In the name of god

Advanced Robotics
Homework Assignment #7

1) Classify the following robot tasks as motion control, force control, hybrid motion-force control, impedance control, or some combination. justify your answer:

a) Tightening a screw with a screwdriver
b) Pushing a box along the floor
c) Pouring a glass of water
d) Shaking hands with a human
e) Throwing a baseball to hit a target
f) Shoveling snow
g) Digging a hole
h) Giving a back massage
i) Vacuuming the floor
j) Carrying a tray of glasses

2) express natural and artificial constraints that achieve the following tasks:
a) opening a cabinet door
b) turning a screw that advances linearly a distance p for every revelation
c) drawing a circle on a chalkboard with a piece of chalk

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3) Aside from joint angels and angular velocities, if we have access to joint angular accelerations, we can accomplish impedance control without having force sensor. Construct the appropriate control law. Draw a block diagram of the control system.

4) For a system with dynamic equation shown below :

$$\frac{ml^2}{2}\ddot{x} + c\dot{x} + m\lg\sin(x) = u$$

Design an inverse Dynamic controller where c & l are known , but m is unknown

And then determine steady state error .

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5) Remember passivity based method, one term is changed and control law is determined as below:

$$
\begin{aligned}
&\tau = \hat{M}\ddot{q}_r + \hat{C}\dot{q}_r + \hat{G} + K\ \mathrm{sgn}(r) \\
&r = \Delta e + \dot{e} \\
&\dot{q}_r = \Delta e + \dot{q}_d \\
&K = diag[k_1, k_2, \ldots, k_i] \qquad k_i >| 0
\end{aligned}
$$

Use a suitable Lyapunov function and proof that the error reach the surface:

$$r = \Lambda e + \dot{e}$$

In addition once on the surface , q(t) will goes to $q_d(t)$ exponentially fast (which implies that r=0 is reached in a finite time. In addition, once in sliding mode, e converges exponentially fast to zero)

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6) Remember passivity based method

Use similar process and design an Adaptive control for robot dynamic equations when control input is changed to below form, when M-C-G are constant but unknown:

$$\tau = K_p\tilde{q} + K_v\dot{\tilde{q}} + M(q)\left[\ddot{q}_d + \Lambda\dot{\tilde{q}}\right] + C(q,\dot{q})\left[\dot{q}_d + \Lambda\tilde{q}\right] + g(q),$$

Hint: use this Lyapunov function candidate:

$$V(t,\tilde{q},\dot{\tilde{q}},\tilde{\theta}) = \frac{1}{2}\left[\dot{\tilde{q}} + \Lambda\tilde{q}\right]^T M(q,\theta)\left[\dot{\tilde{q}} + \Lambda\tilde{q}\right] + \tilde{q}^T K_p\tilde{q} + \frac{1}{2}\tilde{\theta}^T\Gamma^{-1}\tilde{\theta}\,.$$