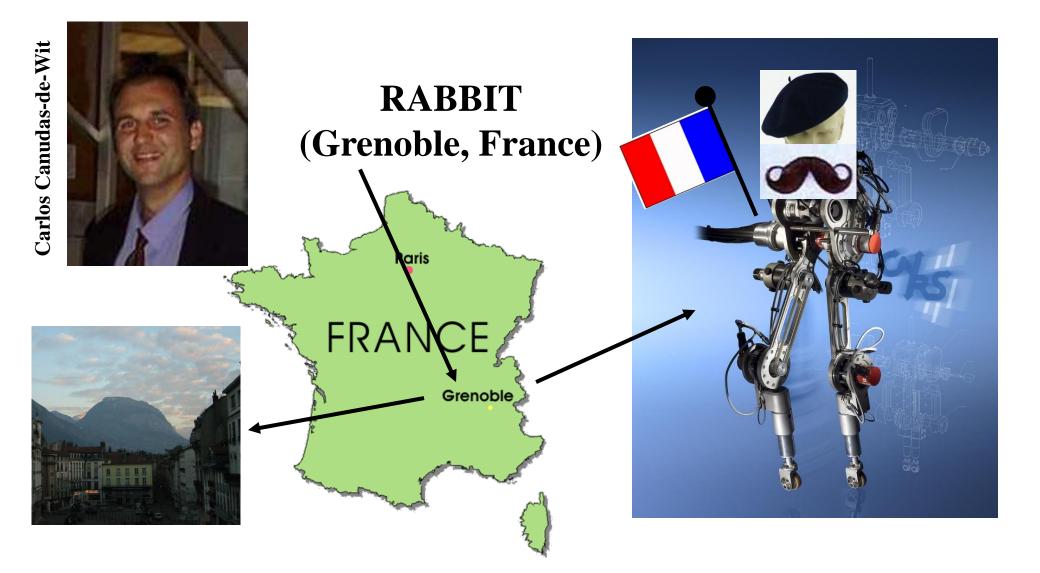
#### **RABBIT** (Grenoble, France)

Eric Westervelt (Ohio State Univ.) (Asst. Professor)



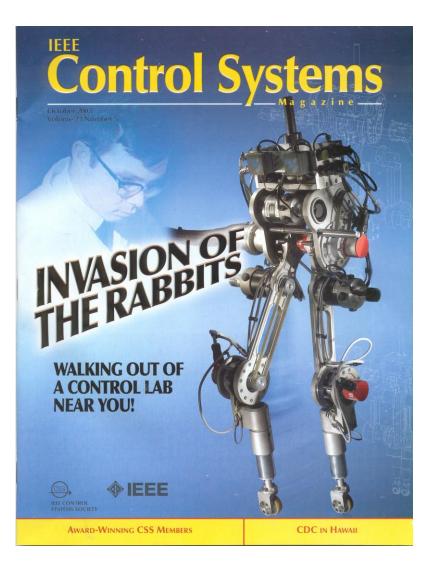


#### Two Further Introductions...



## October 2003 Issue

- CSM paper is very conceptual
- Full details are in various
   IEEE-TAC & IJRR papers
- See my web site for listing of papers and many more videos (type ' grizzle' into Google)



## Outline

- Bipedal background
  - Why study mechanical bipedal walking?
  - What is known about stable gaits?
  - How to model a bipedal walking robot?
- A new look at feedback control for bipeds
  - Finding and exploiting problem structure
  - The key is a two dimensional (hybrid) dynamic
  - Feedback design with the Hybrid Zero Dynamics
- Experiments on RABBIT
  - Walking and running
- Conclusions

## Why biped walking? (robotics)

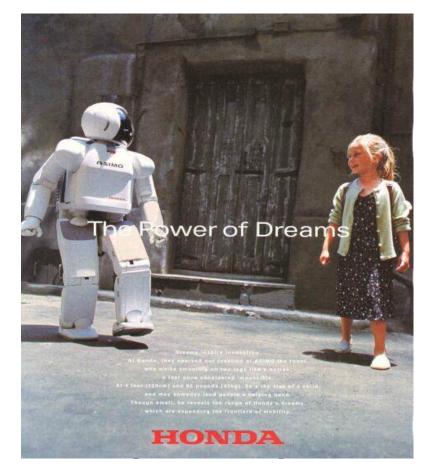
Increased mobility...







The fascination of anthropomorphic robots...



## Why biped walking? (people)

#### Prosthetics: Leg Design



#### [Ottobock C-Leg]

## Rehabilitation of WalkingStrokesSpinal Injury (Weight suspended treadmill therapy)



**AutoAmbulator** 



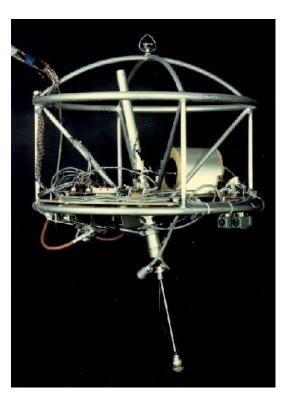
Lokomat (Morari et al.)

#### Why biped walking? (control) Intellectual Way Cool Curiosity AHAJOKES.COM **Mathematics** Awesome Experiments Low-Hanging Fruit

#### Two Approaches to Locomotion and Control

- Analytical Methods
  - rigorous model-based analysis
  - success with very little tweaking
  - experimentation is used to test theory
- Heuristic Methods
  - based on intuition
  - trial and error many trials before success
  - uncertainty as to why success or failure was the outcome
  - usually produces awkward motions--slow, crouching gaits

- One-legged Hopper
  - Koditschek & Beuhler 1991
  - Francois & Samson 1998



Raibert (1984)

- One-legged Hopper
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Raibert (1984)

- One-legged Hopper
- Passive Robots
  - McGeer 1990
  - Espiau & Goswani 1994
  - Ruina et al. 1997-2004
  - Howell & Baillieul 1998
  - Kuo et al. 1999-2004

Gravity Powered Walking Down a Gentle Slope...The Ultimate in Efficiency!



#### Collins and Ruina (2000)

- One-legged Hopper
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Gravity Powered Walking Down a Gentle Slope...The Ultimate in Efficiency!

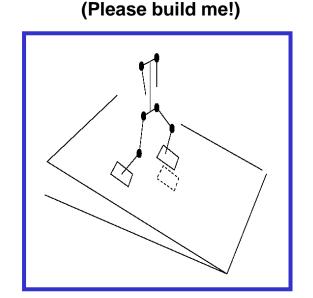
#### Collins and Ruina (2000)





- One-legged Hopper
- Passive Robots
- Lifting Passive Gaits to Fully-Actuated Bipeds
  - Spong 1997
  - Spong & Bullo 2002

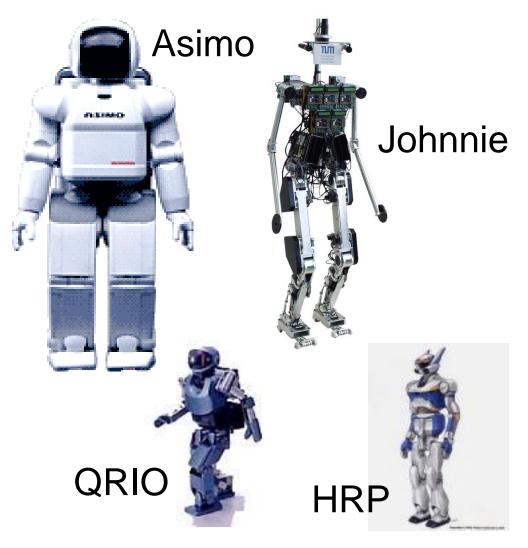
Powered walking on flat and sloped surfaces!



Spong & Bullo (2002)

## Most Powered Biped Robots use <u>Heuristics</u> for Controller Design

- ZMP (Zero Moment Point)
  - Asimo [Honda '96 →],
     \$150,000,000 [dev. cost] and
     \$1,000,000 per robot
  - QRIO [Sony, 2001]
- Intuition
  - Spring Flamingo
     [MIT Leg Lab '96-'00]
- Other Approx. Notions
  - Many

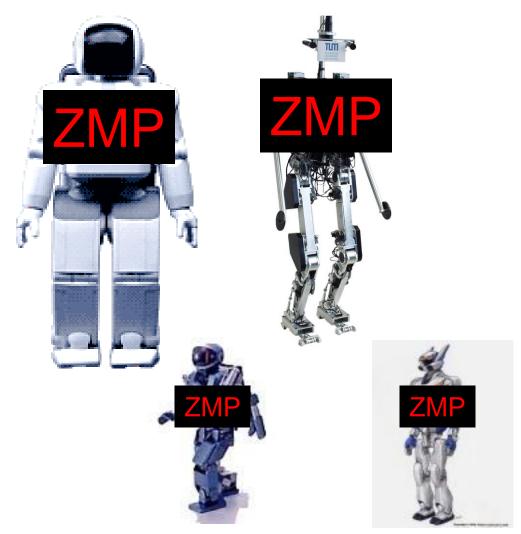


## Most Powered Biped Robots use <u>Heuristics</u> for Controller Design

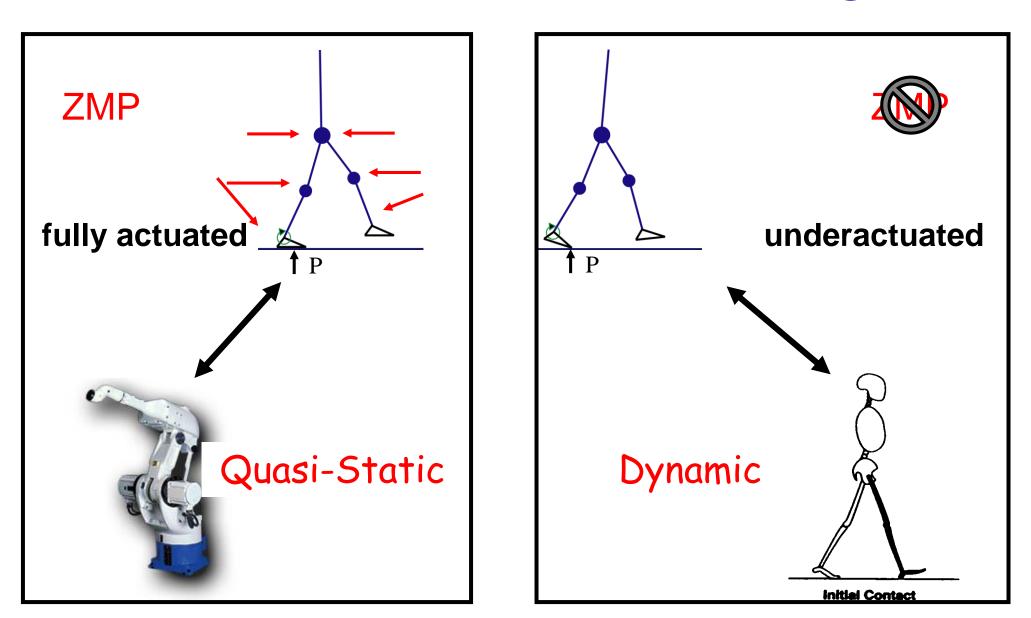
• ZMP (Zero Moment Point)

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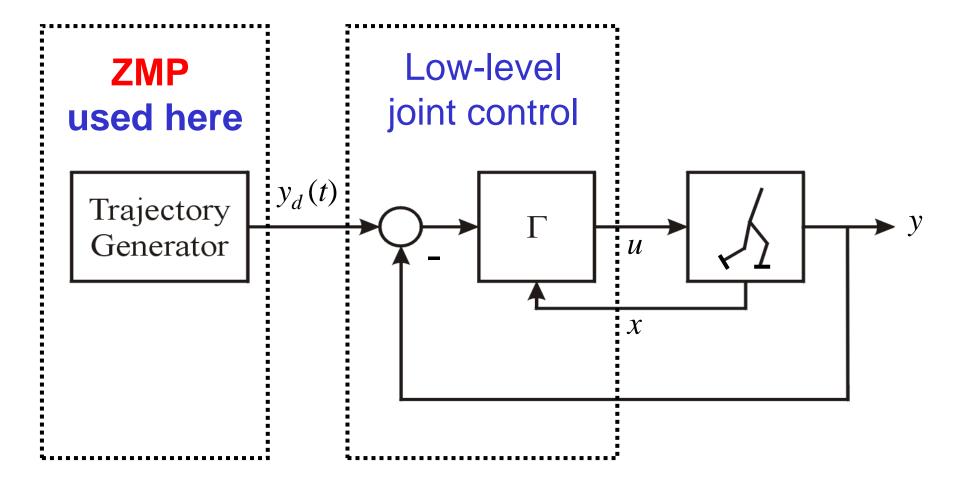
- QRIO [Sony, 2001]
- Intuition
  - Spring Flamingo
     [MIT Leg Lab '96-'00]
- Other Approx. Notions
  - Many



#### ZMP = Flat-Footed Walking



## Prevailing Control Approach is ZMP-Based Trajectory Tracking



#### Prevailing Approach Fights Natural Dynamics of Walking

- Heuristic Methods
  - based on intuition
  - trial and error many trials before success
  - uncertainty as to why success or failure was the outcome
  - usually produces awkward motions--slow, crouching gaits

Walking

**Running!** 





**Qrio-Sony** 

#### Prevailing Approach Fights Natural Dynamics of Walking



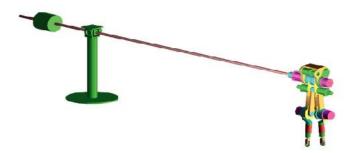
#### **RABBIT** obliges you to EXPLOIT dynamics of walking.

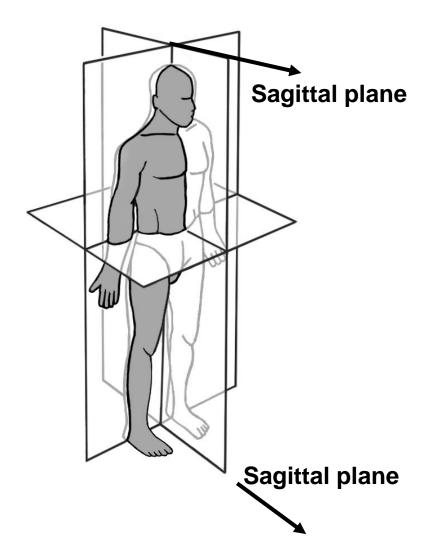
• Two legs, knees, a torso



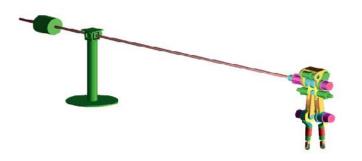


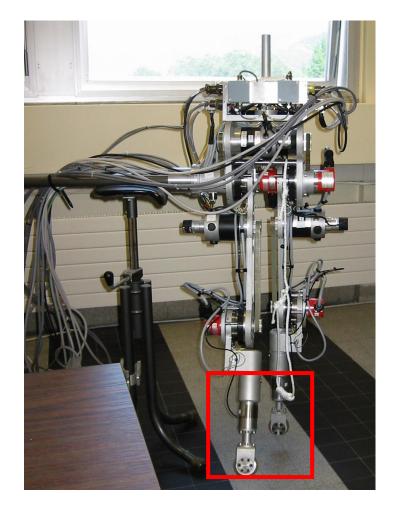
- Two legs, knees, a torso
- Sagittal plane dynamics
- Side-to-side stability assured by a bar





- Two legs, knees, a torso
- Sagittal plane dynamics
- Side-to-side stability
   assured by a bar
- Point feet = <u>No ZMP</u> = Need new control theory!





- Two legs, knees, a torso
- Sagittal plane dynamics
- Side-to-side stability assured by a bar
- Point feet = <u>No ZMP!</u>



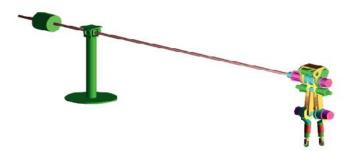
#### **Typical Gait**



LAG: Laboratoire Automatique de Grenoble

Question everyone asks:

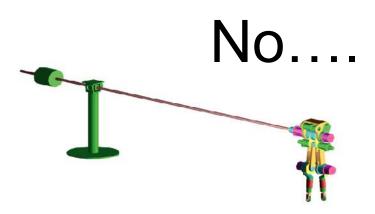
# Does the bar hold up the robot?



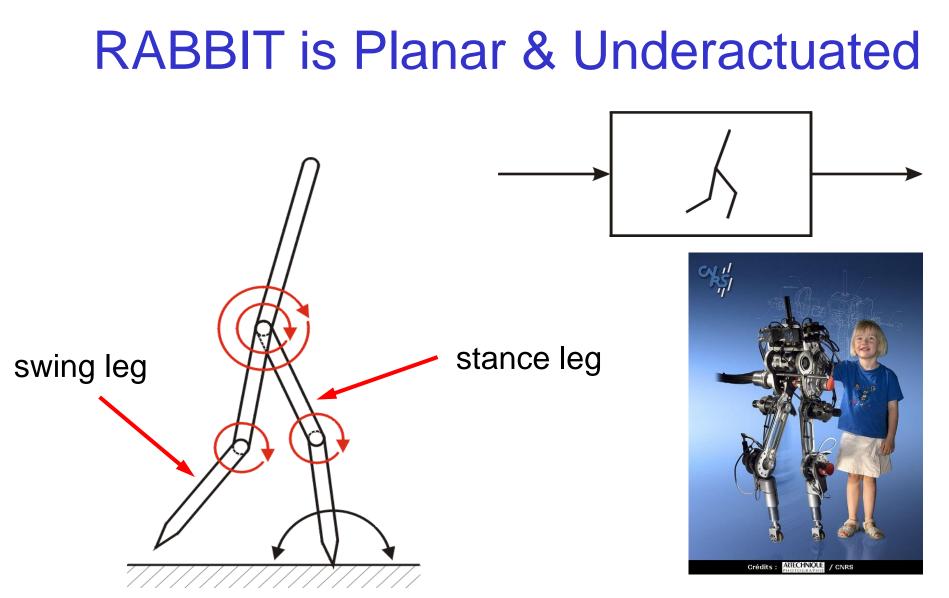


Question everyone asks:

Does the bar hold up the robot?

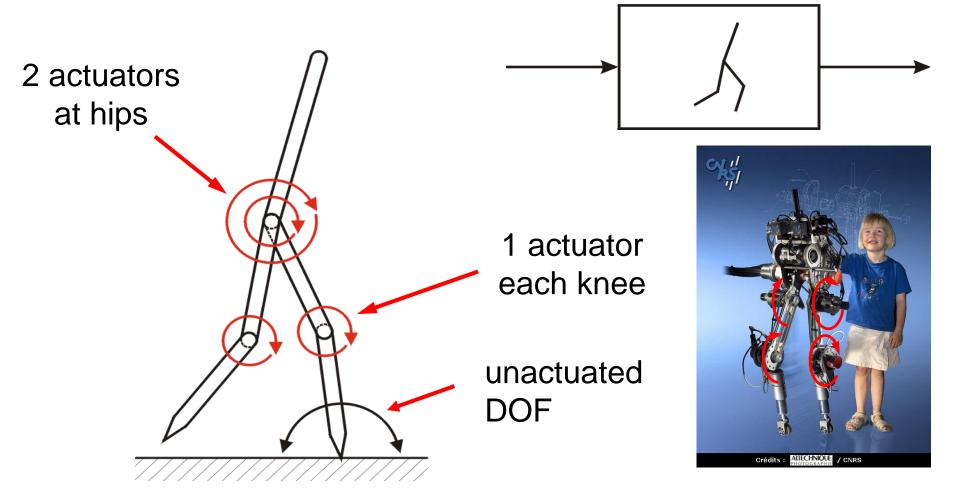






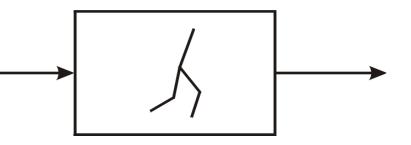
32 kg mass and 1.425 m tall

## **RABBIT is Planar & Underactuated**



32 kg mass and 1.425 m tall

Normal walking:



.... SS, DS, SS, DS, ...

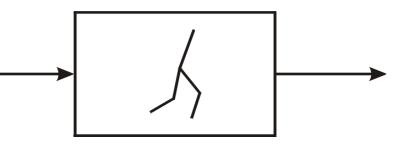
SS — Single Support

DS — Double Support





Normal walking:

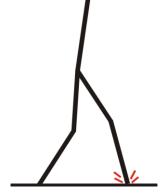


... SS, DS, SS, DS, ...

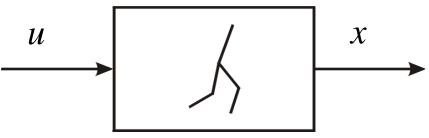
SS — Single Support DS -

DS — Double Support

 $D(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(q) = Bu$ 



Normal walking:



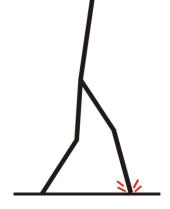
.... SS, DS, SS, DS, ...

SS — Single Support D

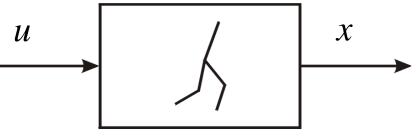
DS — Double Support

$$\dot{x} = f(x) + g(x)u$$

$$x = \begin{bmatrix} q \\ \dot{q} \end{bmatrix}$$



Normal walking:

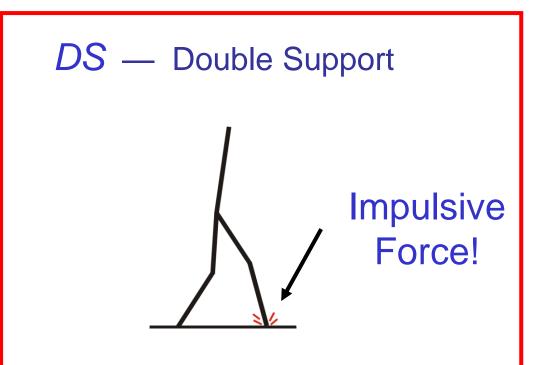


.... SS, DS, SS, DS, ...

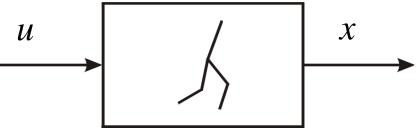
SS — Single Support

 $\dot{x} = f(x) + q(x)u$ 

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Normal walking:

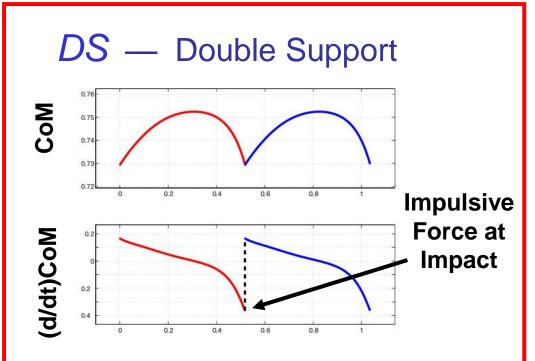


... SS, DS, SS, DS, ...

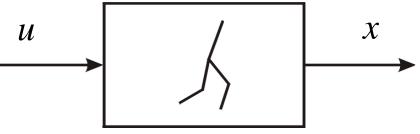
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Normal walking:



.... SS, DS, SS, DS, ...

SS — Single Support

DS — Double Support

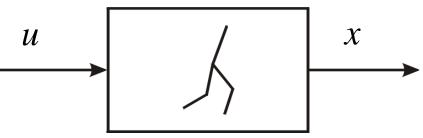
 $x^+ = \Delta(x^-)$ 

 $\dot{x} = f(x) + g(x)u$ 

$$x = \begin{bmatrix} q \\ \dot{q} \end{bmatrix}$$

### Robot Model: SS + DS = Hybrid

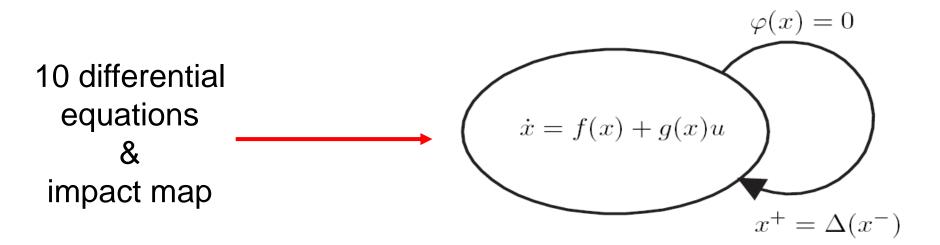
Normal walking:



.... SS, DS, SS, DS, ...

