MAE 143B, Spring 2014, HW #1 Sol'ns

P1.1: The answers have been provided for every item in fig 1.11:

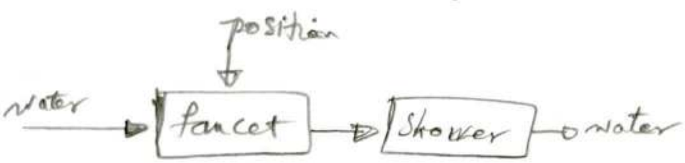
(a)

* input: voltage, output: speed
* voltage is a proper voltage signal applied to a motor terminal/phase depending on the type of the motor.
* Speed is the speed of the shaft of the motor measured by an appropriate sensor, e.g., tacometer.
* The given system is in open-loop provided there is no feedback line in the given block diagram.
* Provided the governing model for every motor is dynamic, thus the relationship b/w input & output is dynamic.
* Let V stand for the voltage, ν stand for the velocity, Gm stand for the motor transfer fcn and Gs stand for the sensor transfer fcn, then:

$$\nu = G_m G_s V \Rightarrow \boxed{\frac{\nu}{V} = G_m G_s}$$

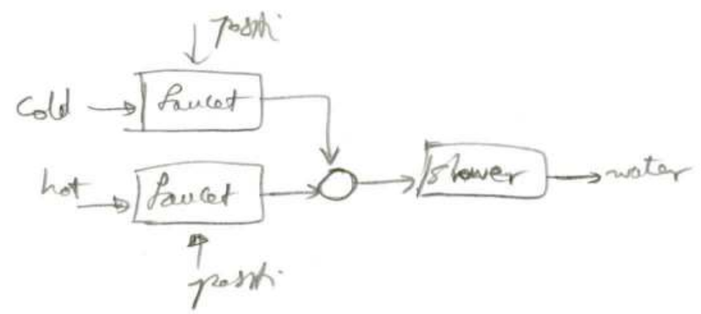
* There is no disturbance signal present in the given blockdiagram.

(b)



* input: water at the faucet side (this may be the water flow rate input to the faucet)
  output: water at the shower side (this may be the level of water in the shower basin).
  position: this signal can be regarded as a control signal, i.e., it may regulate the opening percentage of the faucet and thus it regulates the water flow rate that is input to the shower basin.
* The given system is in open-loop provided there is no feedback line in the given block diagram
* Provided the relation b/w the water inflow rate to the shower and the water level in the shower basin is dynamic, thus the relationship b/w input & output is dynamic.
* There is no disturbance signal in the given block diagram.

(C)



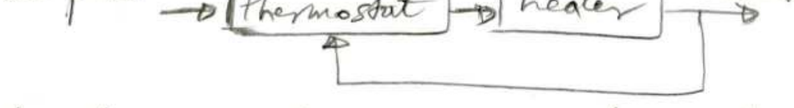
* inputS: one can distinguish 2 inputs, to be hot and coldwater inflow rate at the faucet side
outputs: water at the shower side (this may be the level of water in the shower basin)
Control signals: one can distinguish the 2 position signals at the faucet side to be the control signals to regulate the water inflow rate to the shower basin.

* The given system is in open loop provided there is no feedback provided in the block diagram.

* The relationship b/w the output and inputs is dynamic, provided the relationship b/w water inflow rates and water level in the shower basin is dynamic.

* There is no disturbance signal in the presented block diagram.

(d)

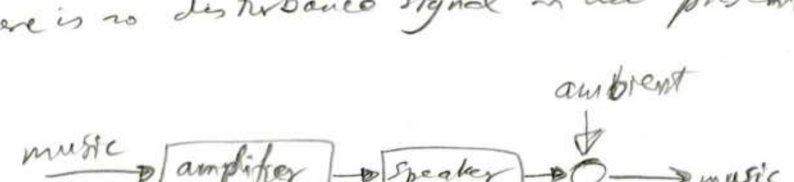


* input: the input would be the desired temprature set at the thermostat side
output: the output would be the water temperature at the heater side.

* the given system is in closed-loop provided the feedback line connecting water temprature at the output side to desired temperature at the input side.
* the relationship b/w input and output is dynamic, provided heater is a dynamic element.

* There is no disturbance signal in the present block diagram.

