

$$\frac{\partial L}{\partial x_1} = mgl \sin x_1 - ml x_2 x_4 \sin x_1$$

$$\frac{\partial L}{\partial x_2} = ml x_4 \cos x_1 + ml^2 x_2$$

$$\frac{\partial L}{\partial x_3} = 0$$

$$\frac{\partial L}{\partial x_4} = (M+m)x_4 + ml x_2 \cos x_1$$

$$1) \frac{d}{dt} [ml x_4 \cos x_1 + ml^2 x_2] - mgl \sin x_1 + ml v_2 x_4 \sin x_1 = 0$$

$$ml \dot{x}_4 \cos x_1 + ml x_4 (-\sin x_1) \dot{x}_1 + ml^2 \dot{x}_2 - mgl \sin x_1 +$$

$$ml x_2 x_4 \sin x_1 = 0$$

$$(\cancel{ml} \cos x_1) \dot{x}_4 + (\cancel{ml}^2) \dot{x}_2 = \cancel{mgl} \sin x_1 \dots (A)$$

$$(\cancel{m} \cos x_1) \dot{x}_4 + \cancel{ml} \dot{x}_2 = \cancel{m} g \sin x_1$$