SS — Single Support

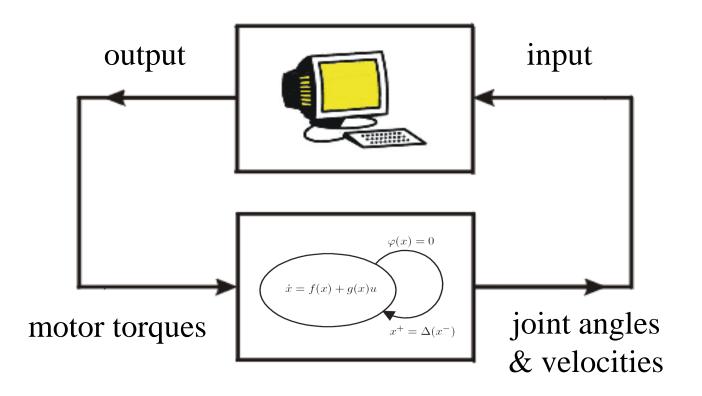
DS — Double Support

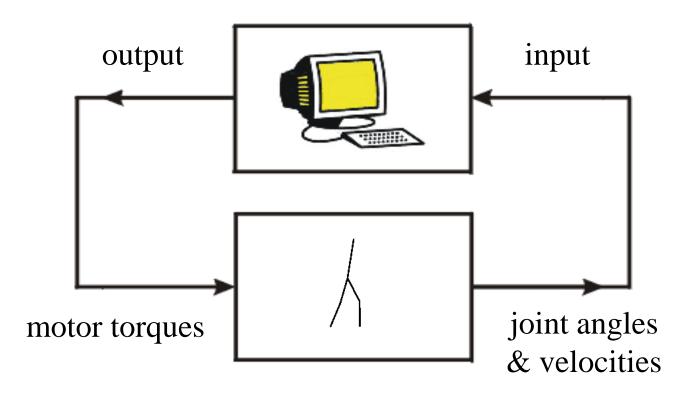


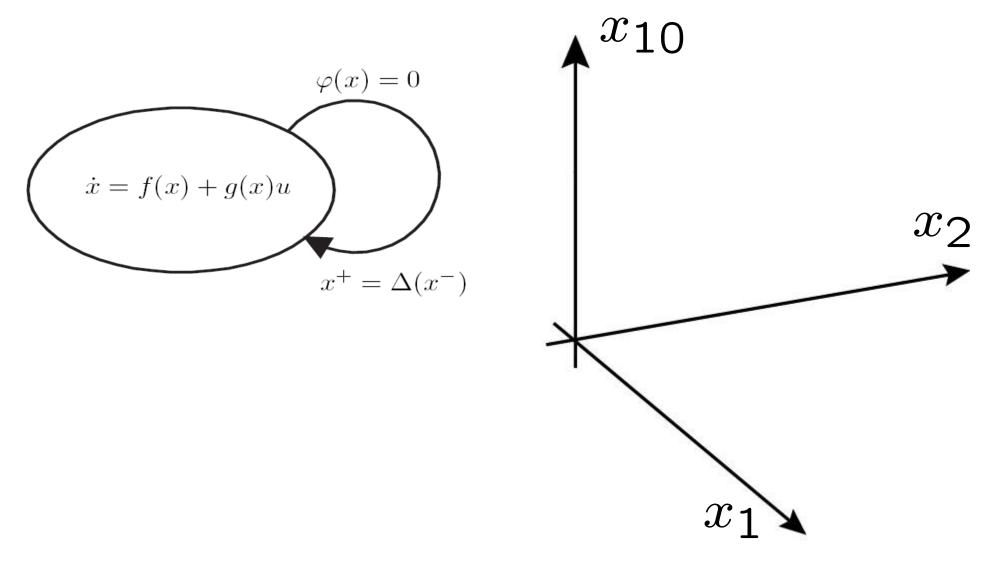
# Terms in the Model ... Oh my!

