# Falling cat problem

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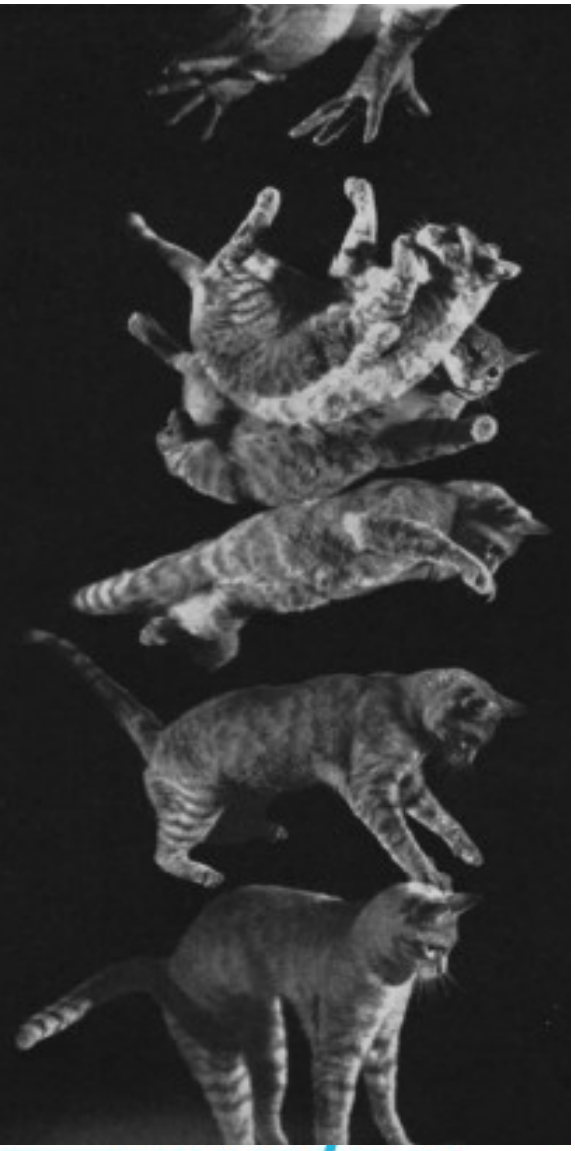
# What is falling cat problem?



- To explain physics of cat righting reflex.
- Cat righting reflex:
  a free fall cat lands on its feet.

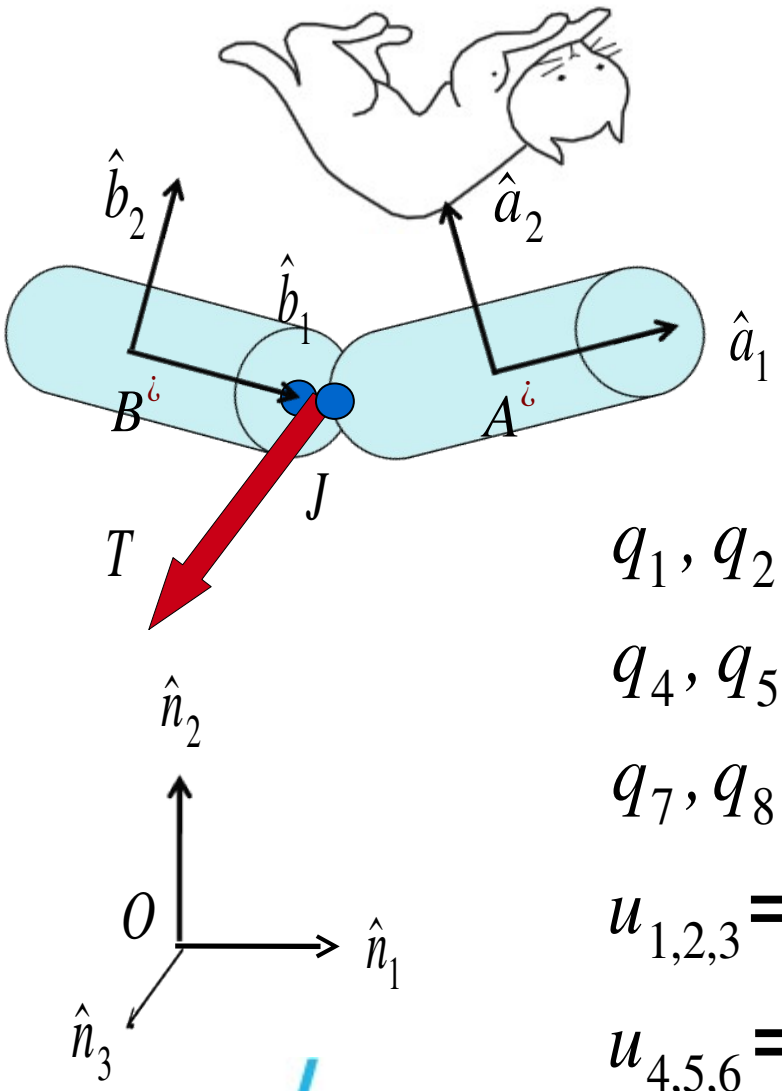
Kane & Scher, 1969

# Previous studies

- **Mechanical model** (Kane & Scher, 1969)
- **Gauge theory** (Montgomery, 1993)
- **Optimal trajectories of the joint angles**
  (Xin-sheng & Li-qun, 2007)