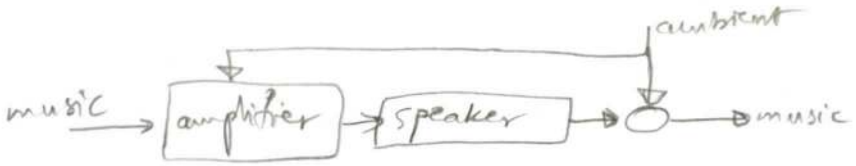
(e)



* input: music at the amplifier side
output: music at the speaker side

* the given system is in open-loop provided there is no feedback provided in the block diagram
* The relationship b/w the input and output is static provided the tuning at the amplifier side and its effect on the speaker part is static
* ambient music which shows itself as an additional element on the output music is disturbance.

(f)



* input: music at the amplifier side
  output: music at the speaker side
* the given system is in open-loop provided there is no feedback provided in the block diagram.
* the relation b/w the input & output is static provided the tuning at the amplifier side and its effect on the speaker part is static
* ambient music which shows itself as additional element on the amplifier part and on the output music signal can be regarded as disturbance.

P1-3:

Before sketching a block diagram we would like to discuss "homeostasis" process. Homeostasis literally means "same state" which refers to the process of keeping the internal body environment in a steady-state despite the changes in the external environment. Much of the hormone system and autonomic nervous system is dedicated to homeostasis, and their acti is coordinated by the hypothalamus. ⇒ The main point is that all homeostatic mechanisms use negative feedback to maintain a constant value of internal body temperature. Therefore, in other words, in a system controlled by negative feedback, the set level is never perfectly maintained, but constantly oscillates about the set point. ⇒ An efficient homeostatic system (as described below) minimises the size of these oscillatis.

Temperature homeostasis (thermoregulation) ⇒ One can differentiate b/w 2 mechanisms that mammals use in order to regulate their internal body temperature
→ (i) Behavioral mechanisms,
→ (ii) Internal mechanisms,
in what follows, we shall be more specific on these 2 mechanisms.

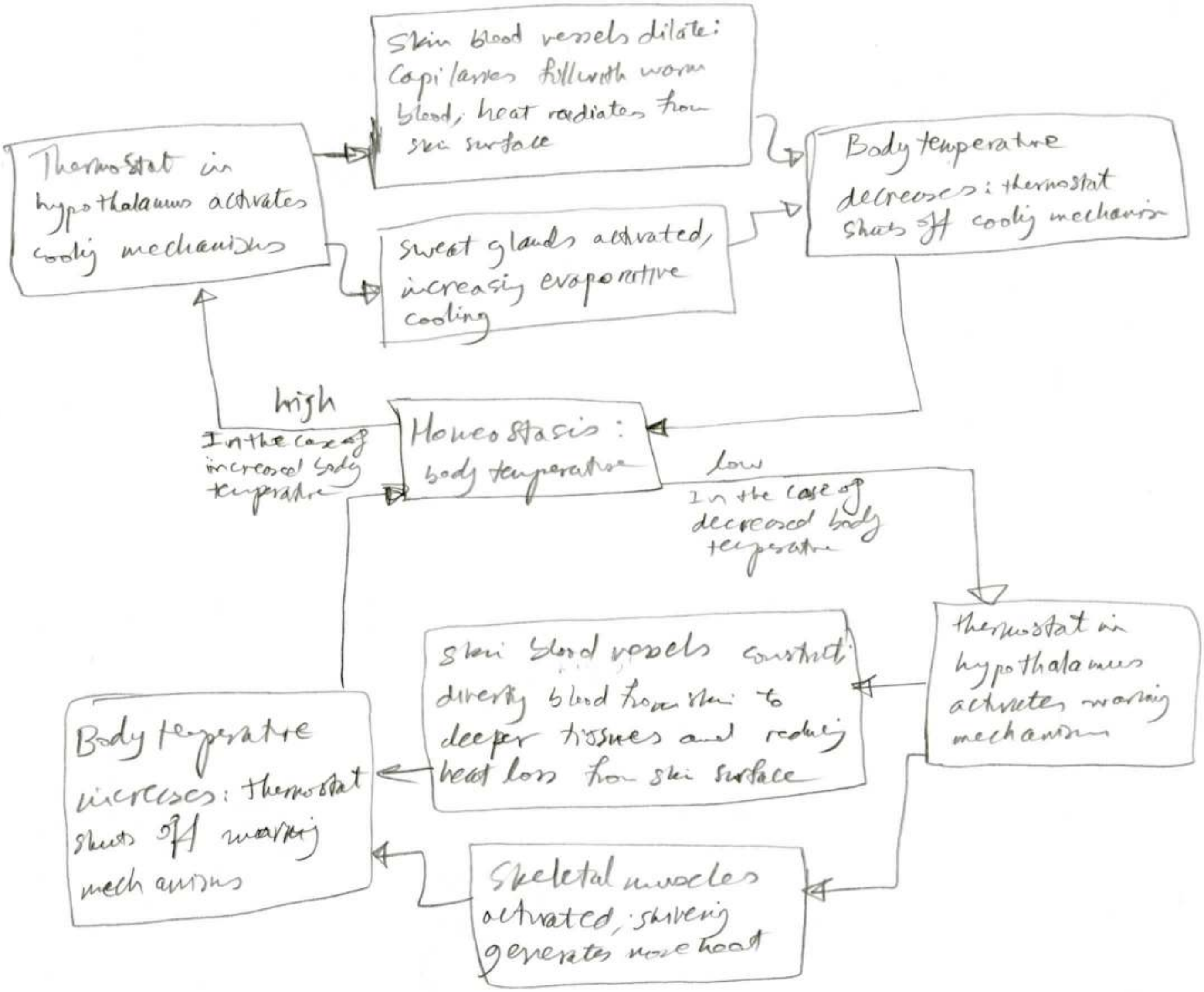
(i) Behavioral mechanisms: In the context of control, this type of mechanisms can be seen as an "open-loop" soluti. To be more specific, behavioral mechanisms may entail lying in the sun when cold or moving into shade when hot. Therefore, one cannot really distinguish a precise f/b line in this type of mechanisms leading in precise thermal regulati.