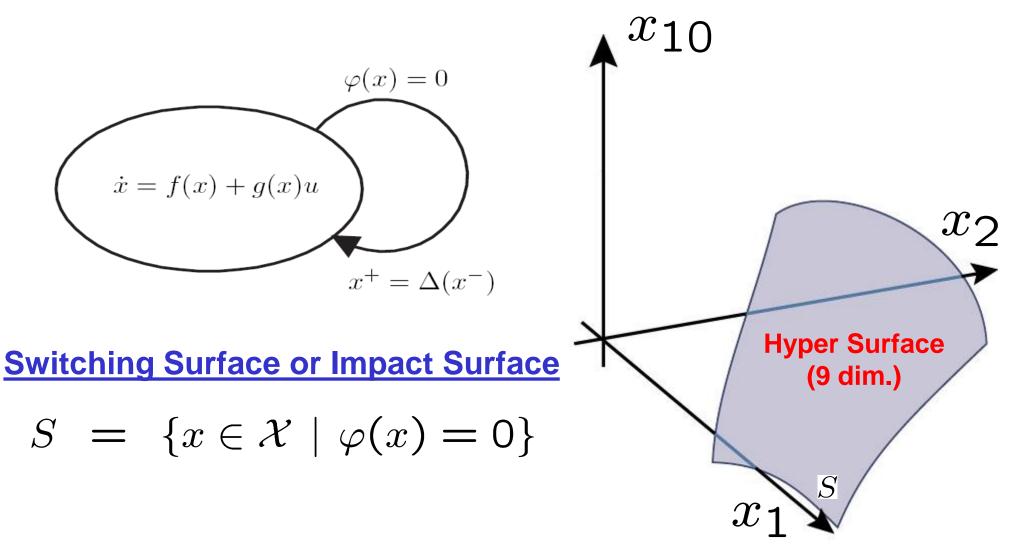
Hybrid Zoro Demanics of N.Link Pl	anar Biped Walkers: Equation Details	$+q_1^N M.L. \cos(-q_1 + q_2 - q_1 + q_4)$	$C_{1,k}(\mathbf{g}) = M g_{1}^{kl} L_{2} \sin(\mathbf{g}_{k}) \dot{\mathbf{g}}_{k}$
		$D_{h,h}(q) = M_{*}L_{2}^{2} - M_{*}L_{2}^{2} \cos(q_{1} - q_{2}) - 2q_{*}^{M}M_{*}L_{2} \cos(q_{1}) - p_{*}^{M}M_{2}L_{2} \cos(q_{1})$	$C_{1,2}(q) = -M_{2}q_{1}^{2d}L_{2}\sin(q_{1})\dot{q}_{2}$ $C_{1,2}(q) = -L_{1}(\dot{q}_{2}q_{1}^{2d}M_{2}\sin(q_{1}))$
E.R. Westervelt <sup>*</sup> , J.W. 0	Grizzle <sup>+</sup> , D.E. Koditschek <sup>‡</sup>	$\pm p \partial^2 M_s L_s \cos (q_s - q_d + q_b)$	$(L_{1}q_{2}M_{1}\sin(q_{2}-q_{2}))$
I. Netwinow	$-g_T^{(0)}M_T L_e \exp(q_1 - q_2 + q_3)$	$-p_T^{2d}M_F L_F \cos(q_1 - q_2)$	$+q_{3}p_{f}^{W}M_{f}\sin(q_{1}-q_{2})$
The notation is as follows. The configuration econditates		$-p_1^{N}ML_c\cos(-q_1 + q_2 - q_1 + q_4)$	$+\frac{1}{2}q_{\mu}^{[0]}M_{\mu}\sin\left(-q_{\mu}+q_{\mu}+q_{\mu}\right)$
are denoted by $q_1, \ldots, q_1$ and their velocities by $q_1, \ldots, q_n$ . The link lengths, masses, inertian, and center of mass loca- tions are denoted by $L_{\alpha}, M_{\alpha}, I_{\alpha}$ , and $p_i^{\alpha \beta}$ , respectively.	$+g_1^M M_0 L_1 \cos (-q_1 + q_2 - q_3 + q_4)$	$+M_{1}L_{1}L_{2}\cos(q_{1} - q_{2} + q_{3})$ $+q_{1}^{N}M_{2}L_{2}\cos(-q_{2} + q_{2} + q_{3}) + I_{2} + I_{3}$	$- p_0^M M_1 \sin(q_1) d_k$ $+ g_0 p_0^M M_2 \sin(q_1) + L_2 g_0 M_1 \sin(q_1 - q_2)$
	$-M_1 L_2 L_1 \cos (q_1 - q_2 + q_3)$	$+p_{1}^{2}M_{F}L_{s}\cos(\eta_{1}+\eta_{1})+I_{F}$	$+ \phi_0 p_1^{p_1} M_1 \sin(q_1 - q_2)$
II. EQUATIONS OF MOTION	$-p_{0}^{2M}M_{c}L_{F}\cos(-q_{1}+q_{2}+q_{3})-I_{f}-I_{c}$ $D_{h,1}(q) = M_{c}L_{f}^{2} - p_{f}^{2M}M_{f}L_{f}\cos(q_{3})$	$D_{5,0}(q) = -M_s L_T^2 + M_s L_T^2 \cos(q_s - q_2)$	$+q_1q_2^M M_1 \sin(-q_1 + q_2 + q_3))$
The equations of motion during the string phase is	$-2p_1^W M_s L_T con(q_1) - M_s L_T^2 con(q_1 - q_2)$	$+2\rho^M M_s L_f \cos(q_c)$	$C_{1,4}(q) = p_1^M M_1 L_J \sin(q_k) (\dot{q}_k - \dot{q}_2 + \dot{q}_3 - \dot{q}_4 + \dot{q}_5)$
$D(q)\bar{q} + C(q,\bar{q})\bar{q} + G(q) = Bu$	$-p^{\frac{1}{2}j}M_FL_F \cos(q_i - q_2) + I_F + I_J$	$-p_1^{W}M_sL_s \cos(q_1 - q_2 + q_1)$ $+p_1^{W}M_sL_s \cos(q_1 - q_2)$	$C_{1,2}(q) = -\frac{1}{6}g_2^{W}M_2L_F \sin(q_1) - L_2^2g_2M_1\sin(q_1 - q_2)$ $-\frac{1}{6}g_2^{W}M_1L_F \sin(q_2 - q_3)$
where	$+ y_1^{M} M_0 L_F \cos([-q_1 + q_2 + q_3) + I_0$	$+p_1^{-1}M_2L_2 \cos(q_1 - q_2)$ $+p_1^{N}M_2L_1 \cos((-q_1 + q_2 - q_1 + q_4))$	$-\frac{1}{2}q_{2}q_{1}^{2}M_{1}^{2}a_{2}^{2}\sin((-q_{2}-q_{2}))$ $-\frac{1}{2}q_{2}q_{1}^{2}M_{2}^{2}L_{2}^{2}\sin((-q_{2}+q_{2}+q_{2}))$
$D_{1,1}(q) = I_f - 2g_i^M M_s L_f \cos(q_b) + I_T + M_s L_f^2 + I_s$	$D_{hB}(g) = -M_{1}L_{f}^{2} + 2p_{i}^{M}M_{1}L_{f}\cos(g_{i})$	$-M_{1}L_{1}L_{2}\cos(q_{1}-q_{2}+q_{3})$	-re <sup>M</sup> M.Levin(n) da
$D_{1,0}(q) = -M_c L_F^2 + 2p_i^M M_c L_F ma(q_1) - I_r - I_A$	$+M_1\Sigma_2^2\cos(q_1-q_2)$	$-g_1^{N}M_iL_4 \cos(-g_1 + g_2 + g_4) - I_f - I_i$	$+q_{5}M_{c}L_{f}L_{c}\sin(q_{1}-q_{2}+q_{3})$
$D_{1,2}(q) = M_1 L_T^2 - p_2^M M_T L_T \cos(q_1)$	$+ g_{2}^{(d)} M_{f} L_{f} reat(q_{1} - q_{2}) - I_{f}$ $- g_{2}^{(d)} M_{c} L_{f} root(-q_{1} + q_{2} + q_{2}) - I_{f}$	$D_{0,3}(q) = 2M_{4}L_{2}^{2} - 2M_{4}L_{2}^{2} \cos(q_{1} - q_{2})$	$-\frac{1}{2} e_F q_1^{(d)} M_1 L_2 \sin \left(-q_2 + q_2 + q_3\right)$
$-2\rho_{\rm c}^M M_0 L_f \cos\left(q_{\rm b}\right) - M_1 L_2^2 \cos\left(q_{\rm c}-q_2\right)$	$D_{k,k}(q) = 2ML_T^2 - 2p_1^2M_TL_f \cos(q_k)$	$-3p_1^{M}M_FL_f \cos(q_1) - 3p_2^{M}M_FL_f \cos(q_1) + p_1^{M}M_FL_f \cos(q_1 - q_2 + q_3)$	$-\frac{1}{6}\varphi_j^{M}M_j\tilde{L}_j \sin(q_k - q_k)$ $-\tilde{L}_j^2q_kM_t \sin(q_k - q_k)$
$-p_T^{M}M_FL_F \cos (q_1 - q_2) + I_F + I_f$ + $p_t^{M}M_tL_F \cos (-q_1 + q_2 + q_1) + I_f$	$-2p_1^{W}M_1L_2 \cos(q_1) - 2M_1L_2^2 \cos(q_2 - q_2)$	$-2r_j^M M_f k_f \cos(q_i - q_i)$	$-\frac{1}{2} \partial_{\mu} \partial_{\mu}^{\mu} M_T L_{\mu} \sin(\eta_1)$
$+p_{1}^{-}M_{1}L_{2}\cos((-q_{1}+q_{2}+q_{3})+z_{1})$ $D_{1,4}(q) = p_{1}^{W}M_{1}L_{2}\cos(q_{1})-L_{1}$	$-2\mu_J^{IF}M_JL_J \cos(q_1 - q_2) + P_T + 2H_J$	$-n^{N}MJ$ , $real - c_{1} + c_{2} - c_{3} + a_{4}$	$+\phi_0 p_1^{00} M_1 L_1 \sin (q_1 - q_2 + q_3)$
$D_{1,1}(q) = MA_{1}^{2} - M_{1}L_{2}^{2} \cos(q_{1} - q_{2})$	$+2M_JL_J^2 - 2p_J^{2F}M_JL_J + M_TL_J^2$	$+M_{1}L_{f}L_{1}\cos(q_{1}-q_{2}+q_{3})$	$+\frac{1}{2}g_{F}^{F}\Delta t_{T}L_{1}\sin\left(q_{1}+q_{2}\right)$
$-2p_h^M M_f L_T \cos(q_h) - p_l^M M_T L_T \cos(q_h)$	$+2p_1^{M}M_1L_2 \cos(-q_1 + q_2 + q_3) + I_1$ $D_{h,4}(q) = p_1^{M}M_1L_2 \cos(q_3)$	$+2q_1^{M}M_2L_2 \cos(-q_1 + q_2 + q_3) + 2l_2' + q_1^{W}M_2L_2 \cos(q_1) - M_2L_2L_2 \cos(q_1)$	$+q_{2}q_{1}^{2\sigma}M_{1}L_{a}\sin(-q_{1}+q_{2}-q_{1}+q_{4})$
$+p_{f}^{W}M_{h}L_{s}\cos{(q_{1}-q_{2}+q_{1})}$	$D_{3,4}(\underline{x}) = p_t^{-M_1L_2} \cos  q_t  - q_t + q_t + q_t) - \tilde{L}_t$	$+pq^{\prime}M_{J}L_{q}\cos(q_{1}) - M_{J}L_{J}L_{q}\cos(q_{2})$ $-M_{q}L_{J}L_{q}\cos(q_{1}) - 2M_{J}L_{J}L_{q}\cos(q_{2})$	$C_{0,k}(q) = -p_1^M M_s L_f \sin(q_k) q_k$ $C_{2,\beta}(q) = -p_1^M M_s L_f \sin(q_k) q_k$
$-p_1^{2\ell}M_sL_f \cos(q_1 - q_2)$ $-p_1^{2\ell}M_sL_s \cos(-q_1 + q_2 - q_3 + q_4)$	$D_{4,0}(q) = -21\delta_{4}L_{f}^{2} - 21\delta_{6}L_{f}^{2} \cos(q_{1} - q_{2})$	$+M_TL_T^2 - 2p_T^MM_TL_T + 2M_TL_T^2 + I_1$	$C_{2,3}(q) = L_F(L_F \oplus M_r \sin(q_2 - q_1))$
$-g_1^{-}M_1L_1 mm(-q_1 + q_2 - q_2 + q_4)$ + $M_1L_1L_1 mm(q_1 - q_2 + q_4)$	$-2p_{i}^{(0)}M_{i}L_{i}\cos(q_{i}) - 2p_{i}^{M}M_{2}L_{i}\cos(q_{i})$	$+p\frac{\partial}{\partial M}M\sigma L_{s} \cos(q_{1}+q_{2}) + I\sigma$	$+d_{3}\sigma_{1}^{W}M_{1}\sin(q_{1}-q_{2})$
$+g_{1}^{30}M_{1}L_{2}\cos(-g_{1}+g_{2}+g_{4}) + I_{2} + L_{1}$	$+p_T^{kl}M_fL_e \cos(q_k - q_k + q_b)$	$D_{0,d}(q) = -I_{\delta} - p_{1}^{W} M_{\delta} I_{A} exc (-q_{1} + q_{2} + q_{4})$	$+ \frac{1}{2} q_1^{W} M_0 \sin \left[ -q_1 + q_2 + q_4 \right]$
$+p_0^{T}M_T I_{\alpha} \cos(q_1 + q_1) + I_T$	$-2p_f^W M_f L_f \cos(q_1 - q_2)$	$+g_1^{N}M_sL_g \cos(q_1)$ $+g_1^{N}M_sL_s\cos(-q_1 + q_2 - q_1 + q_4)$	$-p_1^M M_1 \sin(q_1) \dot{q}_k + L_f \dot{q}_1 M_5 \sin(q_k - q_1)$ $+ \dot{q}_2 p_f^M M_f \sin(q_k - q_1)$
$D_{2\Lambda}(q) = -M_1L_2^2 + 2p_1^NM_1L_T \cos(q_1) - I_1 - I_2$	$\begin{array}{l} -g_{k}^{(2)}M_{k}L_{k}L_{k}\cos\left(-q_{k}+q_{2}-q_{3}+q_{k}\right)\\ +M_{k}L_{p}L_{k}\cos\left(q_{k}-q_{2}+q_{3}\right)\end{array}$	$D_{0,0}(q) = 2p_1^M M_f L_0 \cos(q_0) - 2p_1^M M_f L_f \cos(q_1 - q_2)$	$+q_{1}p_{1}^{M}M_{1}\sin(-q_{1}+q_{2}+q_{3}))$
$D_{2,2}(q) = M_{0}L_{f}^{2} - 2g_{h}^{M}M_{h}L_{f}\cos(q_{h}) + I_{f} + I_{f}$ $D_{3,0}(q) = -M_{c}L_{f}^{2} + 2g_{h}^{M}M_{c}L_{f}\cos(q_{h})$	$+2p_1^{2F}M_1L_J cos(-q_1 + q_2 + q_4)$	$-2M_{2}L^{2}\cos(\eta_{1}-\eta_{2})$	$C_{2,4}(q) = -g_1^M M_1 L_2 \sin(q_1) (\dot{q}_1 - \dot{q}_2 + \dot{q}_3 - \dot{q}_4 + \dot{q}_8)$
$D_{0,0}(q) = -M_c L_F^{-1} + 2q_c^{-1} M_c L_F \cos(q_1)$ $+M_c L_F^{-1} \cos(q_2 - q_3)$	$+2I_F + p_F^M M_F L_1 \cos(\eta_3)$	$+2\rho_{1}^{M}M_{T}L_{1}\cos(q_{1}+q_{2})$	$C_{0,1}(g) = L_{2}^{2} q_{0} M_{c} \sin(g_{1} - g_{0})$
$+ se_{i} \frac{1}{2} f^{a} m_{f} L_{f} \cos (q_{i} - q_{2}) - I_{f}$	$-MyL_JL_e \cos(q_b) - M_cL_fL_e \cos(q_b)$	$+2p_{I}^{M}M_{I}L_{t}\cos(q_{1}-q_{2}+q_{3})$	$+ q_{0}p_{1}^{0}M_{f}L_{f} \sin(q_{0} - q_{0})$
$-g_1^{W}M_sL_d \cos(-g_1 + g_2 + g_4) - L_t$	$-2M_JL_JL_s \cos(\eta_b) + M_FL_2^2$ $-2p_J^2M_JL_J + 2M_JL_2^2 + I_i$	$-2q_F^{M}M_TL_f \cos(q_1) + 2\delta_1 + M_T\delta_1^2$ $-2M_TL_fL_f \cos(q_1) - 2M_TL_fL_e \cos(q_1)$	$+L_f g_{22} q_1^{10} M_t \sin(-q_1 + q_2 + q_4)$
$D_{2,d}(q) = -p_i^{N}M_iL_F m_i(q_4) + I_f$	$-2\rho_T^{-1} M_T L_J + 2N e_J L_J^{-1} + L_1$ + $p_T^{0^+} M_T L_s con (q_1 + q_2) + J_T$	$-4M_{ch}\cos(\omega) + 2f_{c} + d_{T}$	$-p_i^M M_i L_f \sin(q_i) \dot{q}_k$ $+ L_2^2 \dot{q}_2 M_i \sin(q_i - q_j)$
$D_{LS}(q) = -M_s L_f^2 + M_s L_f^2 \cos(q_1 - q_2) + 2q_1^{10} M_s L_f \cos(q_1)$	$D_{h,i}(q) = p_i^M M_i L_f \cos(q_i) - I_i$	$+216E_{1}E_{2}\cos(q_{1}-q_{2}+q_{3})+216E_{2}^{2}$	A WALL MADE A LAND
$+2\rho_1^{AI}M_AL_f con(g_k)$		$-2r_{I}^{M}M_{I}k_{J} + 2M_{2}k_{2}^{2} + 2M_{I}k_{2}^{2} + 2M_{I}k_{2}^{2}$	$+(q_2)^{M_1}M_2L_3\sin(q_2 - q_3)$
"Consequently particle for the second structure, Deriver, Experiment and the second structure, Deriver and State and An Arton. MI (2010) 222, UM, second reflection, edi "Control Structure, Deriver, Territorial Dispations, edi prover Structure, Deriver, Territorial Dispations, and Con- port Structure, Department, University of Mediagon, And Leber, MI (2010) 2010 (2	$D_{k,0}(g) = p_i^M M_i L_f \cos  g_i $	$-2\mu_i^M M_2 L_i + M_F L_f^2$	$-dec n^{22} M_{2} L_{2} \sin (-m_{1} + m_{2} - m_{1} + m_{2})$
(a) Anit Arbor, Mr 6000-2122, USA, constructional and Com- "Control Beatrana Laboratory, Electrical Engineering and Com- tained Internet Determine of Malacone Inter Laboration."	$-g_1^{\mu\nu}M_0L_f \cos([-q_1 + q_2 + q_4) - I_0]$	$+2\rho_{k}^{10}M_{F}L_{f}\cos(-q_{1}+q_{2}+q_{k})$ $-2\rho_{k}^{10}M_{F}L_{f}\cos(q_{k})$	$-\frac{1}{2} M_s L_f L_s \sin (q_1 - q_2 + q_3)$
1018-2120. USA, granuloburati.edu	$D_{k,k}(q) = -q_k$ $D_{k,k}(q) = -I_k - g_k^{kl}M_kL_F \cos[-q_k + q_k + q_k]$	$-2q_1^{-M}M_2L_1 \cos(-q_1 + q_2 - q_3 + q_4),$ $-2q_1^{-M}M_2L_1 \cos(-q_1 + q_2 - q_3 + q_4),$	$\frac{+L_F g_{22}^{W} M_F \sin \left[-q_1 + q_2 + q_3\right]}{C_{1,4}(q)} = L_F \left(q_1 q_2^{W} M_F \sin (q_1) + L_F q_1 M_F \sin (q_2 - q_3)\right)$
puter Science Depictures. University of Madagan. Ann Arbor, MJ 2018-2018, USA, koobunch. edu	$+ p_0^{2d} M_0 L_F \cos(q_d)$		- 11(1)
			I HER TRANS OF ANTOHESIC CONTINUE - REOVEAR PAPER
$-iqp^M M_1 L_2 \sin (q_1)$	$-2\eta^{kl}M_{c}q_{c}L_{c}q_{k}\cos(q_{k})$	$+3I_{2}\dot{q}_{2}\dot{q}_{3}+\frac{1}{2}M_{2}L_{2}^{2}\dot{q}_{1}^{2}+\frac{1}{2}M_{2}L_{2}^{2}\dot{q}_{2}^{2}$	$D_{r,1,0}(q_r) = M_r L_f \cos (q_1 - q_2 + q_3 + q_4) - \rho_1^{10} M_r \cos (q_1 - q_2 + q_3 - q_4 + q_5)$
	$-2g_1^{kl}M_{cl}(\mu, \delta_{l}\mu, \delta_{l}\mu)$ $-2g_1^{kl}M_{cl}\delta_{\mu}\phi_{l}\phi_{l}\phi_{l}$ (eq.) $-2g_1^{kl}M_{cl}\delta_{\mu}\phi_{l}\phi_{l}\phi_{l}$ (eq.)	$+2I_{P}_{2}\phi_{0}^{i}+\frac{1}{2}M_{e}I_{2}^{2}\phi_{1}^{2}+\frac{1}{2}M_{e}I_{2}^{2}\phi_{2}^{2}$ $-M_{P}g_{e}^{2}L_{e}L_{e}\cos(q_{0})+M_{e}L_{2}^{2}\phi_{e}\eta_{e}$	$D_{n,l,k}(q_r) = M_n f_f \cos(q_r - q_l + q_l + q_l) - \rho_l^{ef} M_r \cos(q_l - q_l + q_l - q_l + q_l) + \rho_l^{ef} M_f \cos(q_l - q_l + q_l + q_l)$
$\begin{split} &- \dot{q}_0 q_0^{IJ} M_f L_f \sin\left(q_1\right) \\ &- \dot{q}_0 p_0^{IJ} M_f L_f \sin\left(q_1-q_2\right) \\ &- \dot{q}_0 p_0^{IJ} M_f L_s \sin\left(q_1-q_2+q_1\right), \end{split}$	$-2q_{1}^{10}M_{2}q_{1}M_{2}q_{2}M_{2}q_{3}mm(q_{1})$ $+2q_{1}^{10}M_{2}L_{1}P_{1}q_{2}q_{3}mm(q_{2})$ $+2q_{1}^{10}M_{2}L_{1}P_{2}q_{3}q_{3}mm(q_{1})$ $+p_{1}^{10}M_{2}L_{1}P_{2}q_{3}q_{3}mm(q_{1})$	$+2I_{P}\dot{q}_{P}\dot{q}_{P}$ , $-\frac{1}{2}M_{s}L_{p}^{2}\dot{q}_{P}^{2}$ , $-\frac{1}{2}M_{s}L_{p}^{2}\dot{q}_{P}^{2}$ $-M_{T}\dot{q}_{P}^{2}L_{p}L_{q}$ , $\cos(q_{0}) + M_{s}L_{p}^{2}\dot{q}_{P}$ , $\eta_{1}$ $-M_{s}L_{p}^{2}\dot{q}_{P}\dot{q}_{2}$ , $M_{s}L_{p}^{2}\dot{q}_{q}$ , $\eta_{2}$ , $L_{p}^{2}\dot{q}_{P}\dot{q}_{q}$ ,	$D_{n,h}(q_{1}) = M_{n}L_{f} \cos(q_{1} - q_{2} + q_{3} + q_{4})$ $-q_{f}^{N}M_{f} \cos(q_{1} - q_{2} + q_{3} - q_{4} + q_{1})$ $+p_{f}^{N}M_{f} \cos(q_{1} - q_{2} + q_{3} + q_{1})$ $+\cos(q_{1} + q_{2} + q_{3} + q_{3})$
$\begin{split} &-\partial_{0}p_{1}^{M}M_{1}\xi_{1}\sin\left(q_{1}-q_{2}\right)\\ &-\partial_{0}p_{2}^{M}M_{1}\xi_{2}\sin\left(q_{1}-q_{2}+q_{1}\right),\\ &G_{1}(q)=-g\left(an(q_{1}+q_{2}+q_{3})p_{1}^{M}M_{2}\right)\end{split}$	$-\frac{2\eta_1^{22}}{M_1}\frac{M_2(q, \bar{q}, \eta_1 q, mm; (q_1))}{(q_1 - q_1)^{22}} + \frac{2\eta_1^{22}}{M_1}\frac{M_2(q, \bar{q}, \eta_2 q, mm; (q_2))}{(q_1 - q_1)^{22}} + \frac{2\eta_1^{22}}{M_1}\frac{M_1}{d_1}\frac{q_1 \eta_2 \eta_2}{q_2} \exp \left(q_2\right)}{(q_1 - q_1)^{22}} + \frac{2\eta_1^{22}}{M_1}\frac{M_1}{d_1}\frac{q_1 \eta_2}{q_2} \exp \left(q_1\right)}{(q_1 - q_1)^{22}} + \frac{2\eta_1^{22}}{M_1}\frac{M_1}{d_1}\frac{q_2 \eta_2}{q_2} \exp \left(q_1\right)}{(q_1 - q_1)^{22}} \exp \left(q_1\right)}$	$\begin{split} + 2J_{f} \dot{a}_{1} \dot{a}_{2} &+ \frac{1}{2} M_{1} \dot{a}_{1}^{2} \dot{a}_{1}^{2} + \frac{1}{2} M_{1} J_{1}^{2} \dot{a}_{2}^{2} \\ - M_{1} \dot{a}_{2}^{2} \dot{a}_{1} \dot{a}_{1} &- (m + m) + M_{1} J_{2}^{2} \dot{a}_{2} \dot{a}_{2} \\ - M_{2} J_{1}^{2} \dot{a}_{1} \dot{a}_{2} &- M_{2} J_{2}^{2} \dot{a}_{2} \dot{a}_{2} \\ + M_{2} J_{1}^{2} \dot{a}_{2} \dot{a}_{2} &- M_{2} J_{2}^{2} \dot{a}_{2} \dot{a}_{2} \\ - M_{2} J_{1}^{2} J_{2} \dot{a}_{2} \dot{a}_{2} \dot{a}_{2} \dot{a}_{2} \dot{a}_{2} \dot{a}_{2} \end{split}$	$\begin{array}{ll} D_{-1,0}(\mathbf{p}_{*}) &=& M_{*} \delta_{T} \cos \left(\mathbf{p}_{*} - \mathbf{p}_{*} + \mathbf{q}_{*} + \mathbf{q}_{*}\right) \\ & - p_{*}^{W} M_{*} \cos \left(\mathbf{n}_{*} - \mathbf{n}_{*} + \mathbf{q}_{*} - \mathbf{q}_{*} + \mathbf{q}_{*}\right) \\ & + p_{*}^{W} M_{F} \cos \left(\mathbf{q}_{*} - \mathbf{q}_{*} + \mathbf{q}_{*} + \mathbf{q}_{*}\right) \\ & + \cos \left(\mathbf{q}_{*} + \mathbf{q}_{*} + \mathbf{q}_{*}\right) \frac{Y}{M} M_{F} \\ D_{-1,7}(\mathbf{q}_{*}) & = -M_{*} + \sin \left(\mathbf{q}_{*} - \mathbf{q}_{*} + \mathbf{q}_{*}\right) \end{array}$
$\begin{split} &-\frac{1}{2} g g_{1}^{(0)} M_{2}(k, q_{0}, q_{0}) \\ &-\frac{1}{2} g g_{2}^{(0)} M_{2}^{(0)} f_{1} \sin \left(q_{0}-q_{0}\right) \\ &-g_{2} g_{1}^{(0)} M_{2}^{(0)} f_{1} \sin \left(q_{0}-q_{0}+q_{0}\right) \\ &-g_{1}^{(0)} \left(q_{1}-q_{0}+q_{0}+q_{0}\right) g_{2}^{(0)} M_{1} \\ &+g_{1}^{(0)} M_{1}^{(0)} \left(q_{1}-q_{0}+q_{0}+q_{0}\right) \\ &+g_{1}^{(0)} M_{1}^{(0)} \left(q_{1}-q_{0}+q_{0}+q_{0}\right) \\ \end{split}$	$\begin{split} &-2g_{1}^{20}M_{1}^{2}M_{2}g_{1}^{2}g_{1}^{2}\cos(m_{1})\\ &+2g_{1}^{20}M_{1}^{2}g_{1}^{2}g_{2}^{2}g_{2}^{2}\cos(m_{1})\\ &+2g_{1}^{20}M_{1}^{2}f_{2}g_{2}^{2}g_{2}^{2}\cos(m_{1})g_{1}\\ &+g_{1}^{20}M_{1}^{2}f_{2}g_{1}^{2}g_{2}^{2}\cos(m_{1})g_{1}\\ &+g_{1}^{20}M_{1}^{2}f_{2}^{2}g_{2}^{2}\cos(m_{1}-g_{1}-g_{2}+g_{1})\\ &+g_{1}^{20}M_{1}^{2}f_{2}^{2}g_{2}^{2}\cos(m_{1}-g_{2}-g_{2}+g_{1})\\ &+g_{1}^{20}M_{1}^{2}f_{2}^{2}g_{2}^{2}\cos(m_{1}-g_{2}-g_{2}+g_{1})\end{split}$	$\begin{split} + M_{1} \rho_{1} \rho_{2} \rho_{1} &= \frac{1}{2} M_{1} K_{1}^{2} \rho_{1}^{2} + \frac{1}{2} M_{1} K_{1}^{2} \rho_{1}^{2} \\ - M_{1} \rho_{1}^{2} K_{1} \rho_{2} \rho_{1} \rho_{1} &= M_{1} K_{2}^{2} \rho_{1} \rho_{1} \\ - M_{2} (\rho_{1}^{2} K_{1}^{2} \rho_{1} \rho_{2} + M_{2} K_{2}^{2} \rho_{2} \rho_{2} \rho_{1} \\ + M_{2} (\rho_{1}^{2} K_{2}^{2} - K_{2}^{2} K_{2}^{2} \rho_{2} \rho_{1} \\ - M_{2} (R_{1}^{2} K_{2}^{2} \rho_{2} \rho_{1} \rho_{2} \rho_{2} \rho_{2} \rho_{1} \rho_{2} \rho$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{split} &- \frac{1}{2} \phi_{0} q^{0} M_{1} L_{2} \sin(q_{1}) \\ &- \frac{1}{2} \phi_{0} q^{0} M_{1} L_{2} \sin(q_{1} - q_{2}) \\ &- \frac{1}{2} \phi_{0} q^{0} M_{2} L_{2} \sin(q_{1} - q_{2}) + q_{1} ] , \end{split} \\ G_{1}(q) &= - g \left( \cos(q_{1} + q_{1} + q_{0}) p_{1}^{0} M_{1} \\ &+ p_{1}^{0} M_{1} \sin(q_{1} - q_{2}) + q_{1} + q_{0} \right) \\ &+ L_{2}^{0} M_{1} \sin(q_{1} - q_{2}) + q_{1} = \eta . \end{split}$	$\begin{split} &-2g_{1}^{2}M_{2}^{2}d_{2}d_{2}d_{2}d_{3}mm\left(\mu_{0}\right)\\ &+2g_{1}^{2}M_{2}^{2}d_{2}d_{2}d_{3}d_{3}mm\left(\mu_{0}\right)\\ &+2g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}mm\left(\mu_{0}\right)\\ &+g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}mm\left(\mu_{0}\right)\\ &+g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}mm\left(\mu_{0}\right)\\ &+g_{1}^{2}M_{2}^{2}M_{2}d_{3}d_{3}mm\left(\mu_{0}-\mu_{0}+\mu_{0}\right)\\ &-g_{1}^{2}M_{2}^{2}M_{2}d_{3}d_{3}mm\left(-\mu_{0}-\mu_{0}+\mu_{0}\right)\\ &-g_{1}^{2}M_{2}M_{2}d_{3}d_{3}mm\left(-\mu_{0}-\mu_{0}+\mu_{0}\right) \end{split}$	$-3L_{1}c_{2}c_{2}h_{1} + \frac{1}{2}M_{1}L_{1}^{2}c_{1}^{2}r_{1}^{2} + \frac{1}{2}M_{2}L_{1}^{2}c_{2}^{2}r_{1}^{2}$ $-M_{2}L_{2}^{2}c_{1}r_{2} + m(m) + M_{2}L_{2}^{2}h_{2}h_{1}$ $-M_{2}L_{2}^{2}c_{2}h_{2} + M_{2}L_{2}^{2}h_{2}h_{1}$ $-M_{2}L_{2}^{2}c_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{split} -& [\phi q_1^{0} M_{1} L_{2} dm(q_{1}) \\ &- [\phi q_2^{0} M_{1} L_{1} dm(q_{1} - q_{2}) \\ &- [\phi q_2^{0} M_{2} L_{2} dm(q_{1} - q_{2}) \\ &- [\phi q_1^{0} M_{2} L_{2} dm(q_{1} - q_{2} + q_{2}) ], \end{split} \\ G_{1}(q) &= - q_{1} \{ q_{21}(q_{1} - q_{2} + q_{2}) \\ &+ [\phi_1^{0} M_{2} dm(q_{1} - q_{2} - q_{2} + q_{2}) \\ &+ [\phi_1^{0} M_{2} dm(q_{1} - q_{2} - q_{2} + q_{2}) ], \end{split}$	$\begin{split} &-2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{2}d_{3}\cos(m_{1})\\ &+2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{3}d_{3}\cos(m_{1})\\ &+2g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-(m_{1}-m_{2}+m_{1}))\\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-(m_{1}-m_{2}+m_{1}+m_{1}))\\ &-g_{1}^{20}M_{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-(m_{1}-m_{2}+m_{1}+m_{1}))\\ &-g_{1}^{20}M_{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-(m_{1}-m_{2}+m_{1}+m_{1}))\\ &-g_{1}^{20}M_{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-(m_{1}-m_{2}+m_{1}+m_{1})) \end{split}$	$\begin{split} -& 3 L_{plach} + \frac{1}{2} M M_{p}^2 d_{1}^2 - \frac{1}{2} M M_{p}^2 d_{2}^2 \\ & - M M_{p}^2 M_{1} + 1 L_{1} + m \sin h + M M_{plach} \\ & - M M_{p}^2 M_{1}^2 - M M_{p}^2 M_{plac} - M M_{p}^2 M_{plac} \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{plac} - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - m M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - m M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - m M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 \\ & - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_{p}^2 - M M_{p}^2 M_$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{split} &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})-g_{0}-g_{0}\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})-g_{0}-g_{0}-g_{0}\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})-g_{0}-g_{0}-g_{0}\\ &+\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &+\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &+\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &+$	$\begin{split} &-2g_{1}^{2}M_{2}^{2}d_{2}d_{2}d_{2}d_{3}\cos(mx) g_{2}\rangle \\ &+2g_{1}^{2}M_{2}^{2}d_{2}d_{2}d_{3}d_{3}\cos(mx) g_{2}\rangle \\ &+2g_{1}^{2}M_{2}^{2}d_{2}d_{3}d_{3}d_{3}d_{3}\cos(mx) g_{2}\rangle \\ &+g_{1}^{2}M_{2}^{2}d_{2}d_{3}d_{3}d_{3}d_{3}\cos(mx) g_{2}\rangle \\ &+g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(mx) g_{2}\rangle \\ &+g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3$	$\begin{split} -& 2J_{1} \phi_{1} \phi_{2} + \frac{1}{2} X L_{1}^{2} \phi_{1}^{2} + \frac{1}{2} X L_{1}^{2} \phi_{1}^{2} \phi_{2}^{2} \\ -& 3J_{1} \phi_{2}^{2} L_{1} (-\alpha + \alpha \mu_{2}) + M M_{2}^{2} \mu_{2} \phi_{1} \\ -& 3J_{1} \phi_{1}^{2} + M h_{2}^{2} + M h_{2}^{2} \phi_{2} \phi_{2} \\ -& 3M h_{1}^{2} \phi_{2} + M h_{2}^{2} \phi_{2} \phi_{2} \\ -& 2M h_{2}^{2} \phi_{2} + \alpha + (\alpha + \alpha + $	$\begin{array}{l} B_{-1,1}(\mathbf{p}) &= M_{n,1}^{2} \exp\left(-\mathbf{p} + \mathbf{q} + \mathbf{q}\right) \\ &= p_{n,1}^{2} M_{n-1}(\mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1}) \\ &= p_{n,1}^{2} M_{n-1}(\mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1}) \\ &= p_{n,1}^{2} M_{n-1}(\mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1}) \\ B_{-1,1}(\mathbf{q}_{n-1}) &= -M_{n,1}^{2} M_{n-1}(\mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1}) \\ &= -M_{n,1}^{2} M_{n-1}(\mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1}) \\ &= -M_{n-1}^{2} M_{n-1}^{2} M_{n-1}^{2} + \mathbf{q}_{n-1} + \mathbf{q}_{n-1} \\ B_{-1,1}(\mathbf{q}_{n-1}) &= -M_{n-1}^{2} M_{n-1}^{2} M$
$\begin{split} &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})-g_{0}-g_{0}\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})-g_{0}-g_{0}-g_{0}\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}L\phi(\mathbf{x})-g_{0}-g_{0}-g_{0}\\ &+\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &+\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &-\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &+\frac{\partial \phi^{2}}{\partial t}M_{c}(g_{0}-g_{0}-g_{0}-g_{0})\\ &+$	$\begin{split} -& 2g_{1}^{2} \delta S_{1} \delta S_{1} \delta g_{2} + \cos \left( g_{2} \right) \\ & -& 2g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} \right) \\ & -& 2g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + \cos \left( g_{2} - g_{2} + g_{2} + g_{2} + g_{2} + g_{2} + g_{2} \right) \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} + g_{2} \delta g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} + g_{2} + g_{2} + g_{2} + g_{2} + g_{2} \\ & -& g_{1}^{2} \delta S_{2} + g_{2} + g_$	$\begin{split} -& 3 L_{plach} + \frac{1}{2} M L_{p}^{2} dt^{2} - \frac{1}{2} M L_{p}^{2} dt^{2} \\ & 3 M_{e}^{2} dt^{2} + 1_{e}^{2} + 1_{e}^{2} + 2_{e}^{2} + 2_{e}^{2} M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} - M L_{p}^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt^{2} dt^{2} dt^{2} dt^{2} \\ & - M M_{e}^{2} dt^{2} dt$	$\begin{array}{l} B_{1,1}(\mathbf{p}) &= M_{1,2}^{1} \min\{\mathbf{p}-\mathbf{p}+\mathbf{q}+\mathbf{q},\mathbf{h}\}\\ &= p_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q}+\mathbf{n}-\mathbf{n},\mathbf{h}-\mathbf{q},\mathbf{h}\}\\ &= p_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q}+\mathbf{q}+\mathbf{n},\mathbf{h}+\mathbf{q},\mathbf{h}\}\\ &= m_{1}^{2} \min\{\mathbf{n}-\mathbf{q}+\mathbf{h}-\mathbf{q},\mathbf{h}\}\\ &= m_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q}+\mathbf{q}-\mathbf{q},\mathbf{h}\}\\ &= m_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q}+\mathbf{q}-\mathbf{q},\mathbf{h}\}\\ &= p_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q}+\mathbf{q},\mathbf{h},\mathbf{h}\}\\ B_{1,1}(\mathbf{p}) &= p_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q},\mathbf{h},\mathbf{h}\}\\ B_{1,1}(\mathbf{p}) &= p_{1}^{2} M_{1} \min\{\mathbf{n}-\mathbf{q},\mathbf{h},\mathbf{h}\}\\ B_{1,2}(\mathbf{p}) &= p_{1}^{2} M_{1} M_{1} \min\{\mathbf{n},\mathbf{h},\mathbf{h},\mathbf{h},\mathbf{h}\}\\ B_{1,2}(\mathbf{p}) &= p_{1}^{2} M_{1} M_{1} \min\{\mathbf{n},\mathbf{h},\mathbf{h},\mathbf{h}\}\\ B_{1,2}(\mathbf{p}) &= p_{1}^{2} M_{1} M_{1} \min\{\mathbf{n},\mathbf{h},\mathbf{h}\}\\ \end{array}$
$\begin{split} & -\frac{4}{9}q_{1}^{2}M_{2}L_{2}d_{2}d_{2}\left(p_{1}\right)\\ & -\frac{4}{9}q_{2}^{2}M_{2}L_{2}d_{2}d_{2}\left(q_{1}-q_{2}\right)\\ & -\frac{4}{9}q_{2}^{2}M_{2}L_{2}d_{2}d_{2}\left(q_{1}-q_{2}\right)\\ & -\frac{4}{9}q_{1}^{2}M_{2}L_{2}d_{2}\left(q_{1}-q_{2}-q_{2}\right)\\ & +\frac{4}{9}M_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{2}+q_{2}\right)\\ & +\frac{4}{9}M_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}-q_{2}\right)\\ & -\frac{4}{9}M_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}-q_{2}\right)\\ & -\frac{4}{9}M_{2}d_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}\right)\\ & -\frac{4}{9}M_{2}d_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}\right)\\ & -\frac{4}{9}M_{2}d_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}\right)\\ & -\frac{4}{9}M_{2}d_{2}d_{2}d_{2}\left(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}\right)\\ & -\frac{4}{9}M_{2}d_{2}d_{2}d_{2}d_{2}d_{2}d_{2}d_{2}d$	$\begin{split} -& 2g_{1}^{2}M_{2}^{2}(d_{1},d_{2},d_{3},d_{$	$\begin{split} -& 2J_{10}(a,b,-\frac{1}{2}M_{10}^{2}\int_{0}^{a}d-\frac{1}{2}M_{10}^{2}\int_{0}^{a}d-\frac{1}{2}M_{10}^{2}\int_{0}^{a}dd\\ -& 3M_{10}^{2}H_{10}^{2}(a,-M_{10})a+M_{10}^{2}H_{10}^{2}(a,-M_{10})d\\ -& 3M_{10}^{2}H_{10}^{2}-M_{10}^{2}H_{10}^{2}h_{10}^{2}h\\ -& 2M_{10}^{2}H_{10}^{2}(a,-M_{10})a\\ -& 2M_{10}^{2}H_{10}^{2}(a,-m_{10})a\\ -& 2M_{10}^{2}H_{10}^{2}(a,-m_{10})a\\ -& M_{10}^{2}H_{10}^{2}(a,-m_{10})a\\ -& M_{10}^{2}H_{10}^{2}H_{10}^{2}(a,-m_{10})a\\ -& M_{10}^{2}H_{10}^{2}H_{10}^{2}H_{10}^{2}(a,-m_{10})a\\ -& M_{10}^{2}H_{10}^{$	$\begin{array}{l} B_{-,1,2}(\mathbf{p}) &= M_{-,2}^{2} \exp\left(-\mathbf{p} + \mathbf{q} + \mathbf{q}\right) \\ &= r_{+}^{2} M_{+}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= r_{+}^{2} M_{+}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= r_{+}^{2} M_{+}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ B_{-,1}(\mathbf{p}) &= -M_{-,2}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= -M_{-,2}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= -M_{-,2}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= -M_{-,2}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ B_{-,1}(\mathbf{p}) &= -M_{-,2}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ B_{-,1}(\mathbf{q}) &= -M_{-,2}^{2} \exp\left(-\mathbf{q} + \mathbf{q} + $
$\begin{split} & -\frac{-4gq^2}{M_{1}}M_{2}^{2}\sin(q_{1}-q_{2})\\ & -\frac{-4gq^2}{M_{1}}M_{2}^{2}\sin(q_{1}-q_{2})\\ & -\frac{-4gq^2}{M_{1}}M_{2}^{2}\sin(q_{1}-q_{2}-q_{1}-q_{1})\\ & +\frac{-4gq^2}{M_{1}}M_{2}^{2}\sin(q_{1}-q_{1}-q_{1}-q_{1})\\ & +\frac{2}{M_{1}}M_{1}^{2}\sin(q_{1}-q_{1}-q_{1}-q_{1})\\ & +\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1}-q_{1})\\ & -\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1}-q_{1})\\ & +\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1}-q_{1})\\ & +\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1}-q_{1})\\ & +\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1}-q_{1})\\ & -\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1}-q_{1})\\ & -\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1}-q_{1})\\ & -\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1})\\ & -\frac{2}{M_{1}}M_{1}^{2}m_{1}^{2}(q_{1}-q_{1})\\ & -\frac{2}{M_{1}}M_{1}^{2}m_{1}^{$	$\begin{split} &-2g_{1}^{2}M_{1}^{2}d_{1}d_{2}d_{2}d_{3}\cos\left(m_{1}\right)\\ &+2g_{1}^{2}M_{1}^{2}d_{2}d_{2}d_{3}d_{3}\cos\left(m_{1}\right)\\ &+2g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos\left(m_{1}\right)\\ &+g_{1}^{2}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3$	$\begin{split} -& 2J_{1} \phi_{1} \phi_{2} + \frac{1}{2} M A_{1}^{2} \phi_{1}^{2} + \frac{1}{2} M A_{2}^{2} \phi_{1}^{2} + \frac{1}{2} M A_{2}^{2} \phi_{2}^{2} + M A_{2}^{2} \phi_{2} + M $	$\begin{array}{l} B_{1,12}(q_1) &= M_{1,12}(m_1(q_1-q_1+q_1+q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1+q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1+q_2))\\ &= m_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1+q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1+q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1+q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_1-q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_1-q_1-q_2))\\ &= p_{1,12}^{(2)}M_{1,12}(m_1(q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-$
$\begin{split} & -\frac{-ig \phi_1^2}{M_1^2} M_2 d_1 \sin(q_1 - q_2) \\ & -\frac{-ig \phi_1^2}{M_1^2} M_2 d_1 \sin(q_1 - q_2) \\ & -\frac{-ig \phi_1^2}{M_1^2} M_2 d_1 \sin(q_1 - q_1 - q_2) \\ & -\frac{-ig \phi_1^2}{M_1^2} M_1 d_2 \sin(q_1 - q_1 - q_1 - q_2) \\ & -\frac{ig \phi_1^2}{M_1^2} M_1 \sin(q_1 - q_1 - q_1 - q_1 - q_1) \\ & -ig \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -d_1 \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -d_2 H_1 \sin(q_1 - q_1) M_1 - d_1 M_1 \sin(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \sin(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1 - q_1) \\ & -g \phi_1^2 M_1 \cos(q_1 - q_1) \\ & -$	$\begin{split} -& 2g_{1}^{2} \delta S_{2}^{2} $	$-3J_{1}\phi_{1}\phi_{2}, -\frac{1}{2}M_{1}J_{1}^{2}g_{1}^{2} - \frac{1}{2}M_{1}J_{1}^{2}g_{1}^{2}$ $-3M_{1}g_{1}^{2}A_{1}A_{2}A_{2}A_{3}A_{3}A_{3}A_{3}A_{3}A_{3}A_{3}A_{3$	$\begin{array}{l} B_{-1,0}(\mathbf{p}) &= M_{n,0}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= p_{n}^{2} M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= p_{n}^{2} M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= p_{n}^{2} M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= -M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= -M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} \\ \\ B_{-1,1}(\mathbf{p}) &= -p_{n}^{2} M_{n}^{2} \exp \left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} \\ \\ B_{-1,1}(\mathbf{p}) &= -p_{n}^{2} M_{n}^{2} M_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} \\ \\ B_{-1,1}(\mathbf{p}) &= -p_{n}^{2} M_{n}^{2} M_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} \\ \\ B_{-1,1}(\mathbf{p}) &= -p_{n}^{2} M_{n}^{2} M_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} \\ \\ B_{-1,1}(\mathbf{p}) &= -p_{n}^{2} M_{n}^{2} M_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} \\ \\ \end{array}$
$\begin{split} & -\frac{-ig_0 q^0}{M_0 d_1} M_0 d_1 \sin(q_1 - q_2) \\ & -\frac{-ig_0 q^0}{M_0 d_1} M_0 d_1 \sin(q_1 - q_2) \\ & -\frac{-ig_0 q^0}{M_0 d_1} M_0 d_1 \sin(q_1 - q_2 - q_3) \\ & +\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_2 - q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_2 - q_3 + q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 + q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 + q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 + q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 + q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 + q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 - q_3 \\ & -\frac{ig_0^0}{M_0} M_0 m_0 q_1 - q_3 \\ & -\frac{ig_0^0}{M_0} M_0 \\ & -\frac{ig_0^0}{M_0$	$\begin{split} &-2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{2}d_{3}\cos(m_{1})g_{2})\\ &+2g_{1}^{20}M_{2}^{2}d_{2}d_{3}d_{3}d_{3}\cos(m_{1})g_{2})\\ &+2g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-g_{2}-m_{2}+g_{3}))\\ &-g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-g_{2}-m_{2}+g_{3}))\\ &-g_{1}^{20}M_{2}^{2}d_{4}d_{3}d_{3}d_{3}\cos(m_{1}-g_{2}-m_{2}+g_{3}))\\ &-g_{1}^{20}M_{2}^{2}d_{4}d_{3}d_{3}d_{3}\cos(m_{1}-g_{2}-m_{2}+g_{3}))\\ &-g_{1}^{20}M_{2}^{2}d_{4}d_{3}d_{3}d_{3}\cos(m_{1}-g_{3}-m_{2}+g_{3})\\ &-g_{1}^{20}M_{2}^{2}d_{4}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-g_{3}-m_{2}+g_{3})\\ &-g_{1}^{20}M_{2}^{2}d_{4}^{2}d_{3}d_{3}d_{3}d_{3}\cos(m_{1}-g_{3}-m_{2}-g_{3})\\ &-g_{1}^{20}M_{2}^{2}d_{4}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3$	$-32_A \phi_{abb} + \frac{1}{2} M M_{a}^2 \phi_{ab}^2 - \frac{1}{2} M M_{a}^2 \phi_{ab}^2$ $-3M_{a}^2 \phi_{ab}^2 - 4M_{a}^2 \phi_{abb} + 3M_{a}^2 \phi_{abb}$ $-3M_{a}^2 \phi_{abb} + 3M_{a}^2 \phi_{abb} - 3M_{a}^2 \phi_{abb}$ $-2M_{a}^2 \phi_{abb} - g_{abb} - g_{abb} - 2M_{a}^2 \phi_{abb}$ $-2M_{a}^2 \phi_{abb} - g_{abb} - g_{a$	$\begin{array}{l} B_{-1,0}(\mathbf{p}) &= M_{n,0}^{2} \exp\left(-\mathbf{p} + \mathbf{q} + \mathbf{q}\right) \\ &= p_{n,0}^{2} M_{n} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= p_{n,0}^{2} M_{n} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= p_{n,0}^{2} M_{n} \exp\left(-\mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ &= M_{n,0}^{2} M_{n}^{2} \exp\left(-\mathbf{q} - \mathbf{q} + \mathbf{q}\right) \\ &= M_{n,0}^{2} M_{n}^{2} \exp\left(-\mathbf{q} - \mathbf{q} + \mathbf{q}\right) \\ \\ &= M_{n,0}^{2} M_{n}^{2} \exp\left(-\mathbf{q} - \mathbf{q} + \mathbf{q}\right) \\ \\ &= M_{n,0}^{2} M_{n,0}^{2} \exp\left(-\mathbf{q} - \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ \\ \\ &= M_{n,0}^{2} M_{n,0}^{2} \exp\left(-\mathbf{q} - \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ \\ \\ &= M_{n,0}^{2} M_{n,0}^{2} \exp\left(-\mathbf{q} - \mathbf{q} + \mathbf{q} + \mathbf{q}\right) \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
$\begin{split} & -\frac{-iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s})\\ & -\frac{-iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s})\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s})+q_{s}\right),\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s}-q_{s})+q_{s}\right),\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s}-q_{s}-q_{s})+q_{s}\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}ad_{s}(q_{s}-q_{s}-q_{s}-q_{s}+q_{s})\\ & -\frac{igF}{4}M_{s}^{2}d_{s}ad_{s}(q_{s}-q_{s}-q_{s}-q_{s}+q_{s})\\ & -\frac{igF}{4}M_{s}^{2}d_{s}ad_{s}(q_{s}-q_{s}-q_{s}-q_{s}+q_{s})\\ & -\frac{igF}{4}M_{s}^{2}d_{s}ad_{s}-q_{s}Ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}ad_{s}d_{s}ad$	$\begin{split} -& 2g_{1}^{2m} M_{2}^{2} (d_{1}^{2}, d_{2}^{2}, d_{3}^{2}, d_{$	$-3J_{1}q_{1}d_{0} = \frac{1}{2}M_{1}f_{1}^{2}q_{1}^{2} = \frac{1}{2}M_{1}f_{1}^{2}q_{1}^{2}$ $-3M_{1}g_{1}^{2}A_{1}(z_{1}, z_{1}, z_{1$	$\begin{array}{l} B_{-1,0}(\mathbf{p}) &= M_{n,0}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= p_{n,0}^{2} M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= p_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= p_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= p_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= -M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= -M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ &= -M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ \\ \\ &= M_{n,0}^{2} \exp\left(-\mathbf{q}_{n} + \mathbf{q}_{n} + \mathbf{q}_{n}\right) \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