**Q: What happen when given a torque at joint?**

# Model




$$T = T_1 \hat{a}_1 + T_2 \hat{a}_2 + T_3 \hat{a}_3$$

$q_1, q_2, q_3$: position of A¿ in N

$q_4, q_5, q_6$: Euler angles of A relative to N

$q_7, q_8, q_9$: Euler angles of B relative to A

$$u_{1,2,3} = {}^N V^A \cdot \hat{n}_i \ (i = 1,2,3)$$

$$u_{4,5,6} = {}^N \omega^A \cdot \hat{a}_i \ (i = 1,2,3)$$

$$u_{7,8,9} = {}^N \omega^B \cdot \hat{b}_i \ (i = 1,2,3)$$

# Equation of motion

$$\textit{Equation of motions}$$

$$\dot{q}_1 = f_1(u_1, \cdots u_9, q_{1,} \cdots q_9, t)$$

$$\vdots$$

$$\dot{q}_9 = f_9(u_1, \cdots u_9, q_{1,} \cdots q_9, t)$$

$$\dot{u}_1 = g_1(u_1, \cdots u_9, q_{1,} \cdots q_9, t)$$

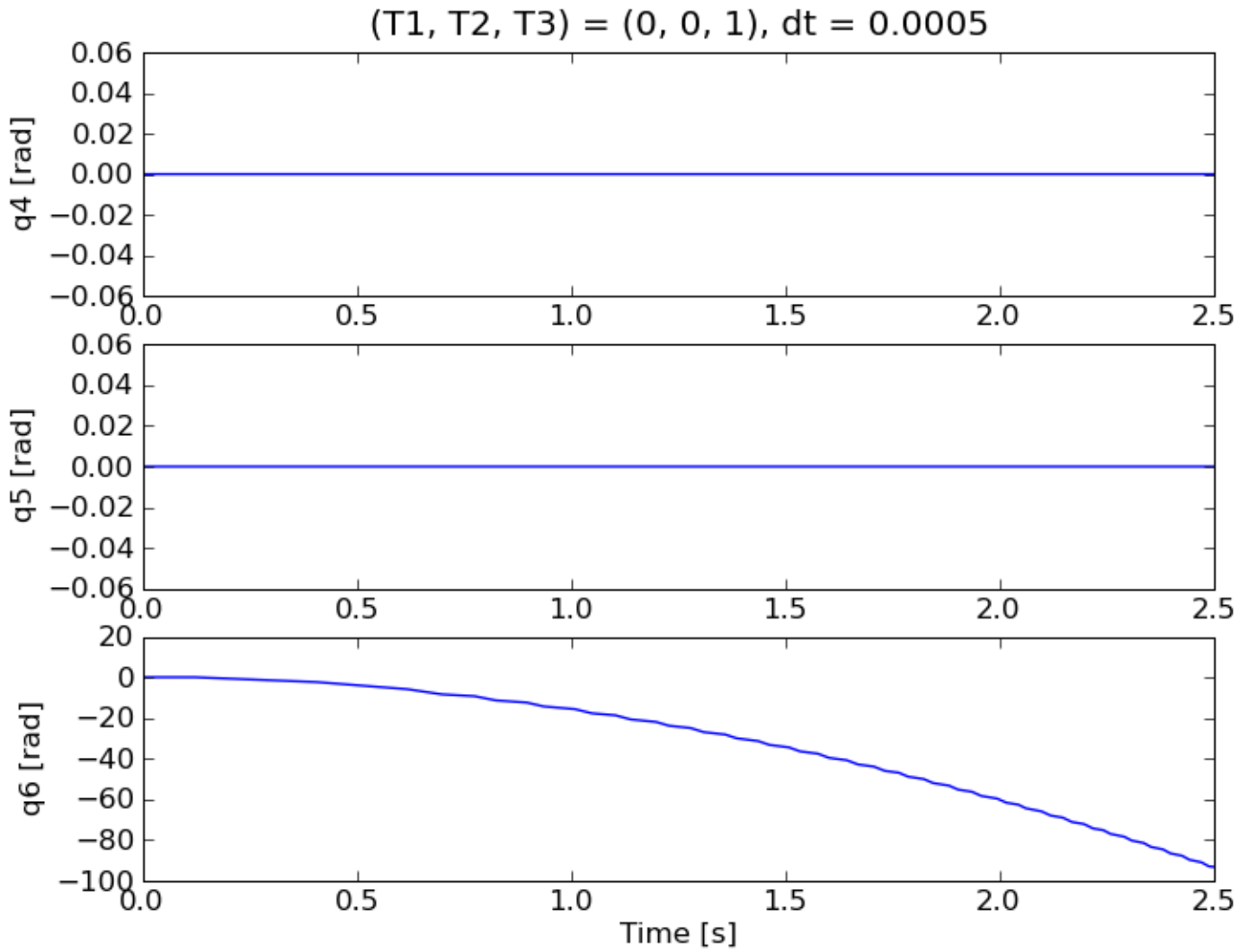
$$\vdots$$

$$\dot{u}_9 = g_9(u_1, \cdots u_9, q_{1,} \cdots q_9, t)$$

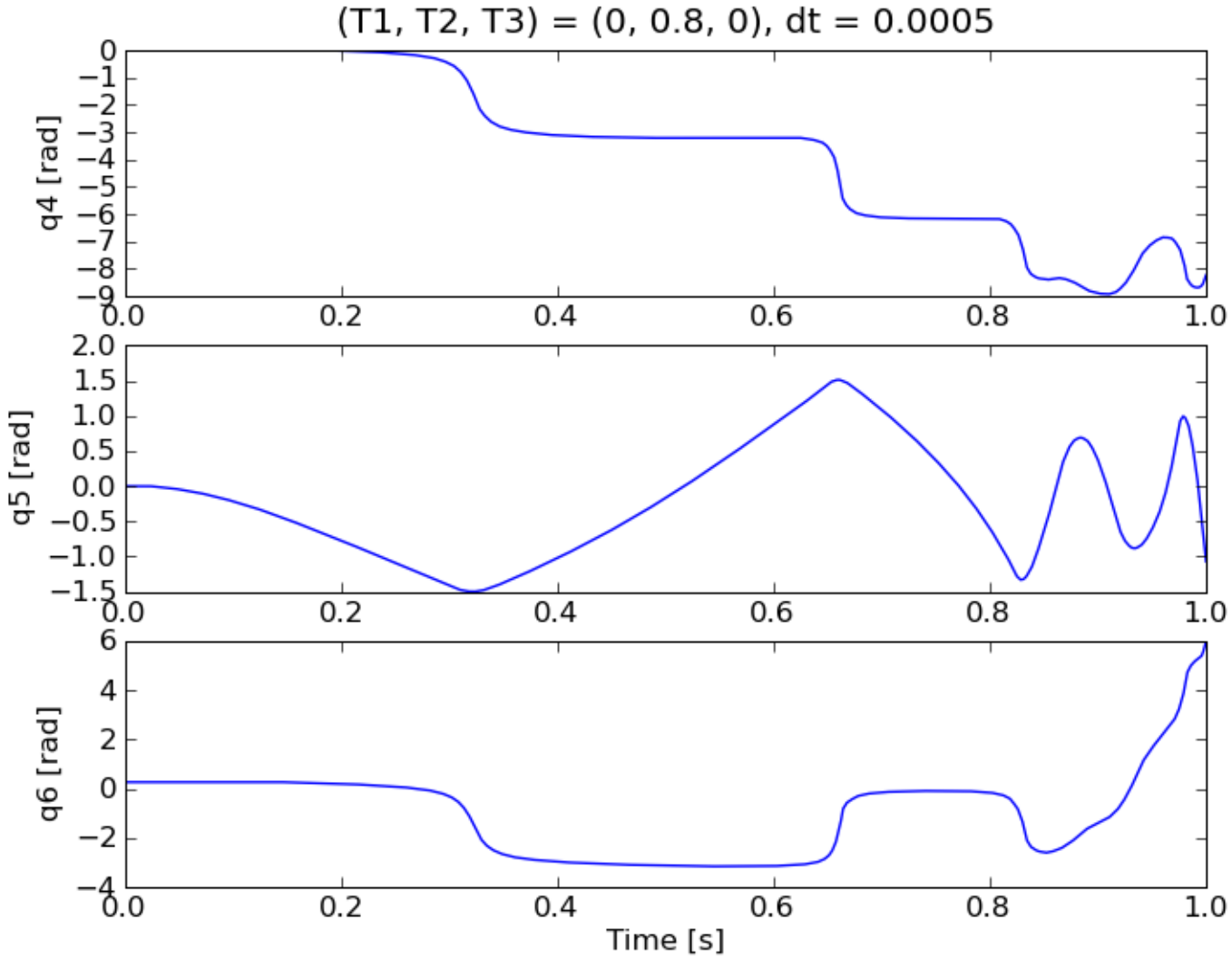
$$\textit{Initial conditions}$$

$$q_6 = \frac{\pi}{12},\ q_9 = -\frac{\pi}{6},\ q_{1,2,3,4,5,7,8} = u_i = 0\ (\forall i)$$