(ii) Internal mechanisms: In the context of control, this type of mechanism can be seen as a "closed-loop" soluti. In other words, under this type of mechanism mammals incorporate a rather precise way of sensing, actuation, and feedback in order to perform thermal regulati. To be more specific, body temperature is controlled by the thermoregulatory center in the hypothalamus. ⇒ It receives inputs from 2 sets of thermoreceptors
→ receptors in the hypothalamus itself that monitor the temperature of the blood as it passes through the brain (the core temperature)
→ receptors in the skin that monitor the external temperature.

indeed, both sets of information (core temperature & external temperature) are needed to make proper internal adjustments to perform thermoregulati. Having discussed sensing system for this type of mechanism, one can also distinguish hypothalamus itself as the controller and reactions such as skin blood vessels dilati, sweat glands activati for actuati techniques for decreasing the temperature, and reaction such as constricti in skin blood vessels and skeletal muscles activation for actuating techniques for increasing temperature.

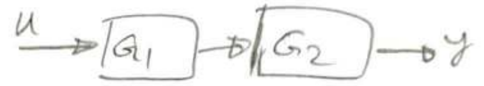
In both the above mentioned mechanisms, one can distinguish phenomena such as snow, rain, heavy wind as plausible disturbances. It goes also w/o saying that internal mechanisms would be more efficient and robust thanks to their closed loop nature; whereas behavioral mechanisms would not be as efficient and precise provided their open-loop nature.

Scheme of the closed-loop action of internal mechanism is depicted below:



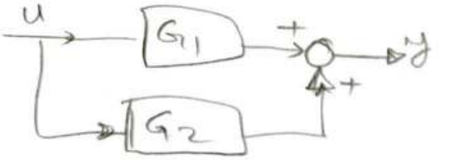
P1.7: The transfer fcn from u to y is computed for every block diagram provided in Fig. 1.12 as follows: (as stated in the problem statement, all the blocks are assumed to be linear) [illegible]

(a)



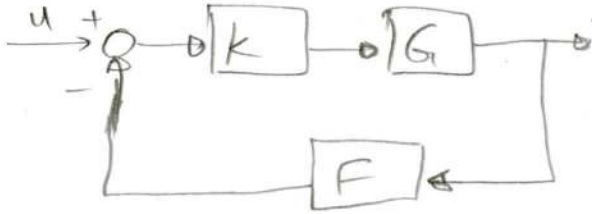
$$y = G_1 G_2 u \Rightarrow \boxed{H = \frac{y}{u} = G_1 G_2}$$