$\begin{split} & -\frac{-iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s})\\ & -\frac{-iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s})\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s})+q_{s}\right),\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s}-q_{s})+q_{s}\right),\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}\sin(q_{s}-q_{s}-q_{s}-q_{s})+q_{s}\\ & -\frac{iggF}{4}M_{s}^{2}d_{s}ad_{s}(q_{s}-q_{s}-q_{s}-q_{s}+q_{s})\\ & -\frac{igF}{4}M_{s}^{2}d_{s}ad_{s}(q_{s}-q_{s}-q_{s}-q_{s}+q_{s})\\ & -\frac{igF}{4}M_{s}^{2}d_{s}ad_{s}(q_{s}-q_{s}-q_{s}-q_{s}+q_{s})\\ & -\frac{igF}{4}M_{s}^{2}d_{s}ad_{s}-q_{s}Ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}^{2}d_{s}ad_{s}ad_{s}d_{s}ad$	$\begin{split} &-2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{2}d_{3}\cos(m_{1})g_{2} \\ &+2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{3}d_{3}\cos(m_{1})g_{2} \\ &+2g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}\cos(m_{1})g_{3}\cos(m_{1})g_{3} \\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3$	$\begin{split} +3J_{10}(a,b,-\frac{1}{2}M_{10}^{2}f_{10}^{2}f_{10}^{2}-\frac{1}{2}M_{10}^{2}f_{10}^{2}f_{10}^{2}\\ +3M_{10}^{2}f_{10}^{2}(a,-4M_{10}^{2})+3M_{10}^{2}f_{10}^{2}(a,-M_{10}^{2})f$	$\begin{array}{l} B_{1,1}(q_1) &= M_{1,1}^2 \exp\left(-q_1+q_1+q_1\right) \\ &= p_{1,1}^2 M_{1,1} \exp\left(-q_1-q_1+q_1-q_1\right) \\ &= p_{1,1}^2 M_{1,1} \exp\left(-q_1-q_1+q_1-q_1\right) \\ &= m_{1,1}^2 \exp\left(-q_1-q_1-q_1\right) \\ &= m_{1,1}^2 \exp\left(-q_1-q_1-q_1-q_1\right) \\ &= m_{1,1}^2 \exp\left(-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1$
$\begin{split} & -\frac{-igr q^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{d}x\mathrm{d}x\mathrm{d}y) \\ & -\frac{-igr q^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{d}x\mathrm{d}y, -g_{\pi}) \\ & -\frac{igr q^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{d}x\mathrm{d}y, -g_{\pi}) + g_{\pi} + g_{\pi}^2(x\mathrm{d}y\mathrm{d}y, -g_{\pi}) \\ & -\frac{igr q^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{d}y, -g_{\pi}, -g_{\pi}, -g_{\pi}, -g_{\pi}) \\ & -\frac{igr q^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{d}y, -g_{\pi}) \\ & -\frac{igr q^2}{4M_{\pi}^2}M_{\pi}^$	$\begin{split} -& 2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{2}d_{3}d_{4}d_{4}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5$	$\begin{split} -3F_{1}(a_{1}b_{2}, \cdots, \frac{1}{2}M_{1}E_{1}^{2}E_{1}^{2}C_{1}^{2}C_{2}^{2}M_{1}E_{2}^{2}E_{2}^{2}\\ -3M_{1}E_{2}^{2}F_{1}(a_{1}-a_{2}b_{2})+3M_{2}^{2}S_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-M_{2}^{2}E_{2}b_{2})-3M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-M_{2}^{2}E_{2}b_{2})\\ -2M_{2}^{2}M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -4M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}(a_{2}-a_{2})-2M_{2}^{2}F_{2}b_{2}a_{2}\\ -3M_{2}^{2}F_{2}^{2}$	$\begin{array}{l} B_{-1,2}(\mathbf{p}) &= M_{-1}^{2} \exp\left(-\mathbf{p} + \mathbf{q} + \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{p} + \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} + \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} + \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} + \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf{q} - \mathbf{q}\right) \\ &= r^{2} M_{-1}^{2} \exp\left(-\mathbf{q} - \mathbf$
$\begin{split} & -\frac{-ig_{0}Q^{2}}{M_{1}}M_{2}^{2}dx_{0}^{2}(\mathbf{p}_{1}) \\ & -\frac{-ig_{0}Q^{2}}{M_{2}}M_{2}^{2}dx_{0}^{2}(\mathbf{p}_{1}-\mathbf{p}_{2}) \\ & -ig_{0}Q^{2}M_{2}^{2}dx_{0}^{2}(\mathbf{p}_{1}-\mathbf{p}_{2}) \\ & -ig_{0}Q^{2}M_{2}^{2}dx_{0}^{2}(\mathbf{p}_{1}-\mathbf{p}_{2}) \\ & -ig_{0}Q^{2}M_{1}^{2}dx_{0}^{2}(\mathbf{p}_{1}-\mathbf{p}_{2}) \\ & -ig_{0}Q^{2}M_{1}^{2}dx_{0}^{2}(\mathbf{p}_{2}-\mathbf{p}_{2}) \\ & -ig_{0}Q^{2}M_{1}^{2}dx_{0}$	$\begin{split} &-2g_{1}^{20}M_{1}^{2}d_{2}d_{2}d_{3}d_{4}d_{4}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5$	$\begin{split} +3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2}\\ +3M_{1}f_{2}^{2}f_{1}f_{2}f_{2}+M_{2}f_{2}^{2}\phi_{2}h_{3}+M_{3}f_{2}\phi_{3}h_{3}\\ +M_{1}f_{2}^{2}f_{2}h_{3}+M_{2}f_{2}\phi_{3}h_{3}-M_{3}f_{2}\phi_{3}h_{3}\\ +2M_{2}f_{2}^{2}f_{2}h_{3}h_{3}h_{3}h_{3}h_{3}h_{3}h_{3}h_{3$	$\begin{array}{l} B_{1,1}(q_1) &= M_{1,1}^{1} m(q_1-q_2+q_1+q_1) \\ &= p_{1,1}^{1} M_{1} m(q_1-q_1+q_1+q_1) \\ &= p_{1,1}^{1} M_{1} m(q_1-q_1+q_1+q_1) \\ &= m_{1,1}^{1} m(q_1-q_1+q_1) \\ &= m_{1,1}^{1} m(q_1-q_1+q_1) \\ &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1) \\ &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1) \\ &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1) \\ \\ B_{1,1}(q_1) &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1) \\ \\ B_{1,1}(q_1) &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1) \\ \\ \\ B_{1,1}(q_2) &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1-q_1) \\ \\ \\ B_{1,1}(q_2) &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1-q_1) \\ \\ \\ B_{1,1}(q_2) &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1-q_1) \\ \\ \\ \\ B_{1,1}(q_2) &= m_{1,1}^{1} M_{1} m(q_1-q_1-q_1-q_1-q_1-q_1) \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
$\begin{split} & -\frac{-iggV}{2}M_{2}L\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{-iggV}{2}M_{2}L\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{iggV}{2}M_{2}L\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{iggV}{2}M_{2}L\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{iggV}{2}M_{2}L\sin(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}+q_{2}-q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2}+q_{2}-q_{2})\\ & -\frac{iggV}{2}M_{2}\sin(q_{1}-q_{2}-q$	$\begin{split} &-2g_{1}^{20}M_{2}^{2}d_{1}d_{2}d_{2}d_{3}\exp(m_{1})(p_{1})\\ &+2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{3}\exp(m_{1})(p_{2})\\ &+2g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d_{3}e(m_{1})(p_{1})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d_{3}d_{3}d_{3}d(m_{1})(p_{1})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d(p_{1}d_{3}d_{3}m_{1})(p_{1}-p_{1})\\ &+g_{1}^{20}M_{2}^{2}d_{3}d(p_{1}d_{3}d_{3}m_{1})(p_{1}-p_{1})p_{1}d(p_{1}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3}d_{3$	$\begin{split} -3J_{1}\rho_{1}\rho_{2}\sigma_{1} &= \frac{1}{2}SLS_{1}^{2}S_{1}^{2}\sigma_{1}^{2} &= \frac{1}{2}SLS_{1}^{2}S_{2}^{2}S_{1}^{2}\\ -3J_{1}S_{2}^{2}S_{1}\sigma_{2} &= A_{2}S_{1}^{2}\sigma_{2}\sigma_{2} &= A_{2}S_{2}^{2}\sigma_{2}\sigma_{2} \\ -3J_{2}S_{2}^{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_$	$\begin{array}{l} B_{1,1}(q_1) &= & M_{1,1}^{1} m (q_1-q_2+q_1+q_1) \\ &= & p_{1,1}^{1} M_{1} - m (q_1-q_1+q_1-q_1) \\ &= & p_{1,1}^{1} M_{1} - m (q_1-q_1+q_1-q_1) \\ &= & m (q_1-q_1+q_1+q_1) \\ &= & m (q_1-q_1-q_1+q_1) \\ &= & m (q_1-q_1-q_1-q_1) \\ &= & m (q_1-q_1-q_1-q_1) \\ &= & m (q_1-q_1-q_1-q_1) \\ &= & m (q_1-q_1-q_1-q_1-q_1) \\ &= & m (q_1-q_1-q_1-q_1-q_1) \\ &= & m (q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-$
$\begin{split} & -\frac{-igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2})\\ & -\frac{-igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2})\\ & -\frac{-igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2})\\ & -\frac{-igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2})\\ & +\frac{-igg^{2}}{4}M_{1}^{2}d_{1}\sin(q_{1}-q_{2})\\ & -\frac{-igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{1}\cos(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{2}\cos(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{2}\cos(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igg^{2}}{4}M_{2}^{2}d_{2}\cos(q_{1}-q_{2}-q_$	$\begin{split} &-2g_{1}^{20}M_{1}^{2}d_{2}d_{2}d_{3}d_{4}d_{4}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5$	$\begin{split} -3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2} 8LE_{1}^{2} d_{1}^{2} &= \frac{1}{2} 3LE_{1}^{2} d_{2}^{2} d_{1}^{2} \\ -3J_{1}d_{2}^{2} L_{1}^{2} (z_{1}, (z_{1},$	$\begin{array}{l} B_{-1,0}(\mathbf{p}) &= M_{n,0}^{-1} \exp\left(-\mathbf{p} + \mathbf{q} + \mathbf{q}\right) \\ &= 2^{n} M_{n,0}^{-1} \exp\left(-\mathbf{q} + \mathbf{q} - \mathbf{q}_{n,0}\right) \\ &= 2^{n} M_{n,0}^{-1} \exp\left(-\mathbf{q} + \mathbf{q}_{n,0}\right) \\ &= 2^{n} M_{n,0}^{-1} \exp\left(-\mathbf{q}_{n,0}\right) \\ &= M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} \\ \\ &= M_{n,1}^{-1} \exp\left(-\mathbf{q}_{n,0}\right) \\ &= M_{n,1}^{-1} M_{n,1}^{-1} \exp\left(-\mathbf{q}_{n,0}\right) \\ \\ &= M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} \\ \\ &= M_{n,1}^{-1} \exp\left(-\mathbf{q}_{n,0}^{-1} M_{n,1}^{-1} \exp\left(-\mathbf{q}_{n,0}\right) \\ \\ &= M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} \\ \\ &= M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} \\ \\ &= M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} M_{n,1}^{-1} \\ \\ &= M_{n,1}^{-1} $
$\begin{split} & -\frac{-igr g^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{de}_{\pi}(\eta_{\pi}))\\ & -\frac{-igr g^2}{4M_{\pi}^2}M_{\pi}^2(x\mathrm{de}_{\pi}(\eta_{\pi}-\eta_{\pi}))\\ & -igr g^2M_{\pi}^2(x\mathrm{de}_{\pi}(\eta_{\pi}-\eta_{\pi})+\eta_{\pi}),\\ & -igr g^2(x\mathrm{de}_{\pi}(\eta_{\pi}-\eta_{\pi})+\eta_{\pi})\\ & -igr g^2(x\mathrm{de}_{\pi}(\eta_{\pi}-\eta_{\pi}-\eta_{\pi})+\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}-\eta_{\pi})+\eta_{\pi}+\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}-\eta_{\pi})+\eta_{\pi}+\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})+\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})+\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}+\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}+\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi}-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi}-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}(\eta_{\pi}-\eta_{\pi})-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}-\eta_{\pi})-\eta_{\pi})\\ & -gr g^2M_{\pi}^2(\eta_{\pi}-\eta_{$	$\begin{split} -& 2g_{1}^{22} M_{2}^{2} M_{2}^{$	$\begin{split} -3J_{1}\rho_{1}\rho_{2}\sigma_{1} &= \frac{1}{2}\delta_{1}J_{1}^{2}J_{2}^{2}d_{1}^{2} &= \frac{1}{2}\delta_{1}J_{1}^{2}J_{2}^{2}d_{1}^{2}\\ -3J_{1}J_{2}^{2}J_{1}\sigma_{1} &= J_{1}J_{2}J_{2}^{2}\sigma_{2} \\ -3J_{1}J_{2}^{2}J_{2}\sigma_{2} &= J_{1}J_{2}J_{2}^{2}\sigma_{2} \\ -3J_{2}J_{2}^{2}J_{2}\sigma_{2} &= J_{2}J_{2}J_{2}^{2}\sigma_{2} \\ &= 2J_{2}J_{1}J_{2}J_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma_{2}\sigma$	$\begin{array}{l} B_{1,2,2}(\mathbf{p}) &= M_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \mathcal{H}_{n}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \mathcal{H}_{n}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ \\ \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ \\ \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ &= \mathcal{H}_{n,2}^{2} \operatorname{Met}_{n} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ \\ &= \mathcal{H}_{n,2}^{2} \operatorname{Met}_{n} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ \\ \\ \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{M}_{n}^{2} + \mathbf{p}_{n}^{2} \operatorname{Met}_{n}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ \\ \\ \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n}^{2} \operatorname{Met}_{n}^{2} \operatorname{Met}_{n} + \mathbf{p}_{n}\right) \\ \\ \\ \\ \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n}^{2} \operatorname{Met}_{n}^{2} \operatorname{Met}_{n}\right) \\ \\ \\ \\ \\ \\ \\ \mathcal{H}_{n,2}^{2} \exp\left(-\mathbf{p}_{n}^{2} \operatorname{Met}_{n}^{2} \operatorname{Met}_{n}^{2} \exp\left(-\mathbf{p}_{n} + \mathbf{p}_{n}\right) \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
$\begin{split} & -\frac{-ign Q^2}{M_{1}} M_{1} A \sin(q_1) \\ & -\frac{-ign Q^2}{4M_{1}} M_{2} A \sin(q_1 - q_2) \\ & -ign Q^2} M_{2} A \sin(q_1 - q_2) + g_1 + g_1 + g_1^2 M_{2} M_{2} a \sin(q_1 - q_2) + g_1 + g_1^2 M_{2} M_{2} a \sin(q_1 - q_2) + g_1 + g_1^2 M_{2} M_{2} m_{2} + g_1 - g_1 + g_$	$\begin{split} &-2g_{1}^{20}M_{2}^{2}d_{2}d_{2}d_{3}d_{4}d_{4}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5$	$\begin{split} -3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2} M_{1} \int_{0}^{2} dt = \frac{1}{2} M_{1} \int_{0}^{2} dt \\ -3J_{1} dt \int_{0}^{2} (L_{1} + c_{1}\phi_{2}) + M_{2} M_{2}\phi_{1} \\ -3J_{1} dt \int_{0}^{2} (L_{1} + c_{2}\phi_{2}) + M_{2} M_{2}\phi_{1} \\ -3J_{2} dt \int_{0}^{2} (L_{1} + c_{2}\phi_{2}) \\ -3J_{2} dt \int_{0}^{2} (L_{1} + c_{$	$\begin{array}{l} B_{1,1}(q_1) &= M_{1,2}^{-1} m(q_1-q_2+q_1+q_2) \\ &= 2^{-1} M_{1,2}^{-1} m(q_1-q_2+q_1-q_2) \\ &= 2^{-1} M_{1,2}^{-1} m(q_1-q_1+q_2-q_2) \\ &= 2^{-1} M_{1,2}^{-1} m(q_1-q_1+q_2-q_2) \\ &= M_{1,1}^{-1} m(q_1-q_1+q_2-q_2) \\ &= M_{1,1}^{-1} m(q_1-q_1+q_2-q_2) \\ &= M_{1,1}^{-1} m(q_1-q_1-q_1-q_2-q_1-q_2) \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} \\ &= M_{1,1}^{-1} M_{1,1}^{-1} M_{1,1}^{-1} M_{$
$\begin{split} & -\frac{-igr g^2}{4M_{1}d_{1}}d_{2}d_{2}d_{2}d_{2}d_{2}d_{2}d_{2}d_{$	$\begin{split} -& 2g_{1}^{2}M_{2}^{2}M_{2}^{2}d_{1}^{2}d_{2}^{2}d_{2}^{2}d_{3$	$\begin{split} +& 2J_{1}c(m)_{1} = \frac{1}{2}M_{1}\int_{0}^{2}c_{1}^{2} = \frac{1}{2}M_{1}\int_{0}^{2}d_{1}^{2}\\ +& M_{1}c_{2}^{2}L_{1}(\omega,\omega,m)_{2} + M_{2}M_{2}(m)_{2}\\ +& M_{2}f(m)_{2}^{2} + M_{2}f(m)_{2} \\ +& M_{2}f(m)_{2}^{2} + M_{2}f(m)_{2}\\ -& M_{2}f(m)_{2}^{2} + M_{2}f(m)_{2}\\ -& M_{2}f(m)_{2}^{2} + M_{2}f(m)_{2} \\ +& M_{2}f(m)_{2}^{2} + M_{2}f(m)_{2}^{2} + M_{2}f(m)_{2} \\ +& M_{2}f(m)_{2}^{2} + M_{2$	$\begin{array}{l} B_{-1,2}(\mathbf{p}) &= M_{-1}^{2} \pi m \left( p - p_{0} + q_{0} + q_{0} \right) \\ &= r_{0}^{2} M_{0}^{2} - m \left( r_{0} - q_{0} + r_{0} + q_{0} \right) \\ &= r_{0}^{2} M_{0}^{2} - m \left( r_{0} - q_{0} + q_{0} \right) \\ &= r_{0}^{2} M_{0}^{2} - m \left( r_{0} - q_{0} + q_{0} \right) \\ &= r_{0}^{2} M_{0}^{2} - m \left( r_{0} - q_{0} + q_{0} \right) \\ &= r_{0}^{2} M_{0}^{2} + m \left( r_{0} - q_{0} + q_{0} \right) \\ &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} + q_{0} \\ \\ B_{-1,1}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} + q_{0} \\ \\ B_{-1,1}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} + q_{0} \\ \\ B_{-1,1}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} + q_{0} \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} - q_{0} \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} - q_{0} \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} - q_{0} \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}^{2} - q_{0} - q_{0} - q_{0} \\ \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}(\mathbf{p}) \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}(\mathbf{p}) \\ \\ B_{-1,2}(\mathbf{p}) &= r_{0}^{2} M_{0}^{2} M_{0}(\mathbf{p}) \\ \\ \\ \end{array} \right) \\ \\ \end{array}$
$\begin{split} & -\frac{-ign q^2}{M} M_{\pi}^2 \sin(q_1 - q_2) \\ & -\frac{-ign q^2}{m} M_{\pi}^2 \sin(q_1 - q_2) \\ & -ign q^2 M_{\pi}^2 \sin(q_1 - q_2) + g_1 + g_1 + g_1^2 M_{\pi}^2 \sin(q_1 - q_2) + g_2 + g_1 + g_2 + g_1^2 M_{\pi}^2 \sin(q_1 - q_2 - q_2) + g_1 + g_1 + g_1^2 M_{\pi}^2 \sin(q_1 - q_2 - q_2) + g_1 - g_1 + g_1$	$\begin{split} &-2g_{1}^{20}M_{2}^{2}d_{1}d_{2}d_{2}d_{3}d_{4}d_{4}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5}d_{5$	$\begin{split} +3T_{qrish} &= \frac{1}{2} XL_{q}^{2} [q_{1}^{2} = \frac{1}{2} XL_{q}^{2} [q_{2}^{2} = \frac{1}{2} XL_{q}^{2} [q_{2}^{2} \\ -3X_{q}^{2} [q_{1}^{2} + q_{2}^{2} + q_{2}^{2} + M_{q}^{2} [q_{2}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{2}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M_{q}^{2} + M_{q}^{2} - M_{q}^{2} ] (q_{1}^{2} - M$	$\begin{array}{l} B_{1,1}(q_1) &= M_{1,2}^{-1}(q_1-q_2+q_1+q_2)\\ &= M_{1,2}^{-1}(M_{1,2}-q_1(q_1-q_1+q_2-q_2))\\ &= M_{1,2}^{-1}(M_{1,2}-q_1(q_1-q_2-q_1-q_2))\\ &= M_{1,2}^{-1}(q_1-q_1-q_1-q_2)\\ &= M_{1,2}^{-1}(q_1-q_1-q_1-q_2-q_1)\\ &= M_{1,2}^{-1}(q_1-q_1-q_1-q_1-q_1)\\ &= M_{1,2}^{-1}(q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-$
$\begin{split} & -\frac{-igr^2}{4}M_{1}^2A_{1}\sin(q_{1}-q_{2})\\ & -\frac{-igr^2}{4}M_{2}^2A_{1}\sin(q_{1}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\cos(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\cos(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2$	$\begin{split} -& 2g_{1}^{2}M_{2}^{2}(d_{1}^{2},d_{2}^{2},d_{3}^{2}$	$\begin{split} -3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2} \delta \mathcal{L}_{1}^{2} \mathcal{L}_{2}^{2} &= \frac{1}{2} \delta \mathcal{L}_{1}^{2} \mathcal{L}_{2}^{2} \\ -3J_{12}\mathcal{L}_{2}^{2} &= (z_{1}+z_{2},z_{2})_{2} + 3J_{2}\mathcal{L}_{2}^{2} \\ &= J_{12}\mathcal{L}_{2}^{2} \phi_{2} &= J_{12}\mathcal{L}_{2}^{2} \phi_{2} \\ &= J_{2}\mathcal{L}_{2}^{2} \phi_{2}^{2} &= J_{2}\mathcal{L}_{2}^{2} \phi_{2} \\ &= J_{2}\mathcal{L}_{2}^{2} \mathcal{L}_{2}^{2} &= (z_{1}-z_{2}) \\ &= J_{2}\mathcal{L}_{2}^{2} \mathcal{L}_{2}^{2} &= J_{2}^{2} \mathcal{L}_{2}^{2} \\ &= J_{2}\mathcal{L}_{2}^{2} \mathcal{L}_{2}^$	$\begin{array}{l} B_{1,1}(q_1) &= & ML_{2} \exp\left(-q_2+q_1+q_1\right) \\ &= & 2 ML_{2} \exp\left(-q_1-q_1+q_1+q_1\right) \\ &= & 2 ML_{2} \exp\left(-q_1-q_1+q_1-q_1\right) \\ &= & 2 ML_{2} \exp\left(-q_1-q_1-q_1-q_1\right) \\ &= & 2 ML_{2} \exp\left(-q_1-q_1-q_1-q_1\right) \\ &= & 2 ML_{2} \exp\left(-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1-q_1$
$\begin{split} & -\frac{-ig_{0} q_{1}^{2} M_{1} d_{1} \sin (g_{1} - g_{2})}{-ig_{0} q_{1}^{2} M_{2} d_{1} \sin (g_{1} - g_{2})}{-ig_{0} q_{1}^{2} M_{2} d_{1} \sin (g_{1} - g_{2})}{-ig_{0} q_{1}^{2} M_{2} d_{2} \sin (g_{1} - g_{1})}{-ig_{0} q_{1}^{2} d_{1} \sin (g_{1} - g_{1})}{-ig_{0} q_{1}^{2} d_{1} \sin (g_{1} - g_{1})}{-ig_{0} q_{1} q_{1} (g_{1} - g_{1})}{-ig_{0} q_{1}^{2} d_{1} (g_{1} - g_{1})}{-ig_{0} q_{1} q$	$\begin{split} &-2g_{1}^{22}M_{2}^{2}M_{2}^{2}g_{1}^{2}g_{2}^{2}g_{3$	$\begin{split} -3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2}\\ -M_{1}f_{2}^{2}f_{1}\phi_{1} &= M_{2}f_{2}^{2}\phi_{2} &= M_{2}f_{2}^{2}\phi_{2} \\ -M_{2}f_{2}^{2}\phi_{2} &= M_{2}f_{2}\phi_{2} \\ -M_{2}f_{2}^{2}\phi_{2} &= M_{2}f_{2}\phi_{2} \\ -M_{2}f_{2}^{2}f_{2}\phi_{2} &= M_{2}f_{2}\phi_{2} \\ -M_{2}f_{2}^{2}f_{2}\phi_{2} &= m_{2}\phi_{2} \\ -M_{2}f_{2}^{2}f_{2}\phi_{2} &= m_{2}\phi_{2} \\ -M_{2}f_{2}^{2}f_{2}\phi_{2}\phi_{2} &= m_{2}\phi_{2} \\ -M_{2}f_{2}^{2}f_{2}\phi_{2}\phi_{2}\phi_{2} \\ -M_{2}f_{2}^{2}f_{2}\phi_{2}\phi_{2}\phi_{2}\phi_{2}\phi_{2}\phi_{2}\phi_{2}\phi$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{split} & -\frac{-igr^2}{4}M_{1}^2A_{1}\sin(q_{1}-q_{2})\\ & -\frac{-igr^2}{4}M_{2}^2A_{1}\sin(q_{1}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}^2A_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\cos(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\cos(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{igr^2}{4}M_{2}\sin(q_{1}-q_{2$	$\begin{split} -& 2g_{1}^{2}M_{2}^{2}M_{2}^{2}(x_{1}^{2},y_{2}^{2},y_{3}^{2},$	$\begin{split} +3L_{plach} &= \frac{1}{2} M_{a} \int_{0}^{2} dt = \frac{1}{2} M_{a} \int_{0}^{2} dt \\ &= M_{a} (R_{a} (L_{a} (m_{b} (m_{b} + M_{a} (M_{b} m_{b} - M_{b} M_{b} m_{b} - M_{a} (M_{b} M_{b} - M_{b} m_{b} - M_{b} M_{b} M_{b} m_{b} - M_{b} M_{b} M_{b} m_{b} m_{b} - M_{b} M_{b} M_{b} m_{b} m_{b} m_{b} - M_{b} M_{b} M_{b} m_{b} m_{b} m_{b} - M_{b} m_{b$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$ \begin{array}{c} -\frac{-i \pi q^2}{q_1} M_{1,2}^2 \sin(q_1-q_2) \\ -\frac{-i \pi q^2}{q_2} M_{1,2}^2 \sin(q_1-q_2) \\ -\frac{-i \pi q^2}{q_1} M_{2,2}^2 \sin(q_1-q_2) \\ -\frac{-i \pi q^2}{q_2} M_{2,2}^2 M_{2,2}^2 M_{2,2}^2 \\ -\frac{-i \pi q^2}{q_2} M_{2,2}^2 \\ --$	$\begin{split} &-2g_{1}^{20}M_{1}^{2}M_{2}^{2}g_{1}^{2}g_{2}^{2}g_{3$	$\begin{split} -3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2}\\ -M_{1}f_{2}^{2}f_{1}\phi_{1}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2}\\ -M_{2}f_{2}^{2}\phi_{2}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2}\\ -M_{2}f_{2}^{2}\phi_{2}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2}\\ -M_{2}f_{2}^{2}f_{2}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2}\\ -M_{2}f_{2}^{2}f_{2}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2}\\ -M_{2}f_{2}^{2}f_{2}^{2}f_{2}^{2} &= M_{2}f_{2}^{2}\phi_{2}^{2}\\ -M_{2}f_{2}^{2}f_{2}^{2}f_{2}^{2}\phi_{2}^{2}\phi_{2}^{2}f_{2}^{2}\phi_{2}^$	$\begin{array}{l} B_{1,2}(q_2) &= M_{2,1}^{-1} m(q_1-q_2+q_2+q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_2+q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_2+q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_2+q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_2+q_3-q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_3-q_3-q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_3-q_3-q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_3-q_3-q_3-q_3) \\ &= r^{-1} M_{2,2}^{-1} m(q_1-q_3-q_3-q_3-q_3-q_3-q_3-q_3-q_3-q_3-q_3$
$ \begin{array}{rcl} -\frac{-iggV}{2}M_{2}d_{2}\sin(q_{1}-q_{2})\\ & -\frac{-iggV}{2}M_{2}d_{2}\sin(q_{1}-q_{2})\\ & -\frac{-iggV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2})\\ & +\frac{igV}{2}M_{2}\sin(q_{1}-q_{2}-q_{1}-q_{2}-q_{1})\\ & +\frac{igV}{2}M_{2}\sin(q_{1}-q_{2}-q_{1}-q_{2}-q_{1})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2}-q_{1})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2}-q_{2})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2}-q_{2})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{1}-q_{1}-q_{2}-q_{2})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2}-q_{2})\\ & -\frac{igV}{2}d_{2}\sin(q_{1}-q_{2}-q_$	$-\frac{2g^{2}}{2}M_{2}^{2}M_{2}^{2}H_{2}^$	$\begin{split} -3J_{1}\phi_{1}\phi_{1} &= \frac{1}{2}\delta_{1}J_{1}^{2}J_{1}^{2}d_{1}^{2} &= \frac{1}{2}\delta_{1}J_{1}^{2}J_{2}^{2}d_{1}^{2}\\ -3J_{1}J_{2}^{2}J_{1}\phi_{1} &= J_{1}J_{2}^{2}J_{2}\phi_{1} &= J_{1}J_{2}^{2}J_{2}\phi_{1} \\ -3J_{1}J_{2}^{2}J_{2}\phi_{1} &= J_{2}J_{2}^{2}J_{2}\phi_{1} \\ -3J_{2}J_{2}^{2}J_{2}\phi_{1} &= J_{2}J_{2}^{2}J_{2}\phi_{1} \\ -3J_{2}J_{2}^{2}J_{2}\phi_{1} &= J_{2}J_{2}J_{2}\phi_{1} \\ -3J_{2}J_{2}^{2}J_{2}\phi_{1} &= J_{2}J_{2}J_{2}J_{2}\phi_{1} \\ -3J_{2}J_{2}^{2}J_{2}\phi_{1} &= J_{2}J_{2}J_{2}J_{2}\phi_{1} \\ -J_{2}J_{2}J_{2}^{2}J_{2}\phi_{1} &= J_{2}J_{2}J_{2}J_{2}\phi_{1} \\ -J_{2}J_{2}J_{2}J_{2}^{2}J_{2}\phi_{1}^{2}J_{2}\phi_{2}J_{2}^{2}J_{2}\phi_{1}^{2}J_{2}\phi_{1}J_{2}J_{2}J_{2}J_{2}J_{2}J_{2}J_{2}J_{2$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$ \begin{array}{c} -\frac{-i \pi q^2}{4} M_{1}^2 A \sin \left( q_1 \right) \\ -\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ -\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_1 - q_2 \right) \\ +\frac{-i \pi q^2}{4} M_{2}^2 A \sin \left( q_2 \right) \\ +\frac{-i \pi q^2}{4$	$\begin{split} &-\frac{2\pi^2}{2} \frac{\delta M_{11}^2 \delta M_{12}^2 \delta M$	$\begin{split} +3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2}\\ &= M_{1}f_{2}^{2}f_{1}f_{2}f_{1}+M_{2}^{2}f_{2}g_{2}h_{2}-M_{2}f_{2}^{2}f_{2}g_{2}h_{2}\\ &= M_{1}f_{2}^{2}f_{2}f_{2}h_{2}^{2}-M_{2}f_{2}^{2}g_{2}h_{2}\\ &= M_{2}f_{2}^{2}f_{2}h_{2}^{2}h_{2}h_{2}^{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{split} & -\frac{-iq}{2}q_{1}^{2}M_{2}L_{2}\sin(q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}L_{2}\sin(q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}L_{2}\sin(q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}L_{2}\sin(q_{1}-q_{2}-q_{1}-q_{2})\\ & +\frac{-iq}{2}M_{2}\sin(q_{1}-q_{2}-q_{1}-q_{2})\\ & +\frac{-iq}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & +\frac{-iq}{2}M_{2}\sin(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{1}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}M_{2}(q_{1}-q_{2}-q_{2}-q_{2})\\ & -\frac{-iq}{2}M_{2}M_{2}M_{2}M_{2}\\ & -\frac{-iq}{2}M_{2}M_{2}M_{2}\\ & -\frac{-iq}{2}$	$\begin{split} &-\frac{2\pi^2}{2} M_{12}^{2} M_{12$	$\begin{split} -3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2} \delta \mathcal{L}_{1}^{2} \mathcal{L}_{2}^{2} &= \frac{1}{2} \delta \mathcal{L}_{1}^{2} \mathcal{L}_{2}^{2} \\ -3J_{1}\mathcal{L}_{2}^{2} &= J_{1}^{2} + J_{2}^{2} \mathcal{L}_{2}^{2} &= J_{2}^{2} + J_{2}^{2} \mathcal{L}_{2}^{2} \\ &= J_{1}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} &= J_{2}^{2} \phi_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \mathcal{L}_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} - J_{2}^{2} \phi_{2}^{2} \\ &= J_{2}^{2} \phi_{2}^{2} - J_{2}^$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$ \begin{array}{rcl} -\frac{-igr{q}^2}{2}M_{1}(d_{1}+ig_{1}, g_{1}-g_{1}) \\ & -\frac{-igr{q}^2}{2}M_{1}(d_{1}+ig_{1}-g_{2}) \\ & -\frac{-igr{q}^2}{2}M_{1}(d_{1}+ig_{1}-g_{1}-g_{1}-g_{1}) \\ & +\frac{-igr{q}^2}{2}M_{1}(d_{1}+ig_{1}-g_{1}-g_{1}-g_{1}+g_{1}) \\ & +\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}+g_{1}) \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}+g_{1}) \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}+g_{1}) \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}) \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}-g_{1}) \\ \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}-g_{1}) \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}-g_{1}) \\ \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_{1}-g_{1}-g_{1}-g_{1}-g_{1}-g_{1}-g_{1}) \\ \\ & -\frac{-igr{q}^2}{2}M_{1}(ig_{1}-g_$	$\begin{split} -& 2g_{1}^{2}M_{2}^{2}M_{2}^{2}g_{1}^{2}g_{2}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}g_{3}^{2}g_{3}g_{3}g_{3}g_{3}g_{3}g_{3}g_{3}g_{3$	$\begin{split} +3J_{1}\phi_{1}\phi_{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2} &= \frac{1}{2}M_{1}f_{1}^{2}f_{2}^{2}\\ &= M_{1}f_{2}^{2}f_{1}f_{2}f_{1}+M_{2}^{2}f_{2}g_{2}h_{2}-M_{2}f_{2}^{2}f_{2}g_{2}h_{2}\\ &= M_{1}f_{2}^{2}f_{2}f_{2}h_{2}^{2}-M_{2}f_{2}^{2}g_{2}h_{2}\\ &= M_{2}f_{2}^{2}f_{2}h_{2}^{2}h_{2}h_{2}^{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_{2}h_$	$\begin{array}{lll} B_{1,1}(q_2) &=& ML_{2}^{2} m (q_1 - q_2 + q_2 + q_3) \\ &=& 2 ML_{2}^{2} m (q_1 - q_2 + q_3 - q_3) \\ &=& 2 ML_{2}^{2} m (q_1 - q_3 + q_3 - q_3) \\ &=& 2 ML_{2}^{2} m (q_1 - q_3 + q_3 - q_3) \\ &=& 2 ML_{2}^{2} m (q_1 - q_3 + q_3 - q_3) \\ &=& 2 ML_{2}^{2} m (q_1 - q_3 + q_3 - q_3) \\ &=& 2 ML_{2}^{2} ML_{2}^{2} m (q_1 - q_3 - q_3 - q_3) \\ &=& 2 ML_{2}^{2} ML_{2}^{2} m (q_1 - q_3 - q_3 - q_3) \\ &=& 2 ML_{2}^{2} ML_{2}^{2} m (q_1 - q_3 - q_3 - q_3) \\ &=& 2 ML_{2}^{2} ML_{2}^{2} m (q_1 - q_3 - q_3 - q_3 - q_3) \\ &=& 2 ML_{2}^{2} ML_{2}^{2} m (q_1 - q_3 - q_3 - q_3 - q_3 - q_3) \\ &=& 2 ML_{2}^{2} ML_{2}^{2} m (q_1 - q_3 -$
$\begin{split} & -\frac{-igr^2}{2}M_{1}^2 L_{2}^2 dx_{1}^2(y_{1}) \\ & -\frac{-igr^2}{-igr^2}M_{2}^2 L_{2}^2 dx_{1}^2(y_{1}-y_{2}) \\ & -\frac{-igr^2}{-igr^2}M_{2}^2 L_{2}^2 dx_{1}^2(y_{1}-y_{2}) \\ & -\frac{-igr^2}{-igr^2}M_{2}^2 L_{2}^2 dx_{1}^2(y_{1}-y_{2}) \\ & -\frac{-igr^2}{-igr^2}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}-y_{1}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}-y_{1}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}-y_{1}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}-y_{2}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}-y_{2}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}-y_{2}-y_{2}-y_{2}-y_{2}) \\ & -\frac{-igr^2}{-igr}M_{2}^2 dx_{1}^2 dx_{1}^2(y_{1}-y_{2}$	$\begin{split} &-\frac{2\pi^2}{2} M_{12}^{2} M_{12$	$\begin{split} +3I_{1}\phi_{1}\phi_{1} &= \frac{1}{2}MA_{1}^{2}\phi_{1}^{2} &= \frac{1}{2}MA_{1}^{2}\phi_{2}^{2}\phi_{1}^{2}\\ +3M_{1}^{2}\phi_{1}^{2}(z_{1},z_{1},z_{2},z_{3},z$	$\begin{array}{lll} B_{-1,0}(\mathbf{p}) &=& M_{-1}^{2} g(m_{0}^{-1}-m_{0}^{-1}+m_{1}^{-1})\\ &=& M_{-1}^{2} M_{-1}^{-1} g(m_{0}^{-1}-m_{1}^{-1}+m_{1}^{-1})\\ &=& M_{-1}^{2} M_{-1}^{-1} g(m_{0}^{-1}+m_{1}^{-1}+m_{1}^{-1})\\ &=& M_{-1}^{-1} g(m_{0}^{-1}-m_{1}^{-1}+m_{1}^{-1}+m_{1}^{-1})\\ &=& M_{-1}^{-1} g(m_{0}^{-1}-m_{1}^{-1}+m_{1}^{-1})\\ &=& M_{-1}^{-1} g(m_{0}^{-1}-m_{1}^{-1})\\ &=& M_{-1}^{-1} g(m_{0}^{-1}-m_{1}^{-1})\\ &=& M_{-1}^{-1} g(m_{0}^{-1}-m_{1}^{-1}+m_{1}^{-1})\\ &=& M_{$
$\begin{split} & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{2} d_{2} d_{2} (p_{1}) \\ & -\frac{1}{2} \phi_{2}^{2} M_{2} d_{2} d_{2} d_{2} d_{2} (p_{1} - p_{1}) \\ & -\frac{1}{2} \phi_{2}^{2} M_{2} d_{2} d_{2} d_{2} d_{2} (p_{1} - p_{1}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{2} d_{2} d_{2} d_{2} d_{2} (p_{1} - p_{1}) \\ & +\frac{1}{2} \phi_{1}^{2} M_{1} d_{2} d_{2} d_{2} d_{2} (p_{1} - p_{1}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{2} d_{2} d_{2} - p_{1} + p_{1} + p_{1} \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{1} d_{2} - p_{1} - p_{1} + p_{1} + p_{1} \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{1} d_{1} - p_{1} - p_{1} + p_{1} + p_{1} \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{1} d_{1} d_{2} d_{2} d_{2} \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{2} d_{1} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{1} d_{1} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} d_{2} \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} d_{1} d_{1} d_{1} d_{1} d_{2} $	$\begin{split} -& -2g^{22} M_{21}^{22} M_{22}^{2} M_{2}$	$\begin{split} -4J_{1}\phi_{1}\phi_{1} &= \frac{1}{2}4Ld_{1}^{2}d_{1}^{2} &= \frac{1}{2}4Ld_{1}^{2}d_{2}^{2} \\ -M_{11}d_{2}^{2}A_{1}^{2}A_{1}^{2}A_{2}^{2}$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{split} & -\frac{1}{2} \phi_{1}^{2} M_{1} d_{1} \sin(q_{1} - q_{2}) \\ & -\frac{1}{2} \phi_{2}^{2} M_{2} d_{1} \sin(q_{1} - q_{2}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{2} d_{1} \sin(q_{1} - q_{2}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{2} d_{1} \sin(q_{1} - q_{2}) \\ & -\frac{1}{2} \phi_{1}^{2} m_{1}^{2} \phi_{1} \cos(q_{1} - q_{2}) \\ & -\frac{1}{2} \phi_{1}^{2} m_{1}^{2} \phi_{1} \cos(q_{1} - q_{2}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\frac{1}{2} \phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{2} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{2} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{2} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{2} - q_{1}) \\ & -\phi_{1}^{2} M_{2} (q_{1} - q_{1} - q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{1}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{2}) \\ \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{2}) \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_{2}) \\ \\ & -\phi_{1}^{2} M_{1} (q_{1} - q_$	$\begin{split} &-2g_{1}^{2}M_{2}^{2}M_{2}^{2}g_{1}^{2}g_{2}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}^{2}g_{3}g_{3}g_{3}g_{3}g_{3}g_{3}g_{3}g_{3$	$\begin{split} +3L_p(a)a, = \frac{1}{2}M_{1}^{2}f_{1}^{2}d_{1}^{2} = \frac{1}{2}M_{1}^{2}f_{2}^{2}d_{1}^{2}\\ +3M_{1}^{2}f_{1}^{2}(z_{1}+A_{2}^{2}(z_{1})) + M_{2}^{2}f_{2}(z_{1})\\ +M_{1}^{2}f_{2}^{2}(z_{1}+A_{2}^{2}(z_{1})) + M_{2}^{2}f_{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) + M_{2}^{2}f_{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) - M_{2}^{2}f_{2}^{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) - M_{2}^{2}f_{2}^{2}(z_{1}) - M_{2}^{2}f_{2}^{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1})\\ +M_{2}^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1}) - L^{2}f_{2}^{2}(z_{1})\\ +L^{2}f_{2}^{2}(z_{1}^{2}-z_{1}^{2}z_{1}^{2}+z_{1$	$\begin{array}{lll} B_{1,1}(q_2) &=& M_{n,1}^{2} \min\{q_{-},q_{-}+q_{+}+q_{1}\}\\ &=& M_{n,2}^{2} M_{n} - m(q_{-}-q_{-}+q_{-}+q_{1})\\ &=& M_{n}^{2} M_{n} - m(q_{-}-q_{-}+q_{-}+q_{1})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}+q_{-}+q_{1})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}+q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}+q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}+q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}+q_{-}-q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}-q_{-}-q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}-q_{-}-q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}-q_{-}-q_{-})\\ &=& M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}-q_{-}-q_{-})\\ &=& M_{n}^{2} M_{n}^{2} M_{n}^{2} m(q_{-}-q_{-}-q_{-})\\ &=& M_{n}^{2} M_{n}^{2} M_{n}^{2} m(q_{-}-q_$
$\begin{split} & -\frac{i}{2}q_{1}^{2}M_{1}^{2}d_{1}d_{2}d_{2}d_{2}(q_{1})\\ & -\frac{i}{2}q_{2}^{2}M_{1}^{2}d_{2}d_{2}d_{2}(q_{1}-q_{2})\\ & -\frac{i}{2}q_{2}^{2}M_{1}^{2}d_{2}d_{2}d_{2}(q_{1}-q_{2})\\ & -\frac{i}{2}q_{1}^{2}M_{1}^{2}d_{2}d_{2}d_{2}(q_{1}-q_{2})\\ & +\frac{i}{2}q_{1}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{2}+q_{1})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{2}+q_{1})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{2}+q_{1})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{1}+q_{2})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{1}+q_{2})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{1}+q_{2}-q_{2})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{1}+q_{2}-q_{2})M_{1}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{1}(q_{1}-q_{1}-q_{2}-q_{1}-q_{2})M_{2}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{2}(q_{1}-q_{2}-q_{1}-q_{1}-q_{2}-q_{2}-q_{2})M_{2}^{2}\\ & -\frac{i}{2}q_{1}^{2}M_{2}^{2}M_{2}(q_{1}-q_{2}-q_{1}-q_{2}-q$	$\begin{split} -& -2g^{22} M_{21}^{22} M_{22}^{2} M_{2}$	$\begin{split} -4J_{1}\phi_{1}\phi_{1} &= \frac{1}{2}4Ld_{1}^{2}d_{1}^{2} &= \frac{1}{2}4Ld_{1}^{2}d_{2}^{2} \\ -3M_{1}^{2}d_{1}^{2}c_{1}^{2}-4M_{2}^{2}d_{2}^{2}a_{1}^{2}-4M_{2}^{2}d_{2}^{2}-4M$	$\begin{array}{llllllllllllllllllllllllllllllllllll$