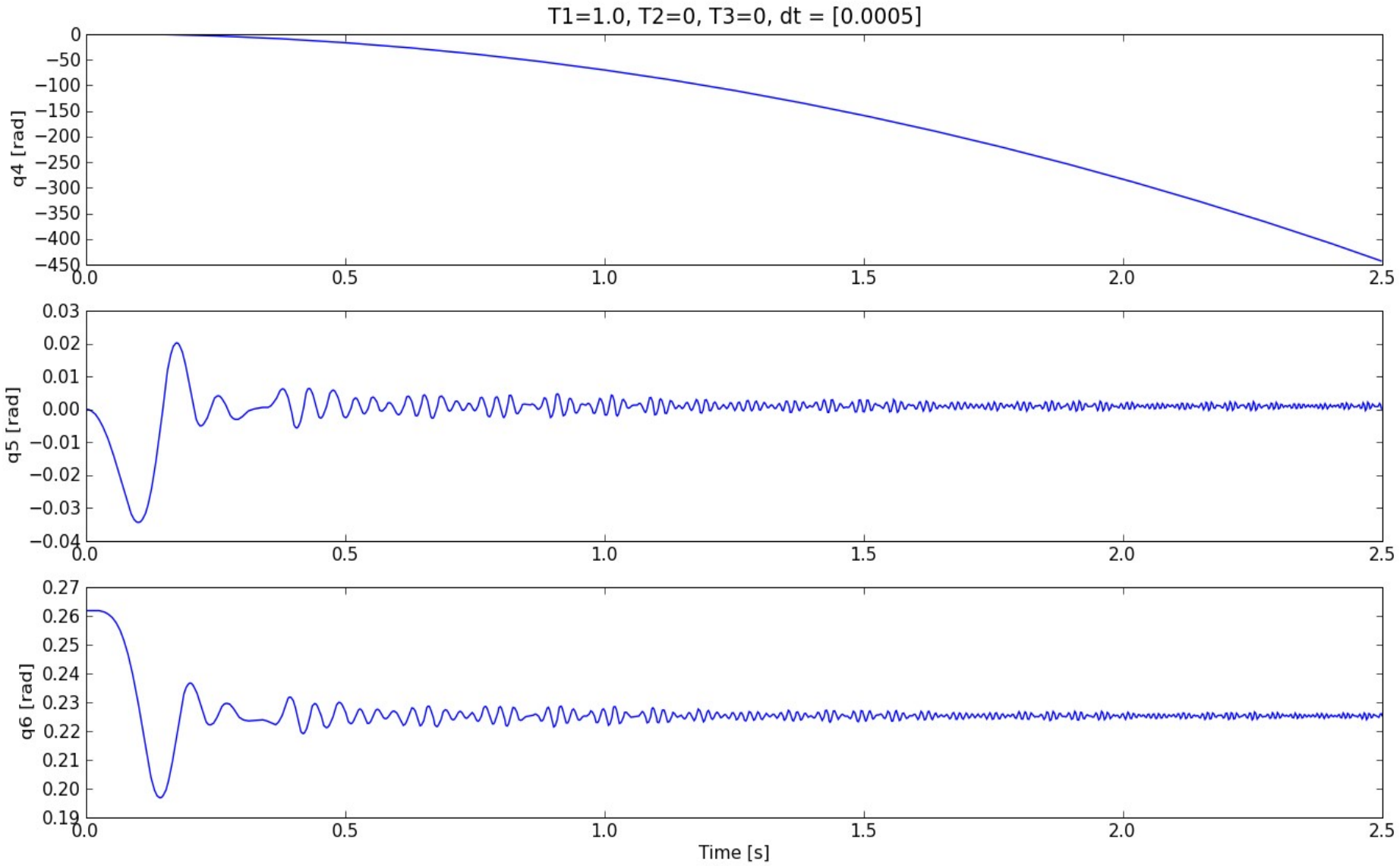
# Result (T3=1.0, T1=T2=0)



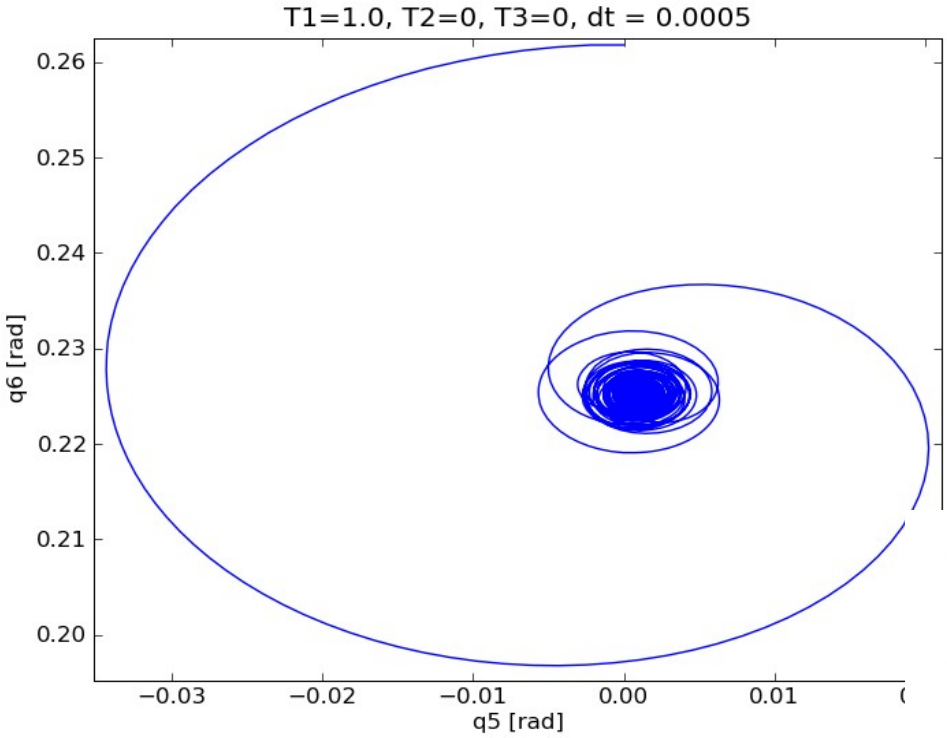
# Result (T2=0.8, T1=T3=0)