(b)



$$y = G_1 u + G_2 u \Rightarrow y = (G_1 + G_2) u \Rightarrow \boxed{H = \frac{y}{u} = G_1 + G_2}$$

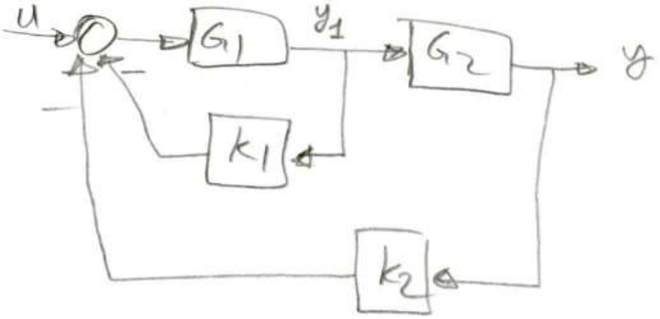
(c)



$$y = (u - Fy) K G \Rightarrow y = kG u - FkG y \Rightarrow y(1 + FkG) = (kG) u$$

$$\Rightarrow \boxed{H = \frac{y}{u} = \frac{kG}{1 + FkG}}$$

(d)



$$\begin{cases} \boxed{y = G_2 y_1} \; (*) \\ (u - k_2 y - k_1 y_1) G_1 = y_1 \Rightarrow G_1 u - G_1 k_2 y - G_1 k_1 y_1 = y_1 \\ \Rightarrow \boxed{G_1 u - G_1 k_2 y = (G_1 k_1 + 1) y_1} \; (**) \end{cases}$$

plugging for y_1 from (**) in (*) yields:

$$y = G_2 \left[\frac{G_1 u - G_1 k_2 y}{G_1 k_1 + 1} \right] \Rightarrow y = \left(\frac{G_1 G_2}{G_1 k_1 + 1} \right) u - \left(\frac{G_1 G_2 k_2}{G_1 k_1 + 1} \right) y$$

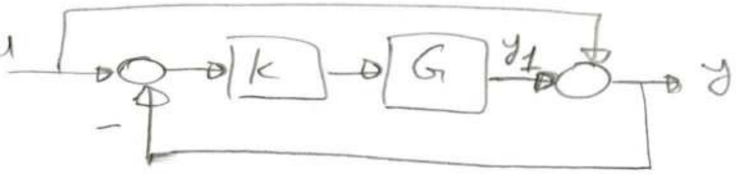
$$\Rightarrow \left[1+\frac{G_1G_2k_2}{G_1k_1+1}\right]y = \left[\frac{G_1G_2}{G_1k_1+1}\right]u$$

after some simplification on the above eq'n, we obtain:

$$\left[G_1k_1+G_1G_2k_2+1\right]y=\left[G_1G_2\right]u$$

$$\Rightarrow \boxed{H=\frac{y}{u}=\frac{G_1G_2}{1+G_1k_1+G_1G_2k_2}}$$

(e)



$$\begin{cases} y = u + y_1 \\ y_1 = (u-y)kG \end{cases} \Rightarrow y = u + (u-y)kG \Rightarrow y + kGy = (1+kG)u$$

$$\Rightarrow y = u \Rightarrow \boxed{H=\frac{y}{u}=1}$$

P1.8:

According to the problem statement and Figure 1.13, we shall consider the following scheme for this problem:

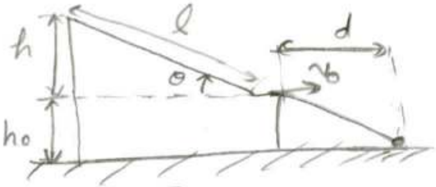


Fig. 1

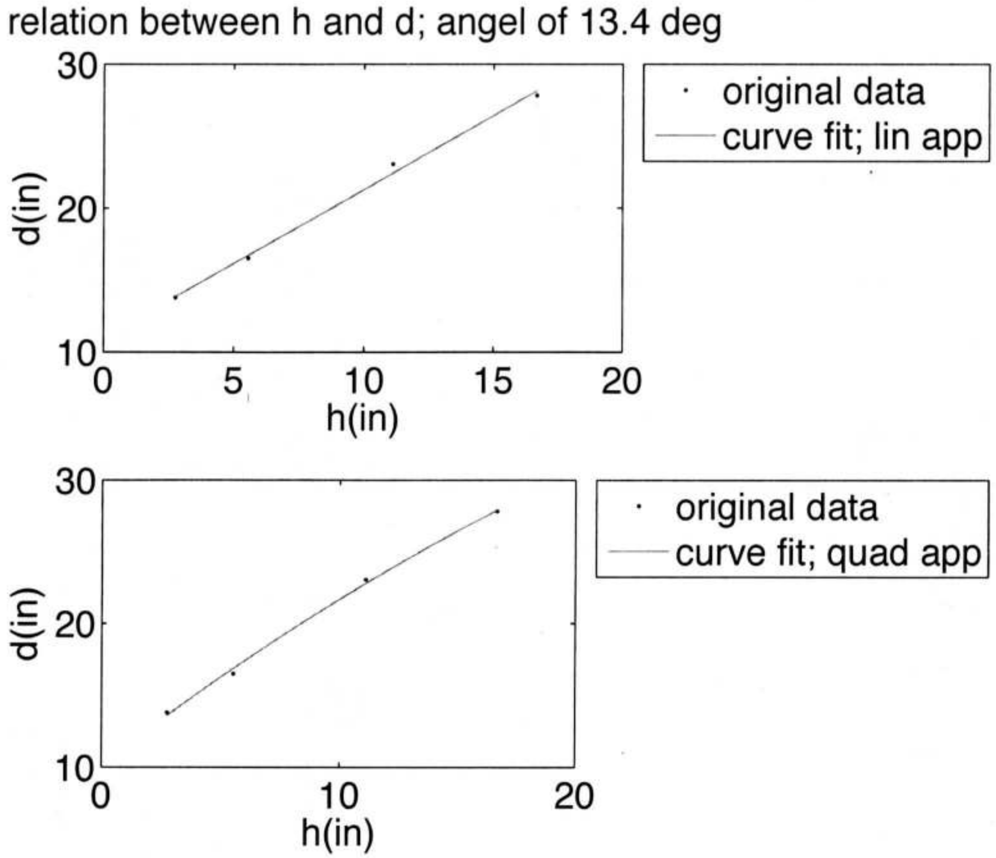
Referring to Fig.1, we note that we have drawn an additional vector, v_0 that is the initial velocity of the ball exactly before leaving the plan. We note that given the explanations in the problem statement, this velocity is a horizontal velocity, i.e., its vertical component is zero. Also, we have considered another element, h_0, in this figure, that according to problem statement we have $h_0 = 40''$.

We have solved the problem as follows:

- We have generated a code which does the following:
    - for every $\theta = 13.4°$ and $6.7°$, it first computes $h = l \sin\theta$
    - for every h, it computes the average of 5 trials for d
    - it draws the result of linearly approximating and quadratically approximating and fitting a curve through h-d dataset.