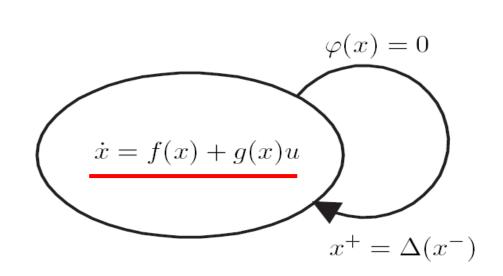
	AREA AND ROBITSCHICK STRATE STRATE	NAMES OF STREET	ALTER BOOTANN	a EQUATION DETAILS FOR SUMMINION TO IEEE	FRAME OF AUTOMOTIV CONTROL - RECEILAR PAPER
C <sub>8,0</sub> 090 = -	$\begin{split} &+ \log^2 M_{1} \sin((\alpha-\eta_{1})-\alpha)\\ &+ \log^2 M_{2} \sin((\alpha-\eta_{2})-\alpha)\\ &+ \log^2 M_{2}$	$C_{k,l}(t) =$ $C_{k,l}(t) =$ $C_{k,l}(t) =$ $C_{l,k}(t) =$	$\begin{split} &-\cos(n_1)(n_1 - q_1^{-1}, \cos(n_1 - q_1 + n_1 + q_2)) \\ &-\cos(n_1 - q_1^{-1}, \cos(n_1 - q_1^{-1}, m_1 + m_1)) \\ &-m_1^{10}M_1(q_1^{-1}, m_1^{-1}, m_1$	$+ig_0\eta^0 M_T \rho L_0 \sin(q_0 - q_0 + q_1)$ $+ig_0\eta^0 M_T \rho L_0 \sin(q_0 - q_0 + q_1)$ $-ig_0\eta^0 M_T \rho L_0 \sin(q_0 - q_0)$ $C_{h_1}$ $+ig_0\eta^0 M_T P L_0 \sin(q_0 - q_0)$	$\begin{split} & - (c_{ij}q_{ij}^{2j}M_{i}d_{j}+d_{ij}q_{ij}q_{ij}) \\ & - (c_{ij}q_{ij}^{2j}M_{i}d_{j}+d_{ij}q_{ij}q_{ij}) \\ & - (c_{ij}q_{ij}^{2j}M_{i}d_{j}+d_{ij}q_{ij}) \\ & - (c_{ij}M_{i}d_{ij}d_{ij}+d_{ij}q_{ij}) \\ & - (c_{ij}M_{i}d_{ij}d_{ij}q_{ij}) \\ & - (c_{ij}M_{ij}d_{ij}d_{ij}q_{ij}) \\ & - (c_{ij}M_{ij}d_{ij}d_{ij}q_{ij}) \\ \\ & - (c_{ij}M_{ij}d_{ij}) \\ \\ & - (c_{ij}M_{ij}d_{ij}d_{ij}q_{ij}) \\ \\ & - (c_{ij}M_{ij}d_{ij}) \\ \\ \\ & - (c_{ij}M_{ij}d_{ij}q_{ij}) \\ \\ & - (c_{ij}M_{ij}d_{ij}q_{ij}) \\ \\ \\ & - (c_{ij}M_{ij}d_{ij}q_{ij}) \\ \\ $
	$D_{e,4,7}(q_e)$	=		$1 - q_2 + q_3 - q_4 + q_5$	
	$D_{e,5,1}(q_e)$	=		$-M_t L_f^2 - 2p_t^M M_t L_f$	
	$D_{e,5,2}(q_e)$	=		$(q_4) - I_f - I_t - M_t$	-
	$D_{e,5,3}(q_e)$	=	-	$s(q_3) - 2p_t^M M_t L_f \cos^2 q_3$	$\operatorname{os}(q_4)$
			,	$+I_t + 2M_t L_f^2$	D
	$D_{e,5,4}(q_e)$		$p_t^M M_t L_f \cos\left(\right.$	- /	$D_{e,7}$ ,
	$D_{e,5,5}(q_e)$	=		$\operatorname{os}(q_3) - 2p_t^M M_t L_f$	$\cos(q_4)$
			$+I_{T}+2I_{f}$ -	$+2I_t+2M_tL_f^2$	
	$D_{e,5,6}(q_e)$	=	$M_t L_f \cos\left(q_3 - M_t L_f\right)$		
			-	$(q_1 - q_2 + q_3 + q_5)$	
				$(q_1 - q_2 + q_3 - q_4 +$	
				$s(q_1 - q_2 + q_3 + q_5)$	$D_{e,7}$
			$+\cos(q_1+q_3+q_5) p_T^M M_T \qquad D_{e,7}$		
			$+p_f^M M_f \cos$	$s(q_3+q_5)-p_t^M M_t$ or	$\cos(q_5)$
	$D_{e,5,7}(q_e)$	=	$-M_t L_f \sin\left(q_3\right)$	- /	
			-	$(q_1 - q_2 + q_3 + q_5)$	
				$(q_1 - q_2 + q_3 - q_4 +$	$-q_5)$
				$q_3 + q_5) p_T^M M_T$	_
			$-p_f^M M_f \sin$	$(q_1 - q_2 + q_3 + q_5)$	$D_{e,7}$
			$-p_f^M M_f \sin$	$(q_3 + q_5) + p_t^M M_t s$	$in(q_5) = D_{e,7}$