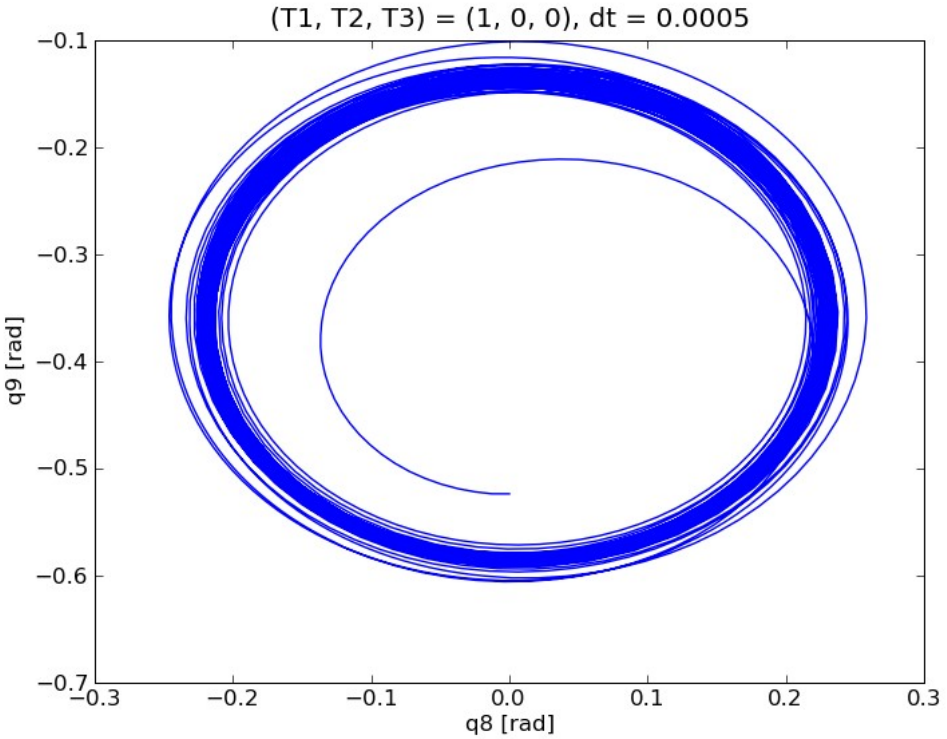


# Result (T1=1.0, T2=T3=0.0)

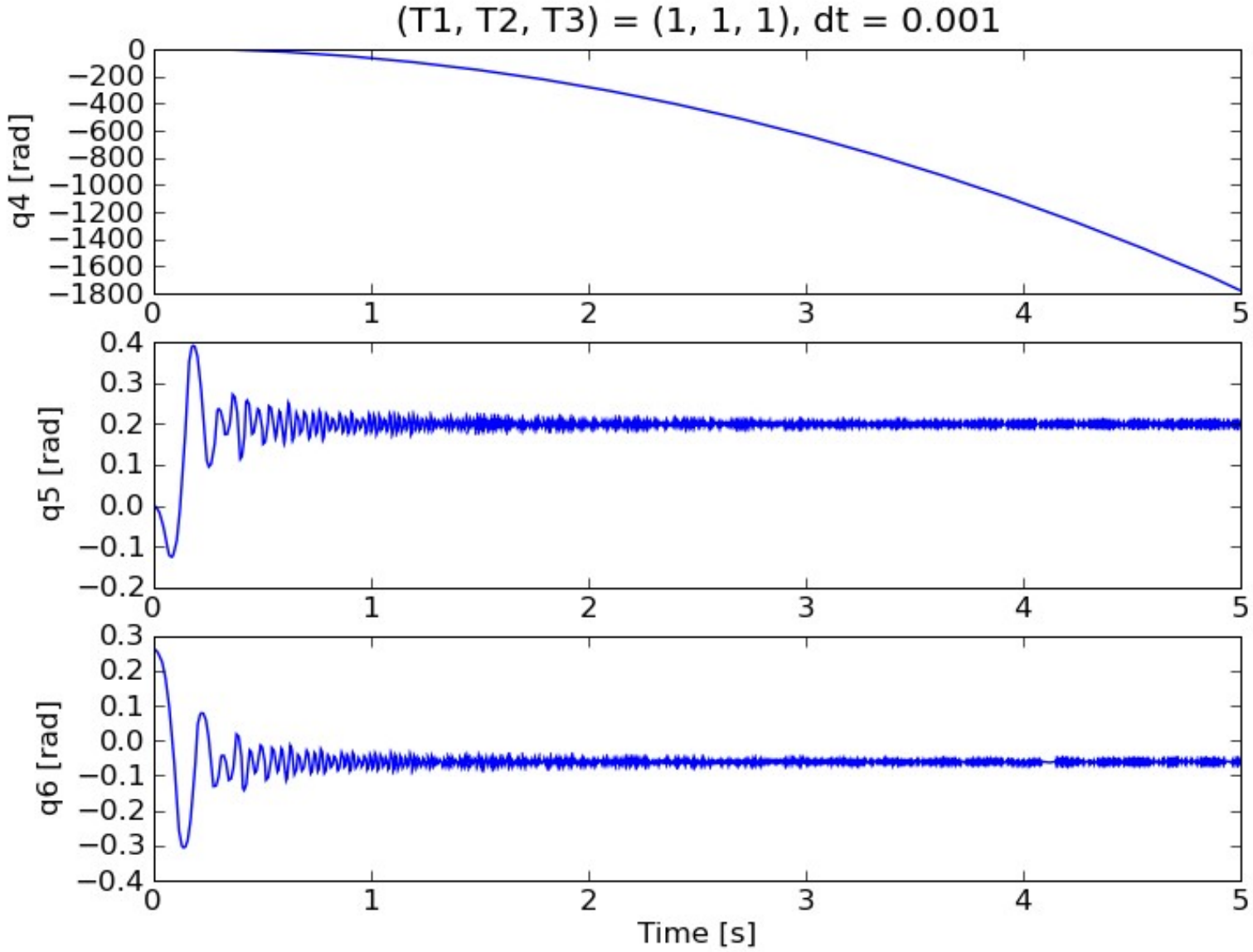


# Result (T1=1.0, T2=T3=0)

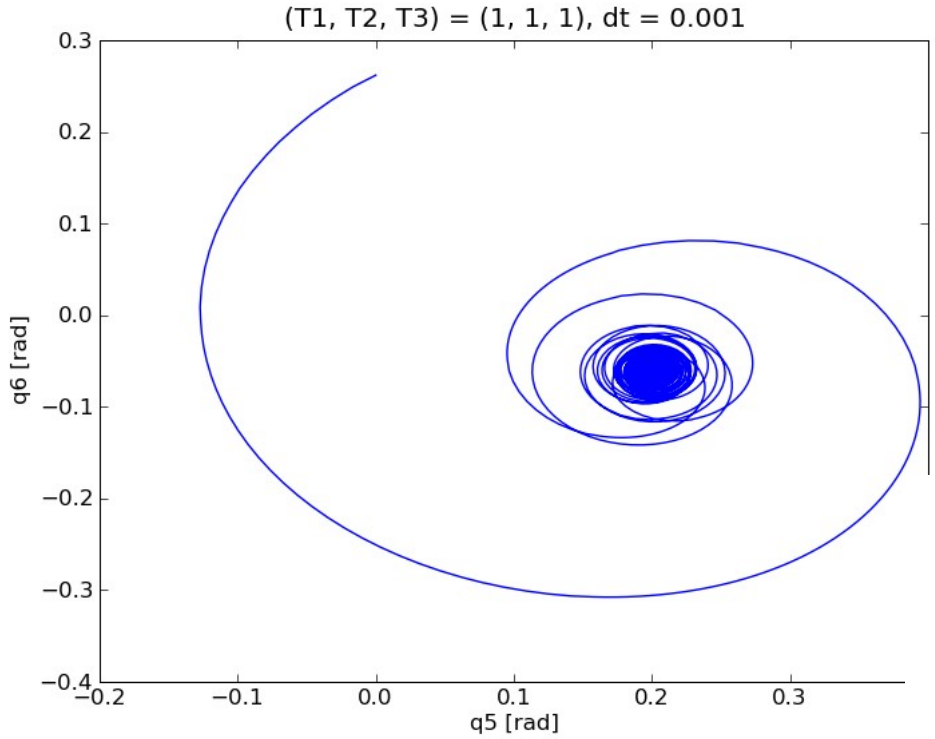