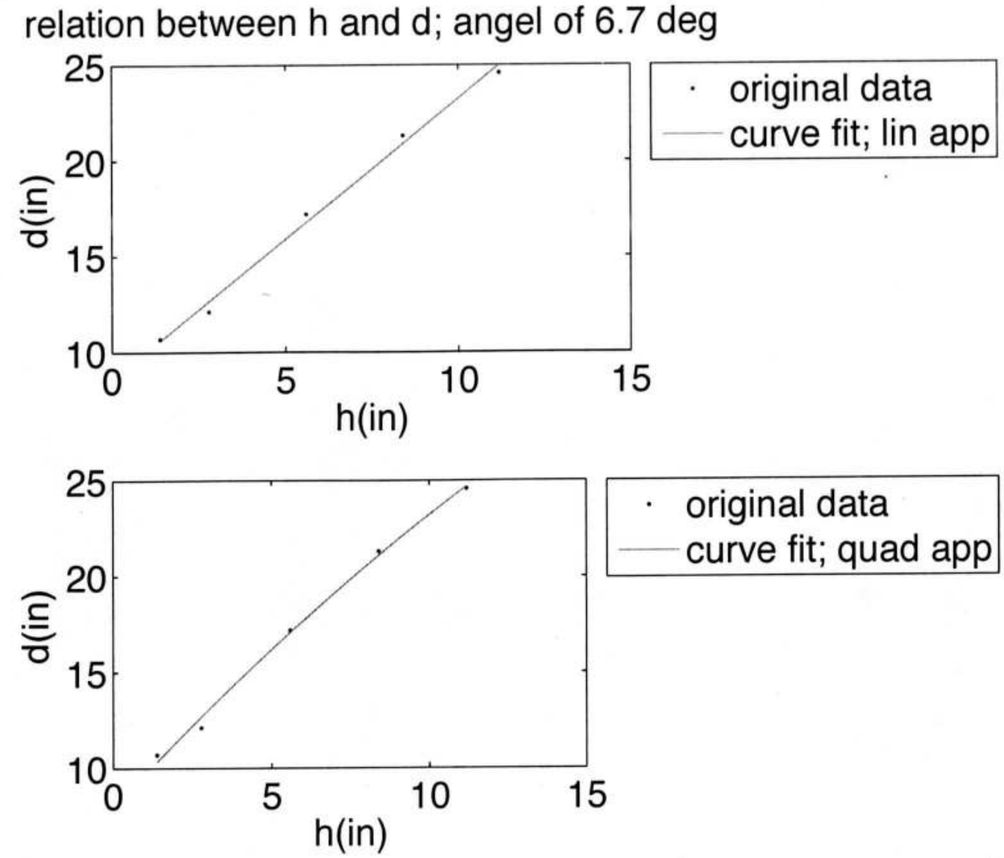
The afore discussed code along w/ the figures are seen in the next pages. We have also discussed and compared the results therein.

The only point that we would like to discuss here is that given the above setup and set of data, we can also derive v_0 — provided it has only a horizontal component and that it is a free projectile problem w/ $h_0 = 40''$.



As it is indicated on the above figure, linear and quadratic approximation have been used in order to fit a proper curve on the given data set. linear approximation has been used provided the rough estimate of the points of data set lying on a straight line, quadratic approximation has been exploited to obtain a better approximation as opposed to linear one.

As expected, the quadratic approximation provides a better estimate while linear one is still good.