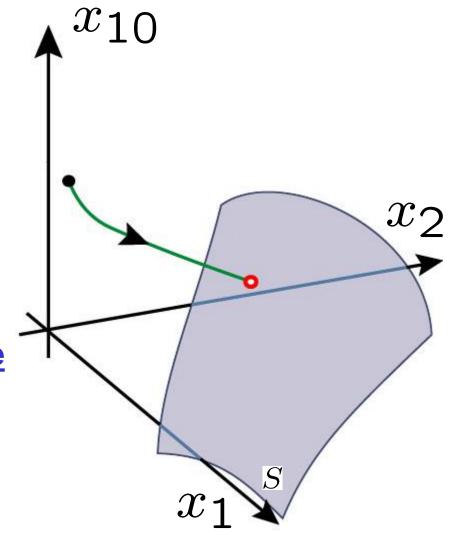




**Switching Surface or Impact Surface** 

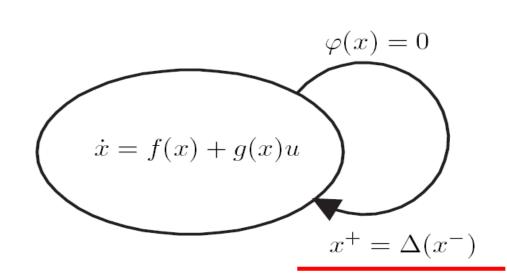
$$S = \{x \in \mathcal{X} \mid \varphi(x) = 0\}$$

(Hyper Surface in state space  $\mathcal{X}$ )



 $x_{10}$ 

 $x_2$ 

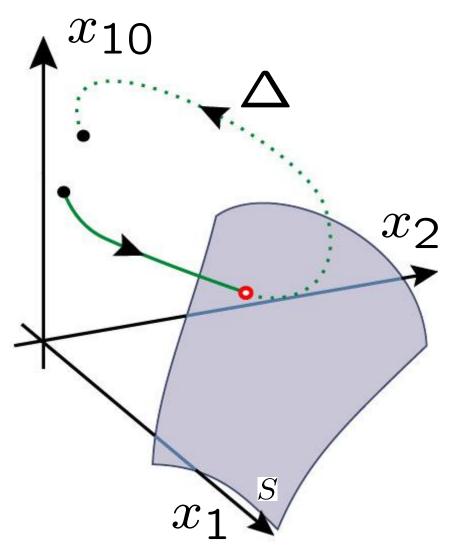


**Switching Surface or Impact Surface** 

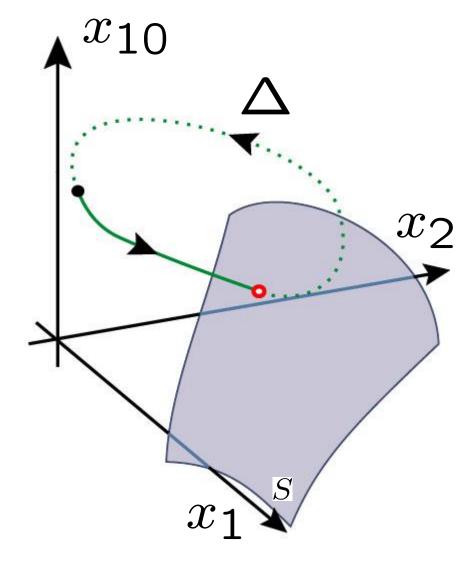
$$S = \{x \in \mathcal{X} \mid \varphi(x) = 0\}$$

(Hyper Surface in state space  $\mathcal{X}$ )

Most solutions are not periodic!

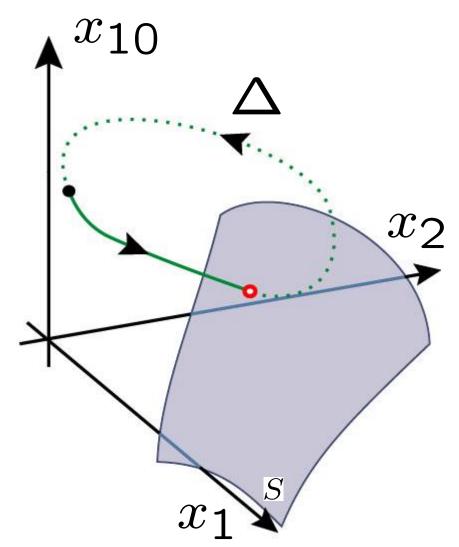


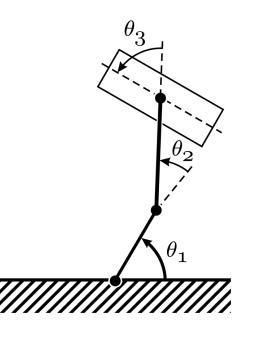
Harder than shown because require stability too!



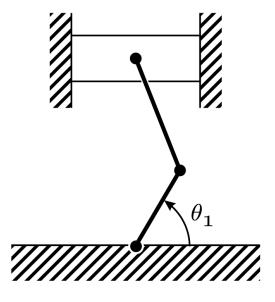
Our Approach

- Step 1: Use Virtual Constraints to reduce the complexity of the problem
- **Step 2:** Optimize performance within the obtained feedback structure...

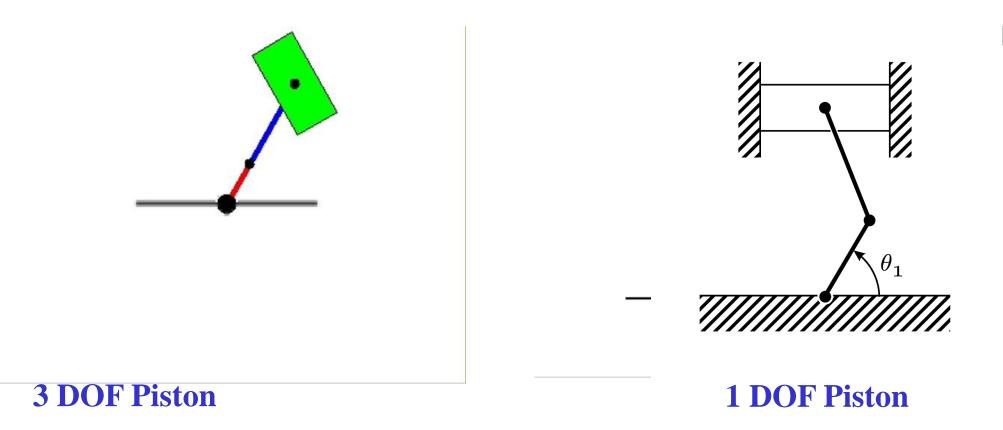


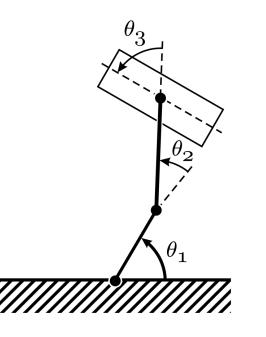


**3 DOF Piston** 

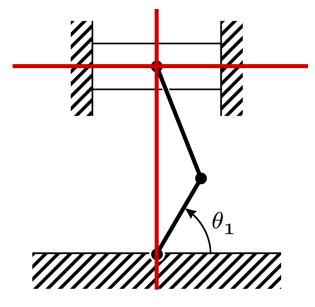


**1 DOF Piston** 



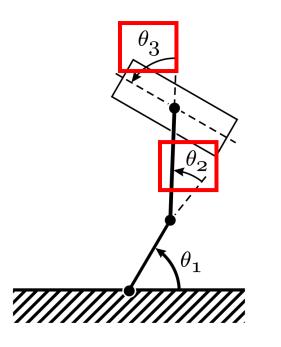


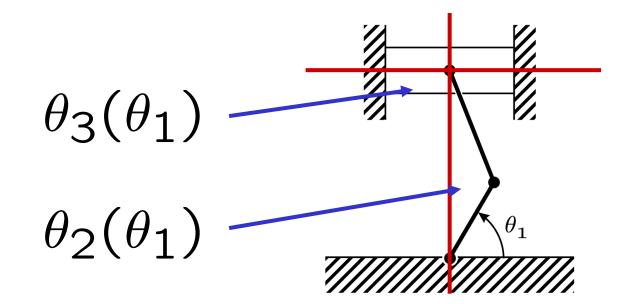
#### **3 DOF Piston**



**1 DOF Piston** 

Cylinder walls impose 2 Constraints

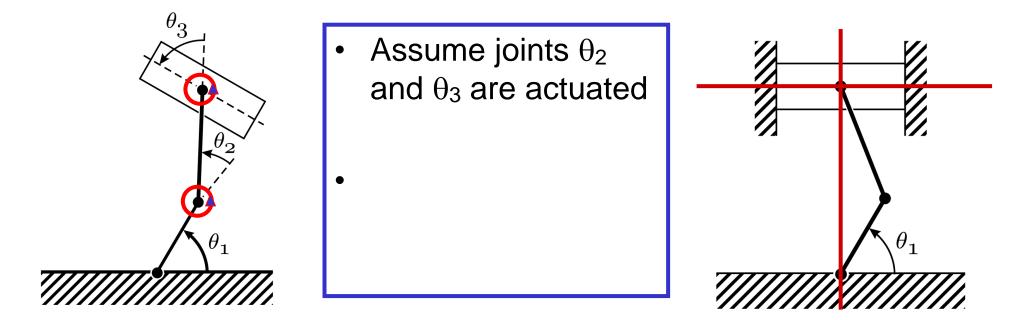




#### **3 DOF Piston**

#### **1 DOF Piston**

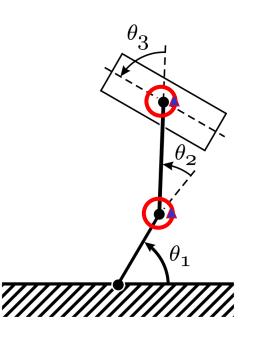
$$\begin{bmatrix} \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} \pi - \theta_1 - \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \\ \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \end{bmatrix}$$



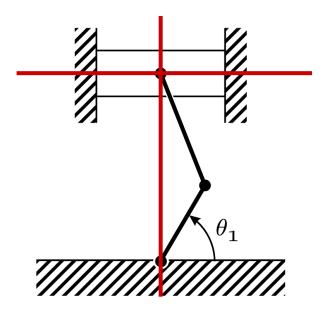
 $\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \theta_2 - \left(\pi - \theta_1 - \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right)\right) \\ \theta_3 - \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \end{bmatrix}$ 

**1 DOF Piston** 

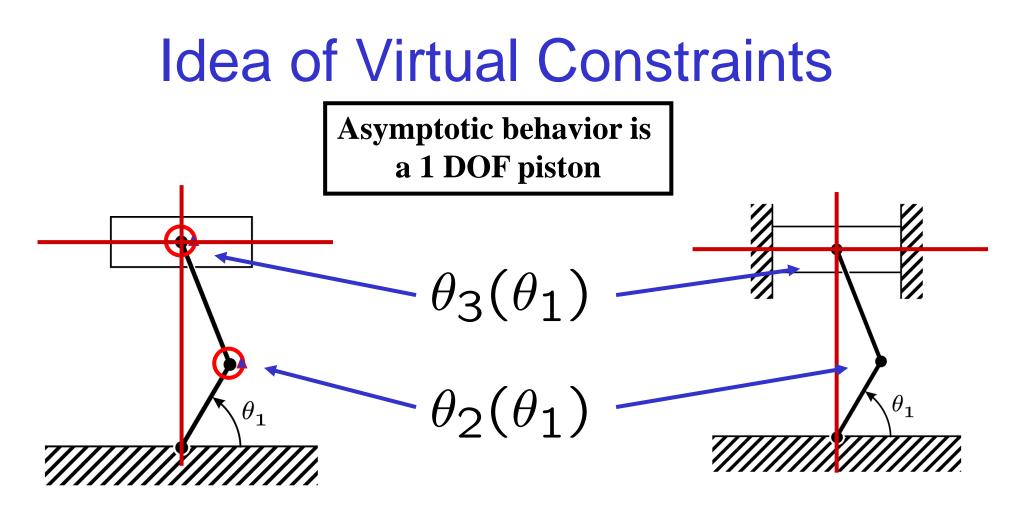
$$\begin{bmatrix} \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} \pi - \theta_1 - \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \\ \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \end{bmatrix}$$



- Assume joints  $\theta_2$ and  $\theta_3$  are actuated
- Use feedback to impose constraints



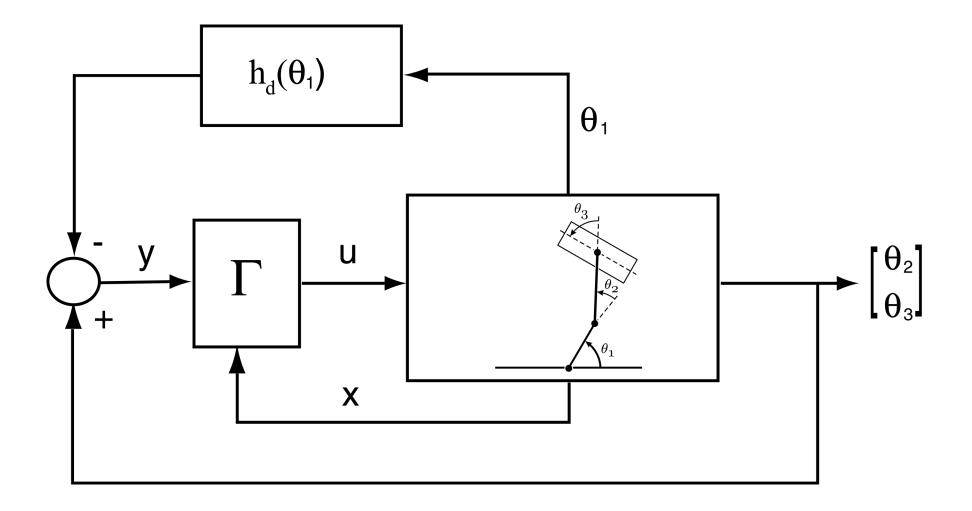
# **3 DOF Piston** $\lim_{t \to \infty} \begin{bmatrix} y_1(t) \\ y_2(t) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \longleftrightarrow \begin{bmatrix} \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} \pi - \theta_1 - \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \\ \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \end{bmatrix}$

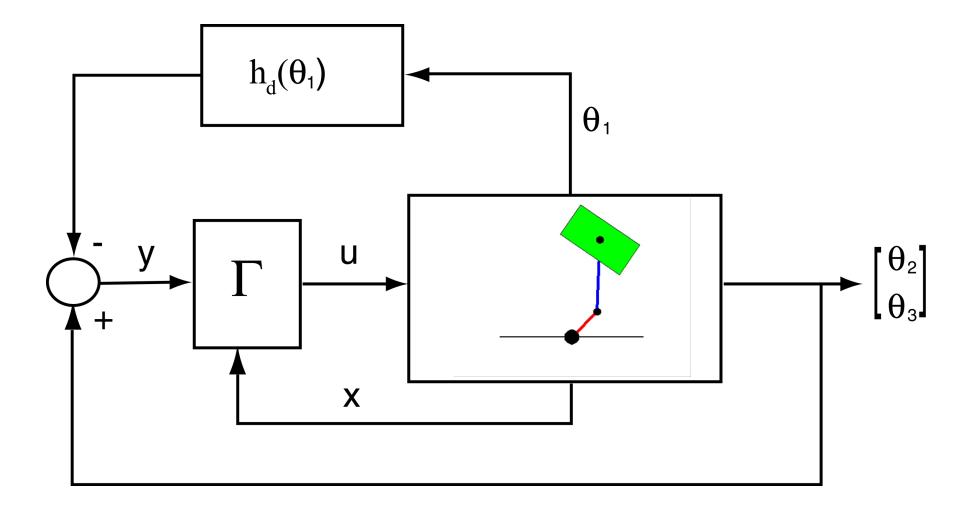


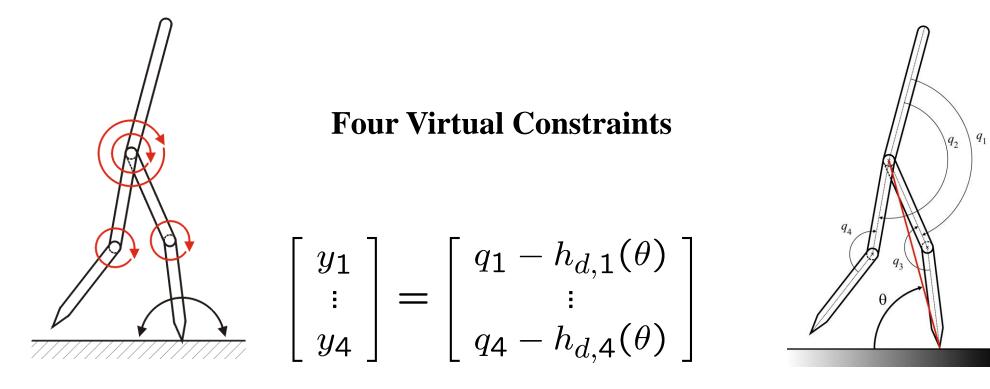
**3 DOF Piston with 2 Actuators** 

**1 DOF Piston** 

$$\lim_{t \to \infty} \begin{bmatrix} y_1(t) \\ y_2(t) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix} \longrightarrow \begin{bmatrix} \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} \pi - \theta_1 - \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \\ \arccos\left(\frac{L_1}{L_2}\cos(\theta_1)\right) \end{bmatrix}$$



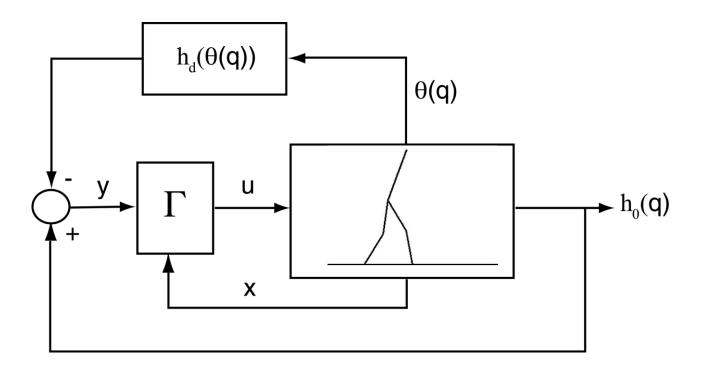




#### **5 DOF Robot**

Asymptotic behavior is a 1 DOF robot 1 Un-Actuated DOF

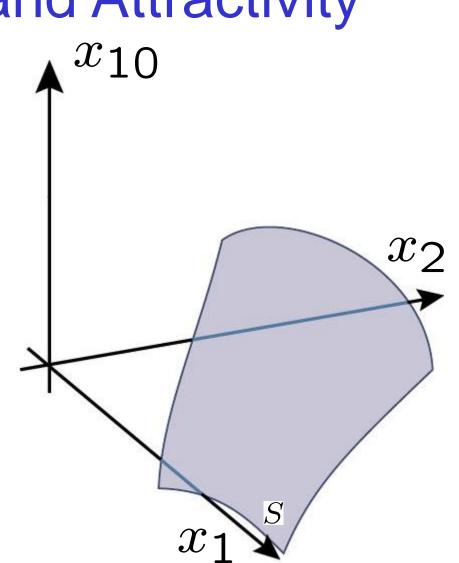
 $y = h(q) = h_0(q) - h_d(\theta(q))$ 



For "posture principles", see [Kajita et al., '92; Hurmuzlu, '93; Ohno '01]