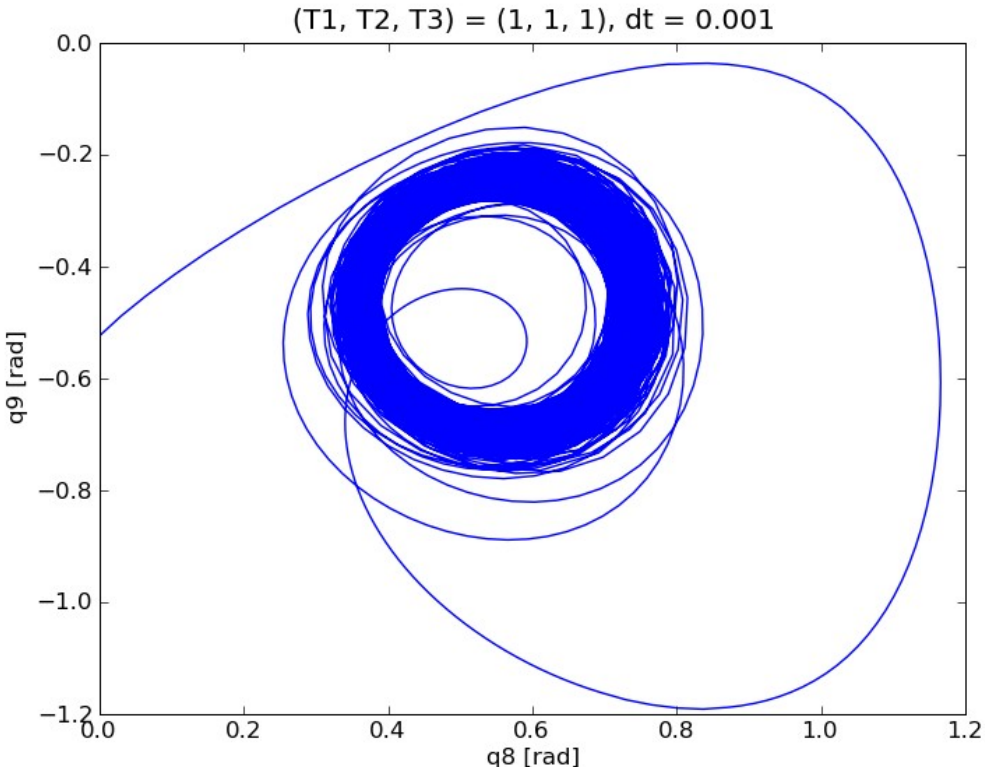



# Result (T1=T2=T3=1.0)



# Result (T1=T2=T3=1.0)

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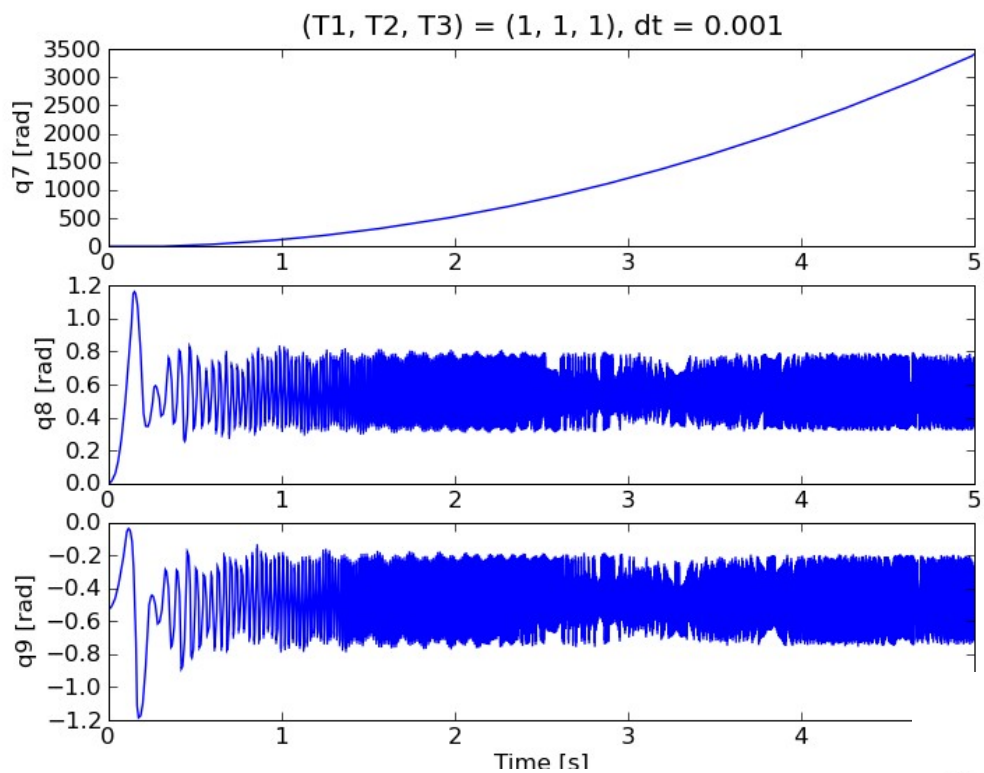