Exactly the same explanation for the case of 13.4° for inclination angel is valid in this case, as well. please thus refer to page 9.

```
% there are two cases, i.e., two angels.
clc;
clear all;
close all;

%% data for theta_1 = 13.4deg,

% to convert degree into radians:
theta_1 = 13.4 * pi/180;

% to convert feet the l-info into inches:
l_1(1) = 1 * 12;
l_1(2) = 2 * 12;
l_1(3) = 4 * 12;
l_1(4) = 6 * 12;

% provided we are lookng for a relation between h and d, we convert l info
% to h:
h_1 = l_1 * sin(theta_1);

% to gather the d-info:
% with the last emelent of each column be the mean value of the elements of
% same column

% for l_1(1) = 1:
d_1(1,1) = (13+15/16);
d_1(2,1) = (13+7/8);
```

```
d_1(3,1) = (14+1/16);
d_1(4,1) = (14);
d_1(5,1) = (13+1/16);
d_1(6,1) = mean(d_1(:,1));

% for l_1(2) = 2:
d_1(1,2) = (19+13/16);
d_1(2,2) = (19+13/16);
d_1(3,2) = (19+13/16);
d_1(4,2) = (19+3/4);
d_1(5,2) = (19+3/4);
d_1(6,2) = mean(d_1(:,2));

% for l_1(3) = 4:
d_1(1,3) = (27+11/16);
d_1(2,3) = (27+3/4);
d_1(3,3) = (27+3/4);
d_1(4,3) = (27+9/16);
d_1(5,3) = (27+9/16);
d_1(6,3) = mean(d_1(:,3));

% for l_1(4) = 6:
d_1(1,4) = (33+3/8);
d_1(2,4) = (33+5/16);
d_1(3,4) = (33+3/16);
d_1(4,4) = (33+7/16);
d_1(5,4) = (33+5/8);
```

```
d_1(6,4) = mean(d_1(:,4));


% to fit different types of curves give the above data:
f_1_lin = fit(h_1', d_1(6,:)', 'poly1');
f_1_quad = fit(h_1', d_1(6,:)', 'poly2');


figure;
subplot(2,1,1); plot(f_1_lin , h_1 , d_1(6,:))


h = legend('original data' , 'curve fit; lin app' , 'Location','NorthEastOutside');
set(h,'FontSize',18);


xlabel('h(in)')
h = get(gca, 'xlabel');
set(h, 'FontSize', 18)
ylabel('d(in)')
h = get(gca, 'ylabel');
set(h, 'FontSize', 18)


title('relation between h and d; angel of 13.4 deg'),
h = get(gca, 'title');
set(h, 'FontSize', 18)
set(gca,'FontSize',18)




subplot(2,1,2); plot(f_1_quad , h_1 , d_1(6,:))
```

```
h = legend('original data' , 'curve fit; quad app' , 'Location','NorthEastOutside');
set(h,'FontSize',18);

xlabel('h(in)')
h = get(gca, 'xlabel');
set(h, 'FontSize', 18)
ylabel('d(in)')
h = get(gca, 'ylabel');
set(h, 'FontSize', 18)
set(gca,'FontSize',18)

%% data for theta_2 = 6.7deg,

% to convert degree into radians:
theta_2 = 6.7 * pi/180;

% to convert feet the l-info into inches:
l_2(1) = 1 * 12;
l_2(2) = 2 * 12;
l_2(3) = 4 * 12;
l_2(4) = 6 * 12;
l_2(5) = 8 * 12;

% provided we are lookng for a relation between h and d, we convert l info
% to h:
h_2 = l_2 * sin(theta_2);
```

```
% to gather the d-info:
% with the last emelent of each column be the mean value of the elements of
% same column

% for l_2(1) = 1:
d_2(1,1) = (10+11/16);
d_2(2,1) = (10+11/16);
d_2(3,1) = (10+11/16);
d_2(4,1) = (10+11/16);
d_2(5,1) = (10+11/16);
d_2(6,1) = mean(d_2(:,1));

% for l_2(2) = 2:
d_2(1,2) = (14+1/2);
d_2(2,2) = (14+9/16);
d_2(3,2) = (14+1/2);
d_2(4,2) = (14+1/2);
d_2(5,2) = (14+9/16);
d_2(6,2) = mean(d_2(:,2));

% for l_2(3) = 4:
d_2(1,3) = (20+3/4);
d_2(2,3) = (20+3/4);
d_2(3,3) = (20+3/4);
d_2(4,3) = (20+3/4);
d_2(5,3) = (20+3/16);
d_2(6,3) = mean(d_2(:,3));
```

```
% for l_2(4) = 6:
d_2(1,4) = (25+7/16);
d_2(2,4) = (25+1/2);
d_2(3,4) = (25+3/4);
d_2(4,4) = (25+1/2);
d_2(5,4) = (25+5/8);
d_2(6,4) = mean(d_2(:,4));

% for l_2(5) = 8:
d_2(1,5) = (29+5/8);
d_2(2,5) = (29+1/2);
d_2(3,5) = (29+1/2);
d_2(4,5) = (29+5/16);
d_2(5,5) = (29+1/2);
d_2(6,5) = mean(d_2(:,5));
% to visualize the data, i.e., relation between h and d
% to fit different types of curves give the above data:
f_2_lin = fit(h_2', d_2(6,:)', 'poly1');
f_2_quad = fit(h_2', d_2(6,:)', 'poly2');

figure;
subplot(2,1,1); plot(f_2_lin , h_2 , d_2(6,:))

h = legend('original data' , 'curve fit; lin app' , 'Location','NorthEastOutside');
set(h,'FontSize',18);
```

```
xlabel('h(in)')
h = get(gca, 'xlabel');
set(h, 'FontSize', 18)
ylabel('d(in)')
h = get(gca, 'ylabel');
set(h, 'FontSize', 18)

title('relation between h and d; angel of 6.7 deg'),
h = get(gca, 'title');
set(h, 'FontSize', 18)
set(gca,'FontSize',18)


subplot(2,1,2); plot(f_2_quad , h_2 , d_2(6,:))

h = legend('original data' , 'curve fit; quad app' , 'Location','NorthEastOutside');
set(h,'FontSize',18);

xlabel('h(in)')
h = get(gca, 'xlabel');
set(h, 'FontSize', 18)
ylabel('d(in)')
h = get(gca, 'ylabel');
set(h, 'FontSize', 18)
set(gca,'FontSize',18)
```