Virtual Constraints in ODE model

$$\dot{x} = f(x) + g(x)u$$

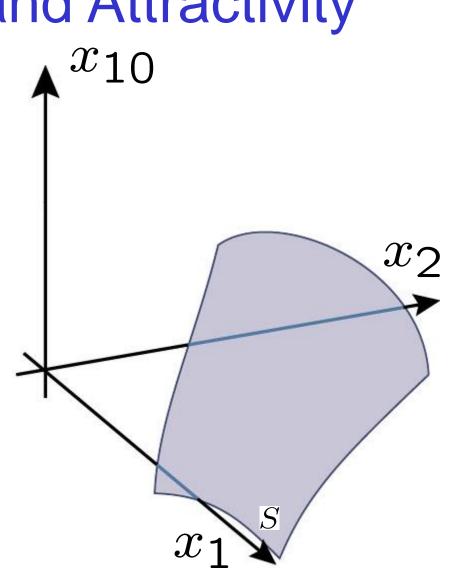


**Complexity Reduction Through** (Hybrid)-Invariance and Attractivity  $x_{10}$ Virtual Constraints in ODE model  $\dot{x} = f(x) + g(x)u$  $y = h(q) = h_0(q) - h_d(\theta(q)) \in \mathbb{R}^4$  $x \gamma$ S

### Virtual Constraints in ODE model

$$\dot{x} = f(x) + g(x)u^*(x)$$
  
 $y = h(q) = h_0(q) - h_d(\theta(q)) \in \mathbb{R}^4$ 

Design:  $u^*(x)$  s.t.  $y(t) \rightarrow 0$ 



Z

 $x_{10}$ 

 $x_{\mathcal{I}}$ 

#### Virtual Constraints in ODE model

$$\dot{x} = f(x) + g(x)u^*(x)$$

$$y = h(q) = h_0(q) - h_d(\theta(q)) \in R^2$$

Design:  $u^*(x)$  s.t.  $y(t) \rightarrow 0$ 

Create: 2-dim. invariant surface:  $Z = \{(q, \dot{q}) \mid y(q) = 0 \& \dot{y}(q, \dot{q}) = 0\}$ 

#### Virtual Constraints in ODE model

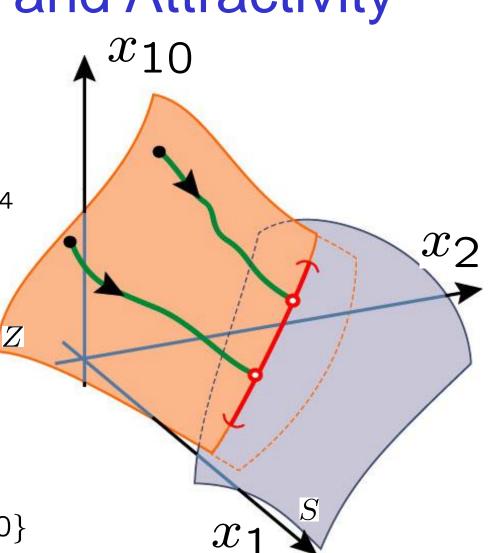
$$\dot{x} = f(x) + g(x)u^*(x)$$

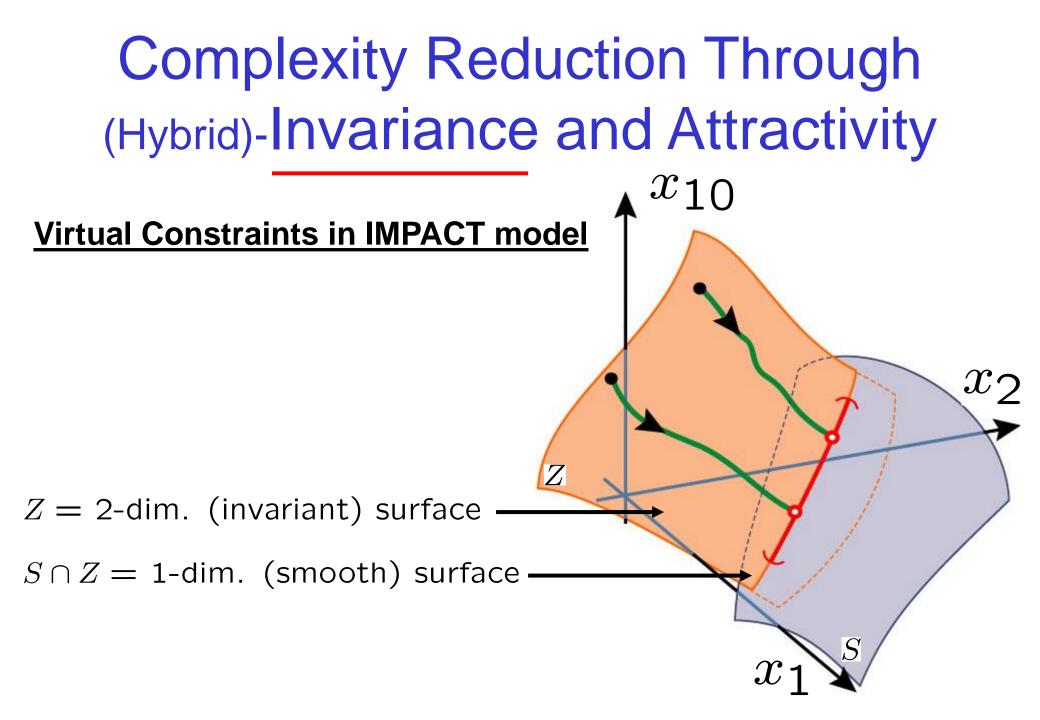
$$y = h(q) = h_0(q) - h_d(\theta(q)) \in R^4$$

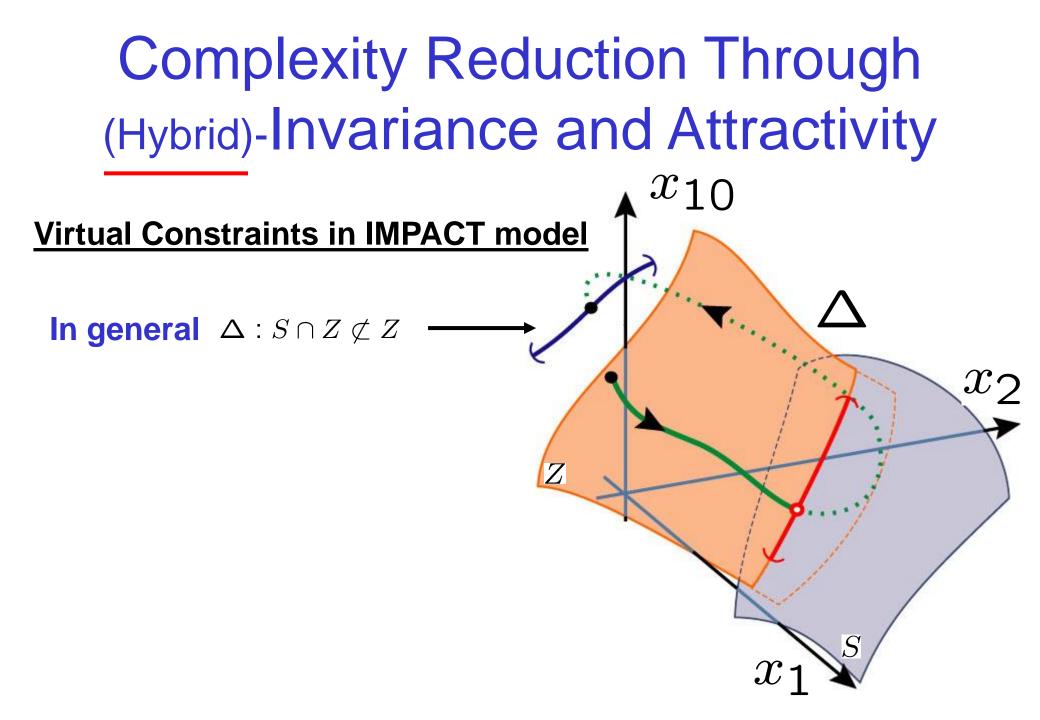
Design: 
$$u^*(x)$$
 s.t.  $y(t) \rightarrow 0$ 

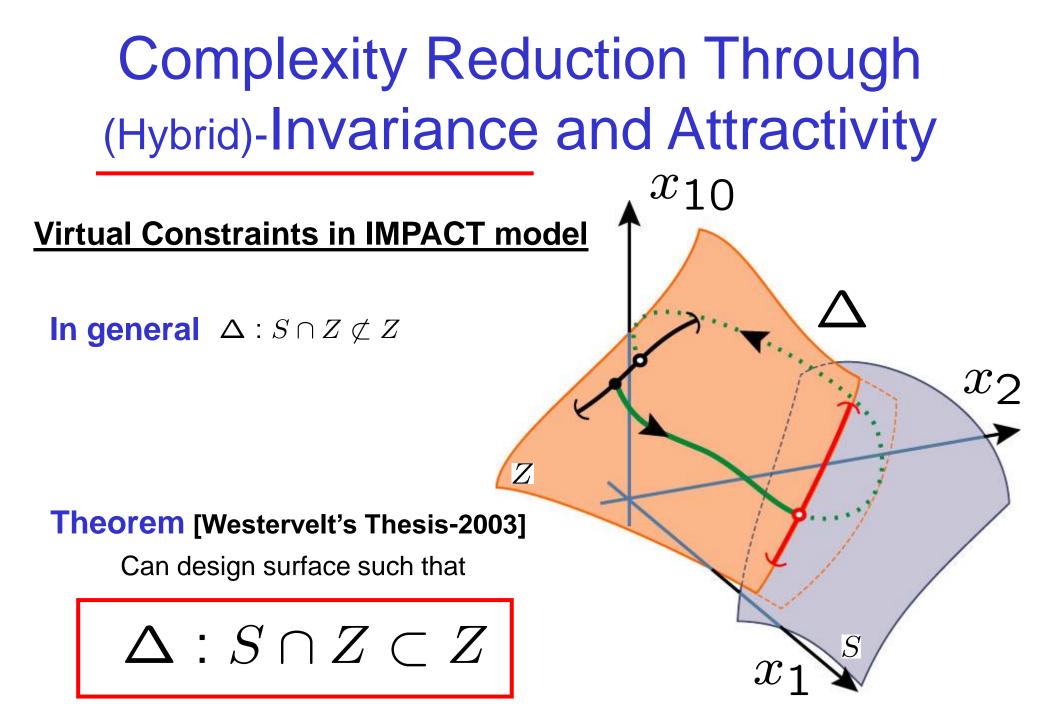
**Byrnes-Isidori Zero Dynamics** 

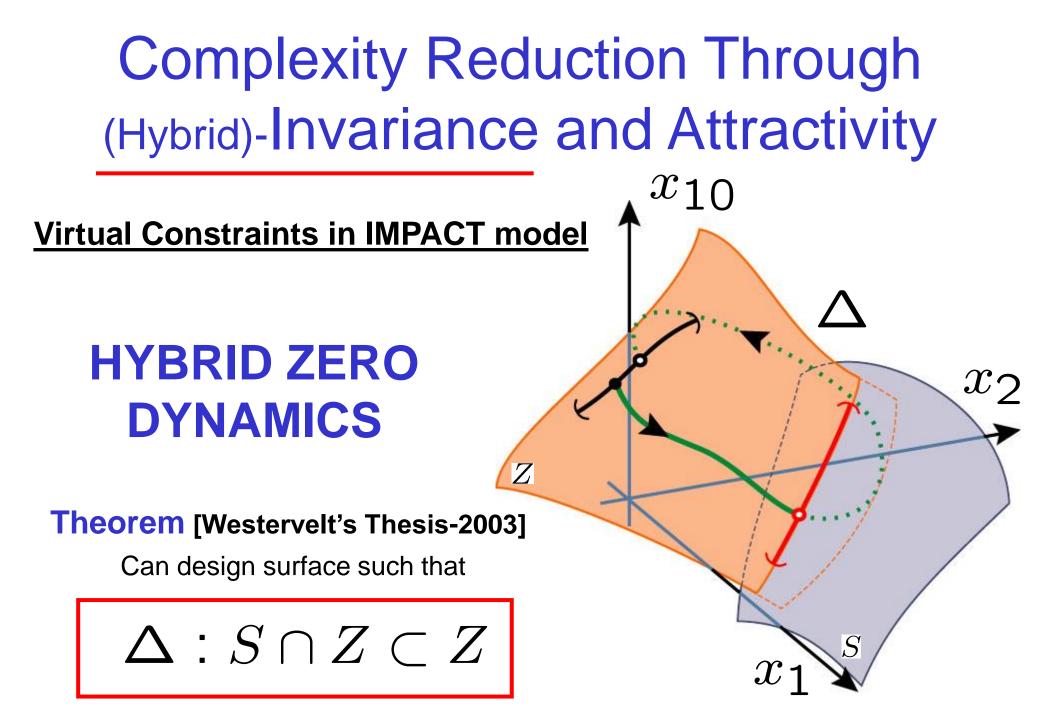
Create: 2-dim. invariant surface:  $Z = \{(q, \dot{q}) \mid y(q) = 0 \& \dot{y}(q, \dot{q}) = 0\}$ 



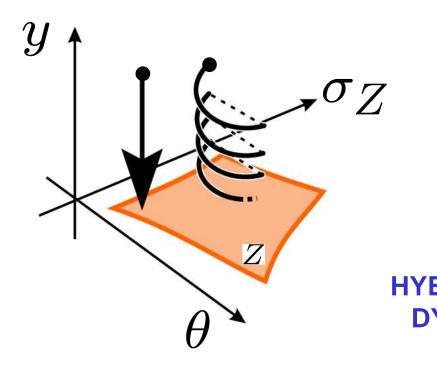


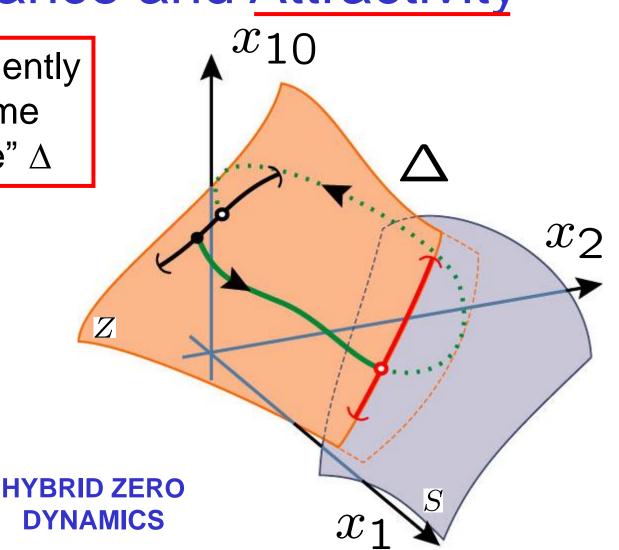




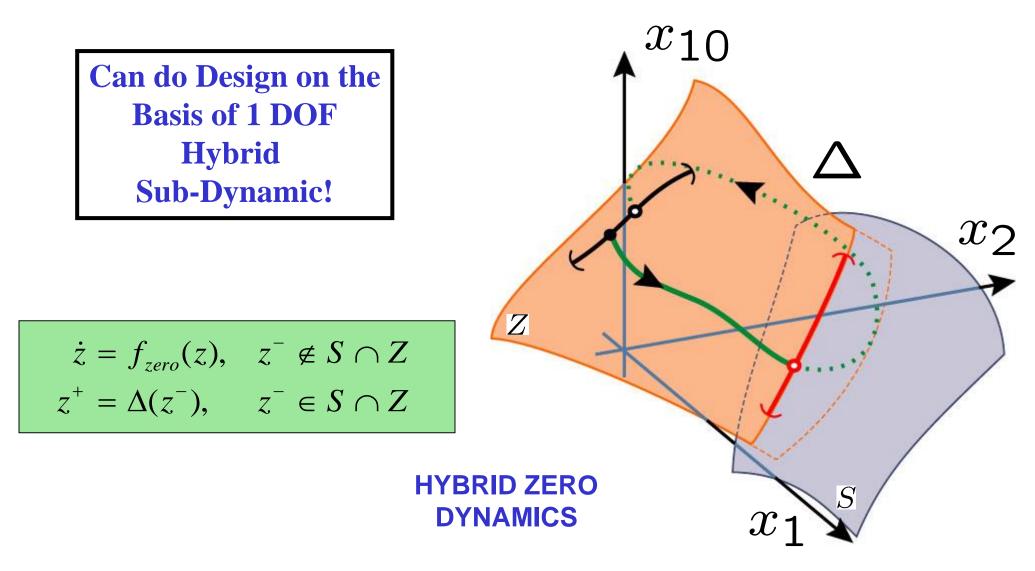


Render surface sufficiently attractive to overcome impulse "disturbance"  $\Delta$ 

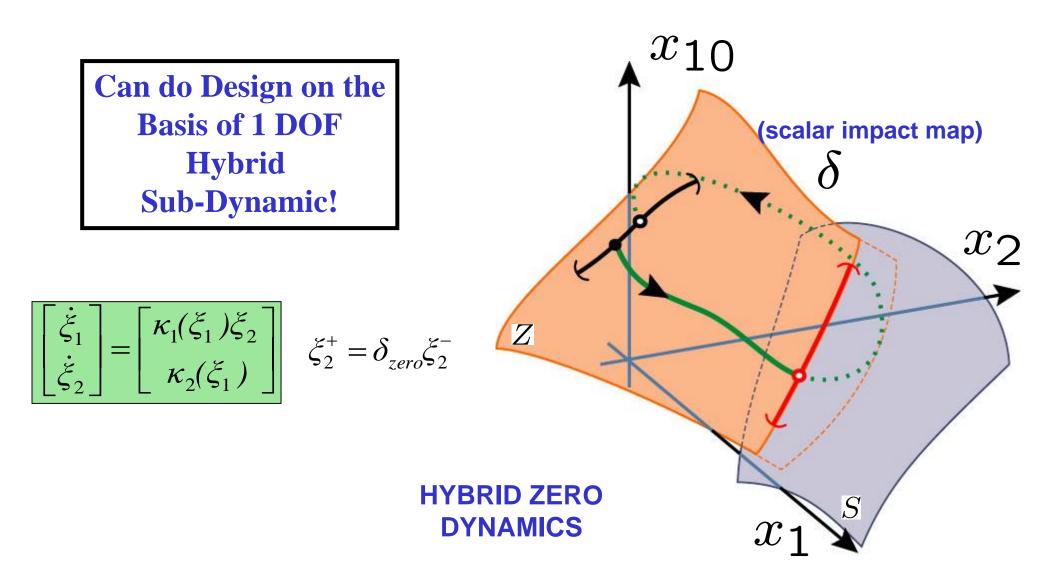




# Hybrid Zero Dynamics for Bipeds



# Hybrid Zero Dynamics for Bipeds



# Hybrid Zero Dynamics Analysis

 $L_{zero} = K_{zero} - V_{zero} =$  Lagrangian of swing phase model

$$\frac{d}{dt}\frac{\partial L_{zero}}{\partial \dot{\theta}} - \frac{\partial L_{zero}}{\partial \theta} = 0 \implies \begin{bmatrix} \dot{\xi}_1 \\ \dot{\xi}_2 \end{bmatrix} = \begin{bmatrix} \kappa_1(\xi_1)\xi_2 \\ \kappa_2(\xi_1) \end{bmatrix}$$

$$L_{zero} = \frac{1}{2} \left( \frac{\dot{\xi}_1}{\kappa_1(\xi_1)} \right)^2 - \left( \int_{\theta^+}^{\xi_1} - \frac{\kappa_2(\xi)}{\kappa_1(\xi)} d\xi \right)$$
  
KineticEnergy PotentiaEnergy

# 

**Theorem:** [Westervelt's Thesis-2003] There exists an exponentially stable periodic orbit of the hybrid zero dynamics if, and only if,

a) 
$$(\delta_{zero})^2 < 1$$
 (energy loss at impact)

b) 
$$\frac{\delta_{zero}^2}{1 - \delta_{zero}^2} V_{zero}(\theta^-) + V_{max} < 0$$
 (evolution of energy during SS)

**Theorem:** [Grizzle-Abba-Plestan 2001] Above orbit is asymptotically stabilizable in the full-order model.

- Finitely parametrize the outputs:  $y = h_a(q) = h_0(q) h_d(q, a)$
- Impose invariance condition:

$$h_a \circ \Delta \Big|_{(S \cap Z_a)} = 0$$
$$L_f h_a \circ \Delta \Big|_{(S \cap Z_a)} = 0$$

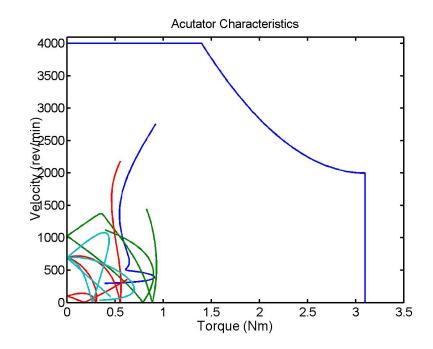
Stability guaranteed if, and only if, two inequalities hold

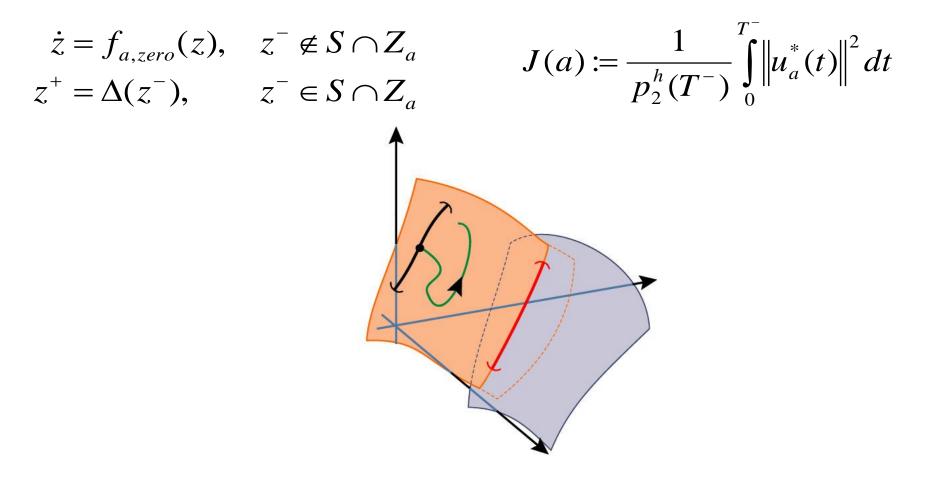
a) 
$$(\delta_{zero})^2 < 1$$
  
b)  $\frac{\delta_{zero}^2}{1 - \delta_{zero}^2} V_{zero}(\theta^-) + V_{max} < 0$ 

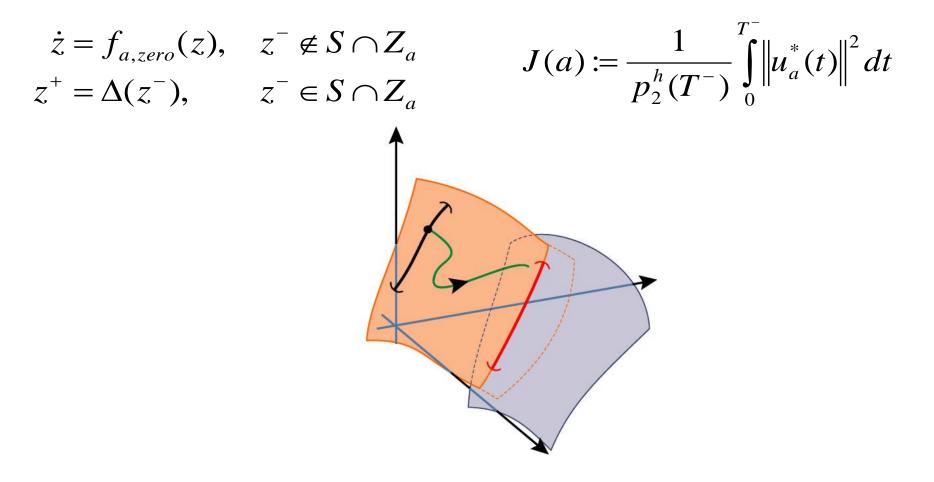
$$\dot{z} = f_{a,zero}(z), \quad z^- \notin S \cap Z_a$$
  
 $z^+ = \Delta(z^-), \qquad z^- \in S \cap Z_a$ 

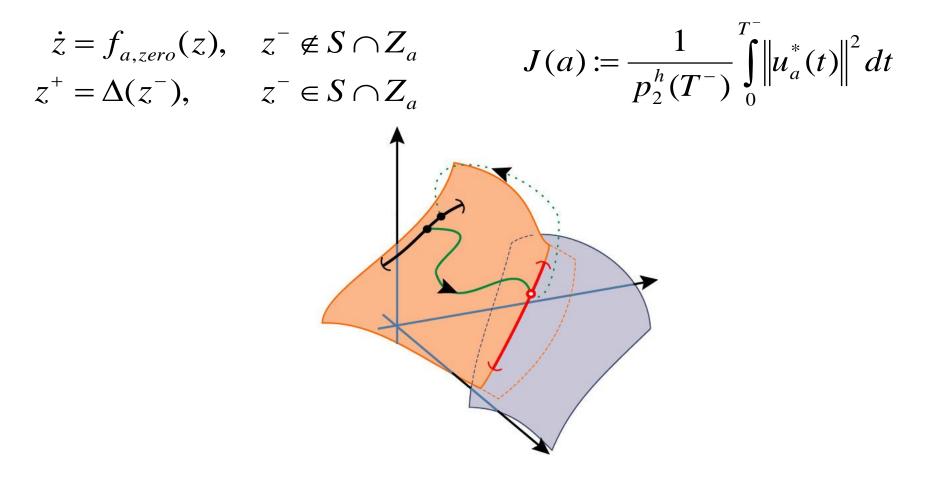
$$J(a) \coloneqq \frac{1}{p_2^h(T^-)} \int_0^{T^-} \left\| u_a^*(t) \right\|^2 dt$$

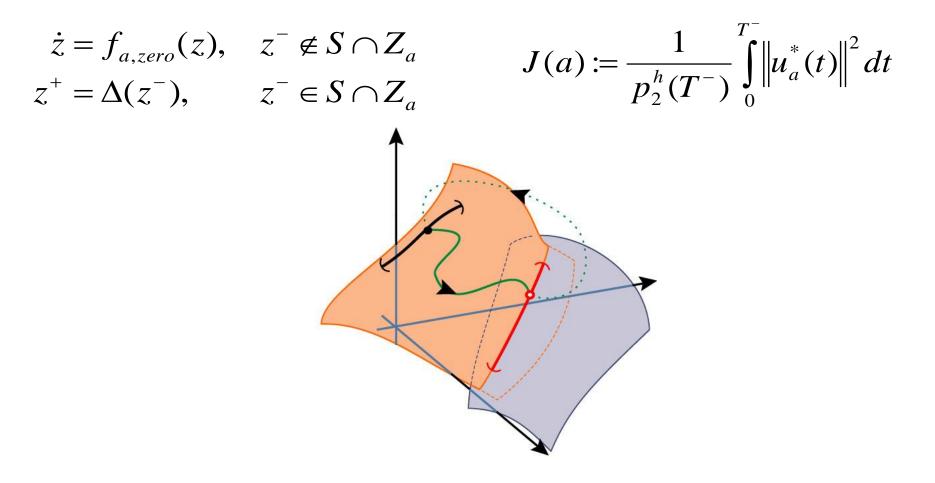
- Can also include contact constraints
- They can be written as affine functions of the (squared) velocity
  Actuator limitations, etc.