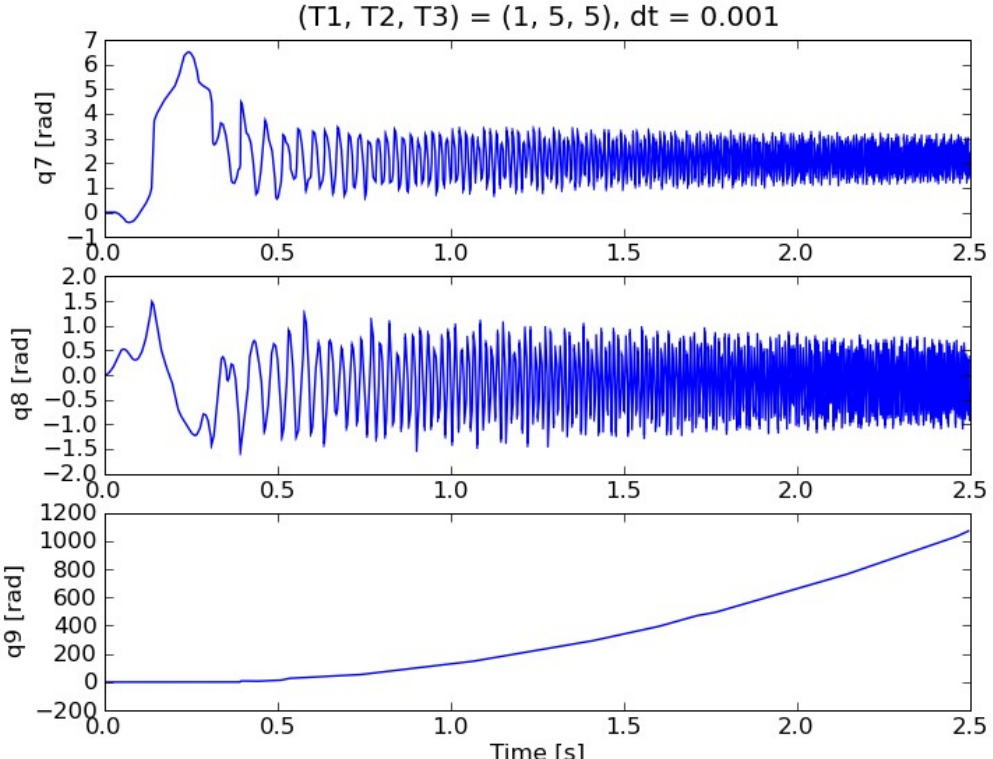


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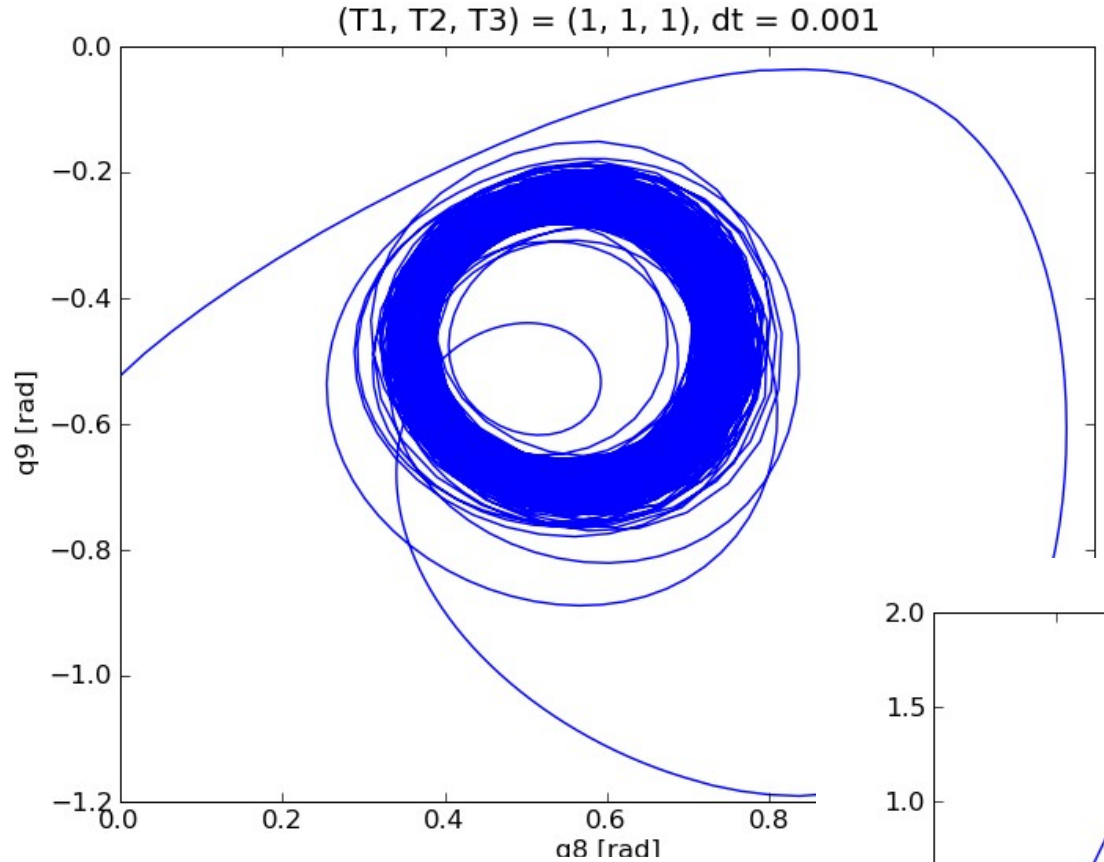