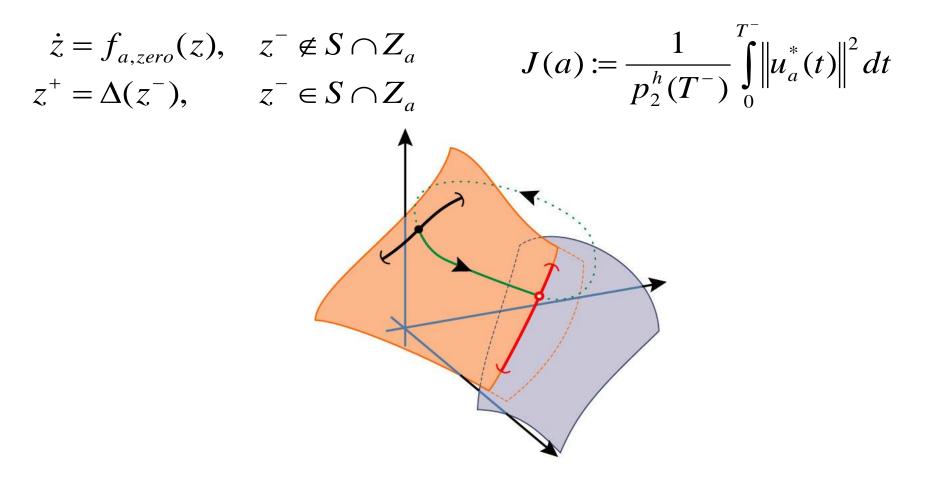








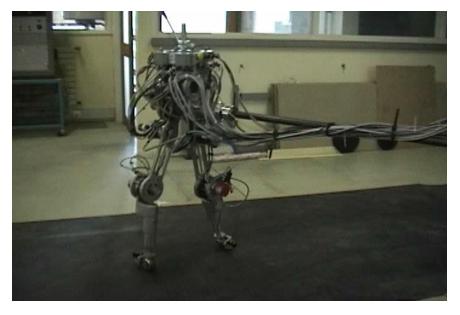




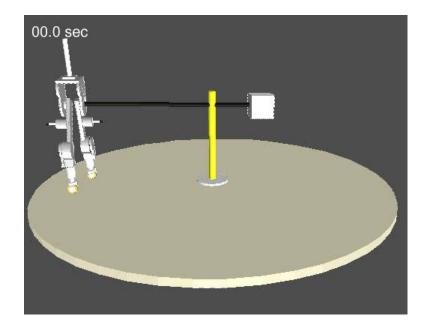
 Achieve performance by tuning parameters via optimization on 2-dimensional model, subject to previous constraints.

$$\dot{z} = f_{a,zero}(z), \quad z^- \notin S \cap Z_a$$
$$z^+ = \Delta(z^-), \qquad z^- \in S \cap Z_a$$

$$J(a) \coloneqq \frac{1}{p_2^h(T^-)} \int_0^{T^-} \left\| u_a^*(t) \right\|^2 dt$$



LAG: Laboratoire Automatique de Grenoble



### GeomView Animation by Evan Leung

### **Robustness Experiment**

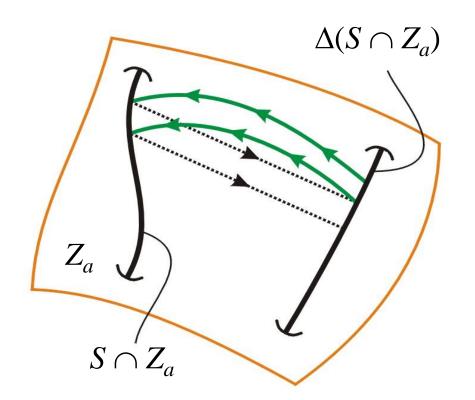
### Robot + Controller = Time-Invariant, Hybrid, Exp. Stable, Oscillator!





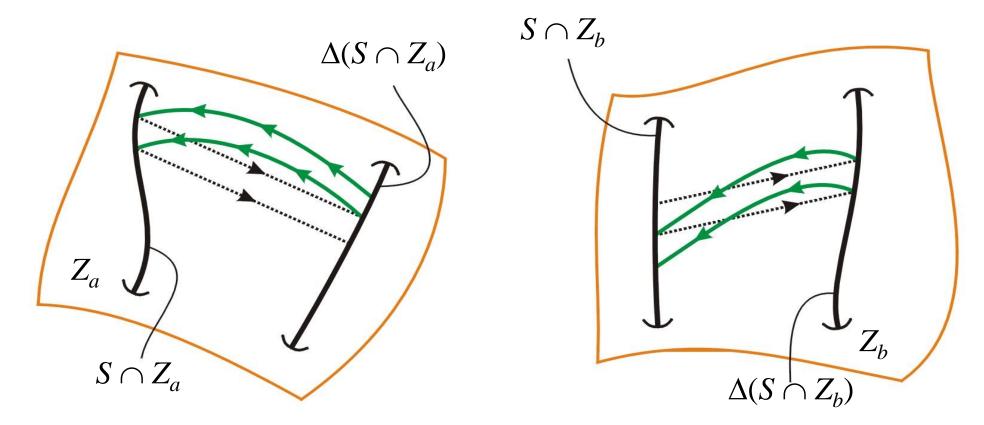
# **Composition of Walking Motions**

 Introduce controller to transition from domain of one Poincaré map to another



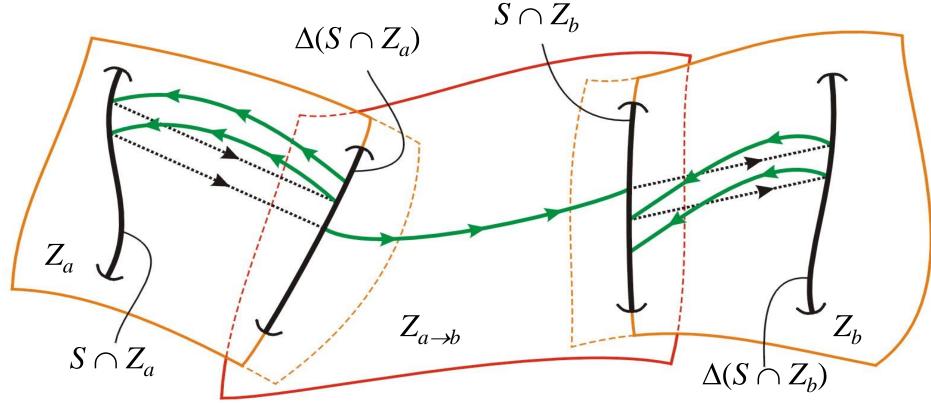
# **Composition of Walking Motions**

 Introduce controller to transition from domain of one Poincaré map to another



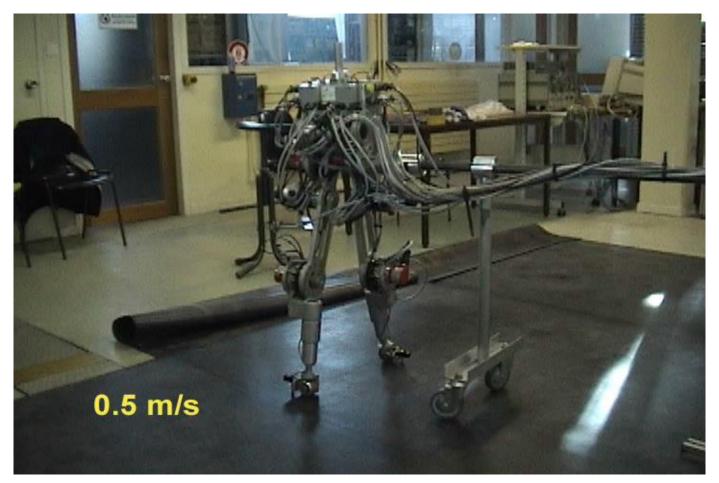
# **Composition of Walking Motions**

 Introduce controller to transition from domain of one Poincaré map to another



Westervelt, Grizzle, & Canudas-de-Wit (2003)

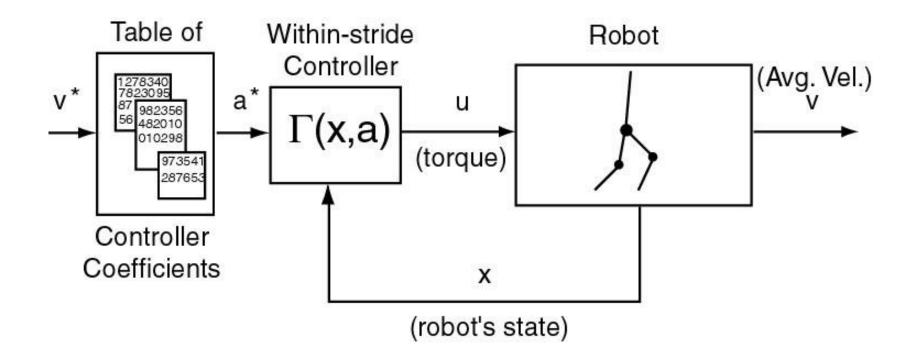
### Experimental Implementation $0.5 \rightarrow 0.6 \rightarrow 0.7 \rightarrow 0.8 \rightarrow 0.7 \rightarrow 0.6 \rightarrow 0.5 \rightarrow \dots$



LAG: Laboratoire Automatique de Grenoble

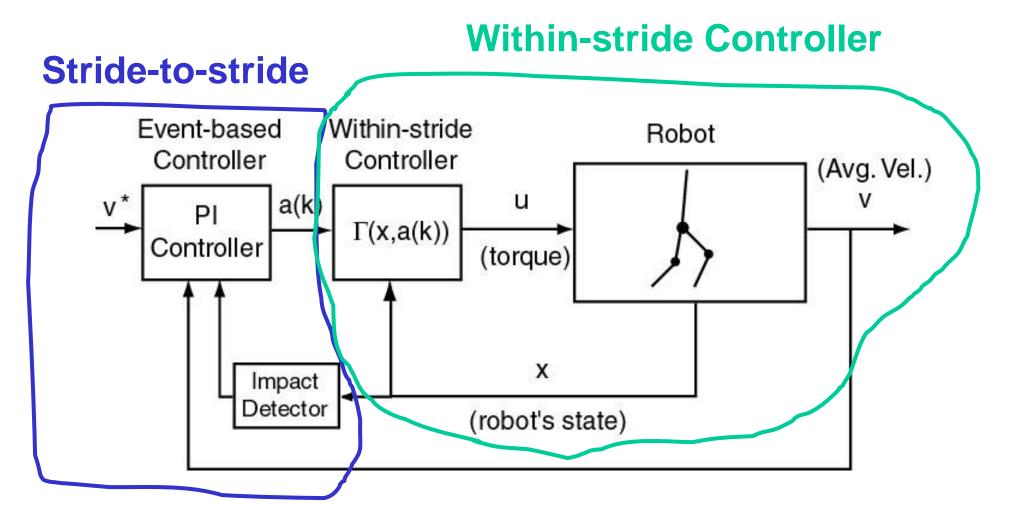
### **Event-Based Control**

Key Idea: Use the parameters of the within-stride controller as control knobs



### **Event-Based PI Control**

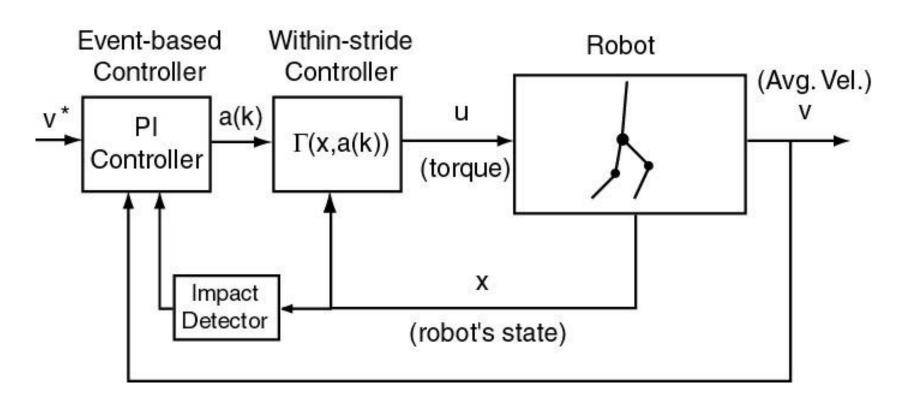
Key Idea: Use the parameters of the within-stride controller as control knobs



### **Event-Based PI Control**

Key Idea: Use the parameters of the within-step controller as control knobs

- Maintain invariance
- Modify "posture (surface)" to change speed

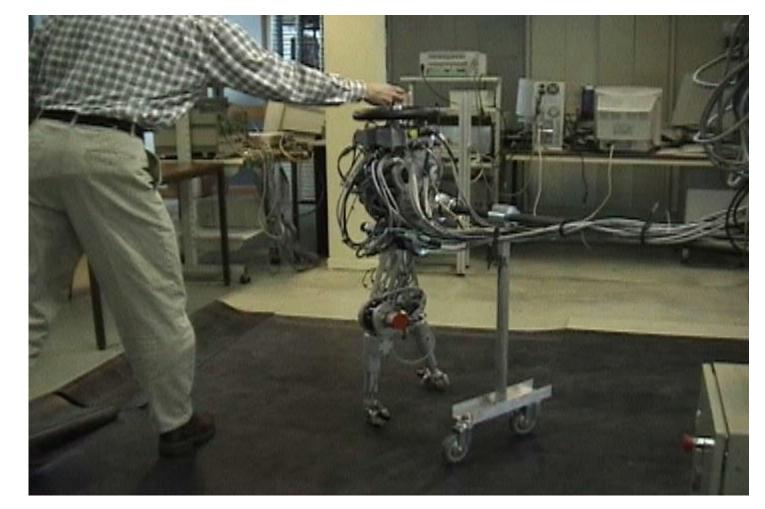


### Experimental Implementation (PI control to reject perturbation)

Extra mass shifts fixed point to faster walking speed



Event based control recovers original walking speed



### Westervelt, Grizzle, & Canudas-de-Wit (2003)

## **Natural Progression**

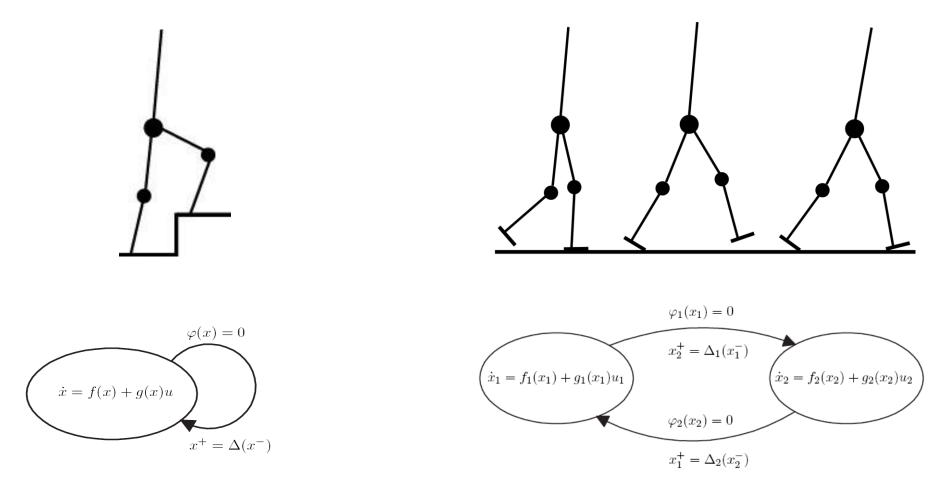
Grizzle, Abba & Plestan 1999

### RABBIT

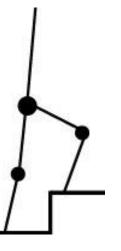
Plestan, Grizzle, Abba & Westervelt 2000 Westervelt, Grizzle & Koditschek 2001

### **Stairs or Slopes**





### **Stairs or Slopes**



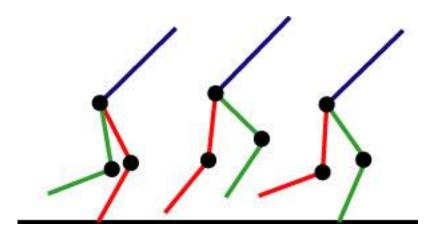
**Adding Feet** 

- Single Continuous-Phase
  - underactuated
- Ben Morris, M.S. Work

- Multiple Continuous-Phases
  - fully-actuated
  - underactuated
  - over-actuated
- Jun Ho Choi, ACC-2005 (submitted)

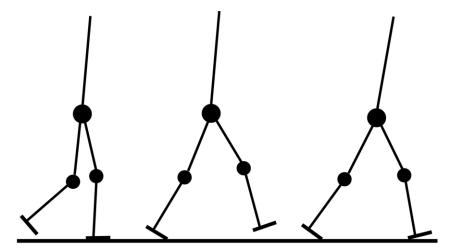
### Running





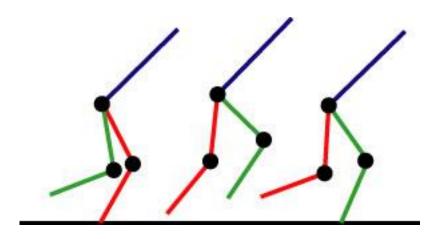


- single support
- flight
- varying degree of actuation
- CDC 2004



- Multiple Continuous-Phases
  - fully-actuated
  - underactuated
  - over-actuated
- Jun Ho Choi, ACC-2005 (submitted)

### <u>Running</u>



- Multiple Continuous-Phases
  - single support
  - flight
  - varying degree of actuation
- CDC 2004 (Chevallereau, Westervelt)

- Theory parallels HZD of walking
- Novel part: event-based control of the flight phase
- Closed-form computation of reduced Poincaré map
- Experiments started...

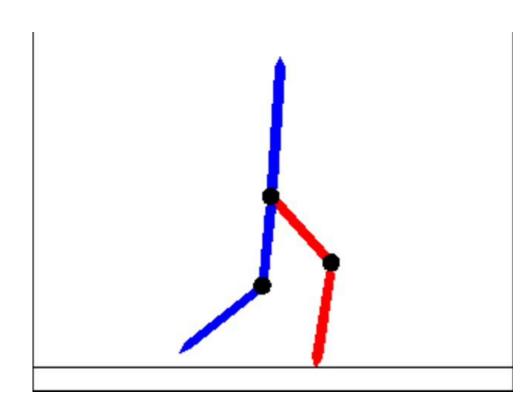
### B. Morris C. Chevallereau



G. Buche E. Westervelt



### **Running**



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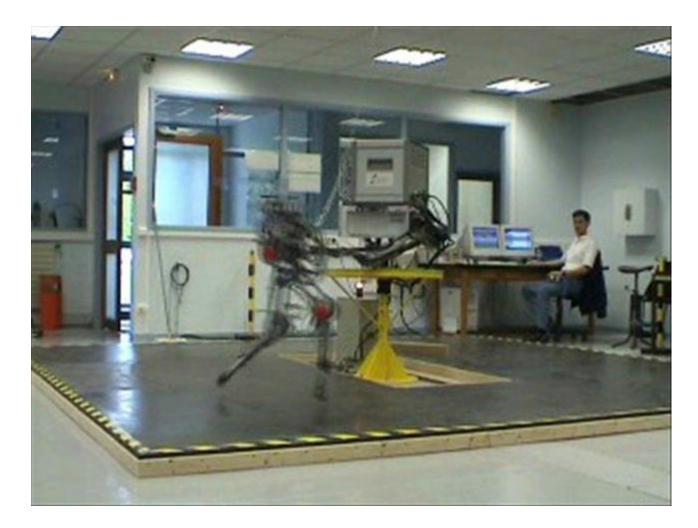
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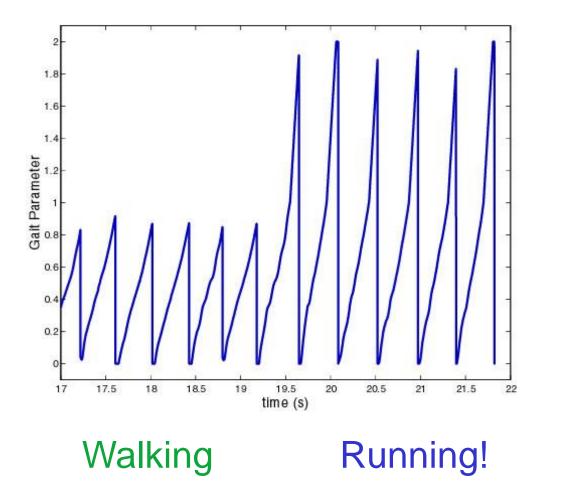
G. Buche E. Westervelt



### Six Steps Toward Infinity Our First Running Experiment (September 2004)



### Six Steps Toward Infinity Our First Running Experiment (September 2004)



Score Sony ∞ Rabbit 6

Power Automatically Cut 🛞

# Many Open Problems

- Running .....Experimental verification!
- Controlled compliance (equivalent of tendons, muscles, ...)
  - Energy efficiency
  - Impact attenuation
- Higher degrees of underactuation
- Remove the boom: 3-dimensional (non-planar) robots! [preliminary result: Doi, Hasegawa, & Fukuda, Humanoid Robots Conf., Oct. 2004]
- Much more is unknown than is known... rough terrain, vision, reflexes, ...

### Conclusions

- Models for legged robots are hybrid (ODE + Impact Map).
- Control strategy should be tailored to assist analysis and design
  - Hybrid zero dynamics
  - High analytical insight follows from low-dimensional geometry.
- Robot + Controller is a stable, time-invariant, hybrid, oscillator.
- Experiments are hard...but informative and exciting.
- Fortunately, we had time to think before experimenting.

# Robot at Michigan

- Stay tuned! A robot is being designed.
- Joint with A. Rizzi & J. Hurst (CMU).