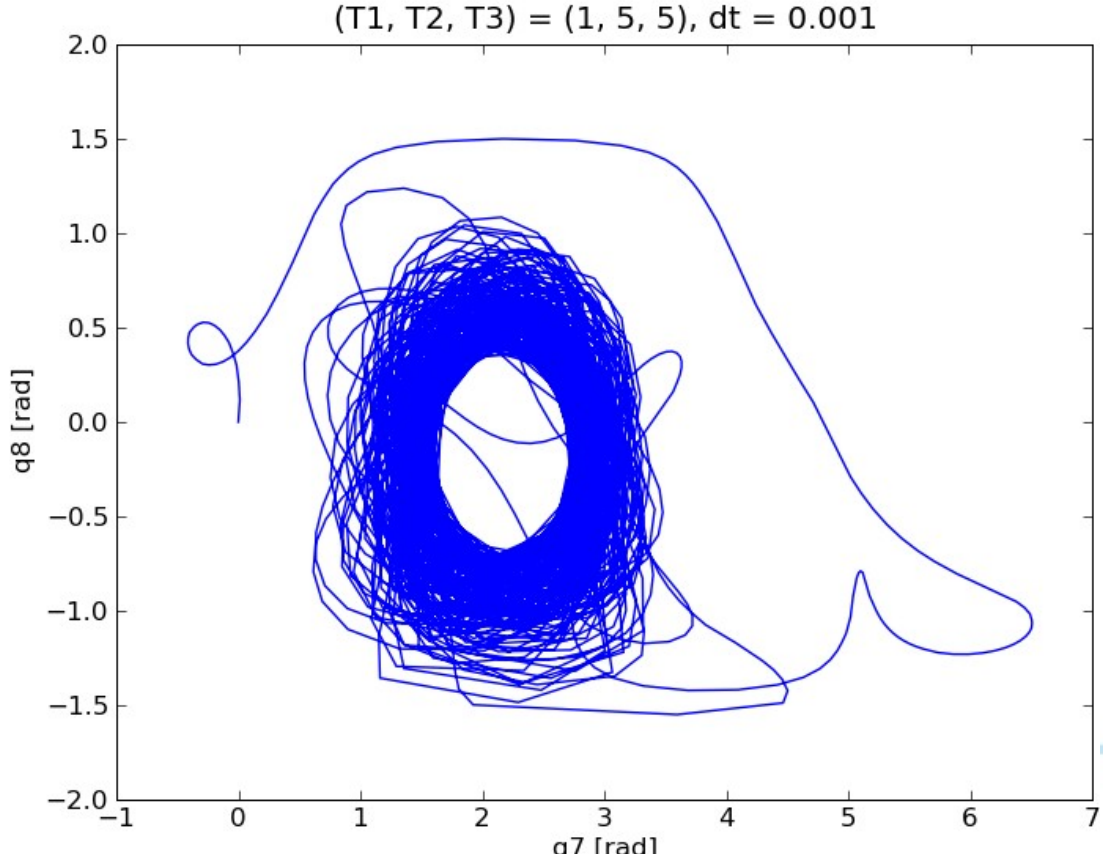


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