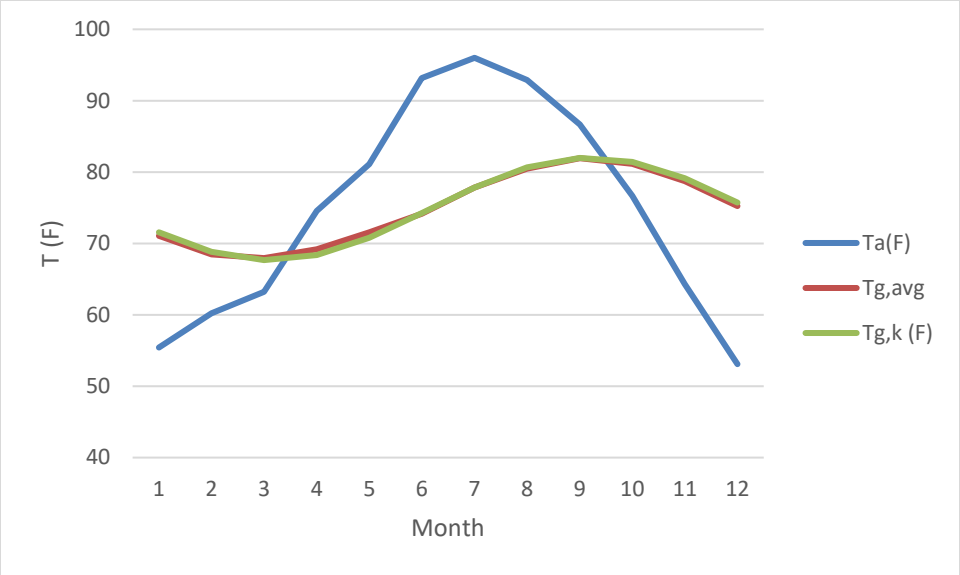
Energy Efficient Buildings
Floor and Basement Homework

1) (U,G) Using TMY3 data for Phoenix Sky Harbor Intl AP and WeaTran, make a graph with:
   - Monthly outdoor air temperature over a year
   - Monthly effective ground temperatures for slab heat loss over a year calculated using the averaging method
   - Monthly effective ground temperatures for slab heat loss over a year calculated using the Kasuda method. Soil diffusivity α is 1.6 ft^2/day. In the Kasuda method, tshift is always 30 days and tnow for month 1 is 30, tnow for month 2 is 60, etc.

Input Data	
Ta,avg (F)	74.84
Tmean (F)	74.84
Tamp (F)	21.46
Thermal diffusivity (alpha) (ft2/day)	1.617
depth (ft)	15
tshift (day)	30

Calculations

Mo	Yr	Ta(F)	Toa,3mo	Tg,avg	tnow	X1 = cos {2 pi/365 x (tnow - tshift - Depth/2 (365/pi/alpha)^0.5}	X2 = Tamp x exp[- Depth x (pi/365/alpha)^0.5]	Tg,k (F)
1	1995	55.42	64.69	71.08	30	0.46	7.18	71.55
2	1995	60.20	57.61	68.46	60	0.84	7.18	68.82
3	1995	63.21	56.24	67.95	90	1.00	7.18	67.67
4	1995	74.58	59.61	69.20	120	0.90	7.18	68.39
5	1995	81.12	66.00	71.56	150	0.56	7.18	70.79
6	1995	93.18	72.97	74.15	180	0.08	7.18	74.24
7	1995	96.01	82.96	77.85	210	-0.42	7.18	77.86
8	1995	92.88	90.10	80.49	240	-0.81	7.18	80.68
9	1995	86.69	94.02	81.94	270	-0.99	7.18	81.98
10	1995	76.66	91.86	81.14	300	-0.92	7.18	81.42
11	1995	64.31	85.41	78.75	330	-0.60	7.18	79.14
12	1995	53.09	75.89	75.23	360	-0.13	7.18	75.74



2) (U,G) Consider a house with inside air temperature of 70 F and a 40 ft x 60 ft slab-on-grade floor. The effective ground temperature for slab heat loss is 40 F.

a) Calculate the heat loss rate (Btu/hr) if the floor is slab-on-grade with no perimeter insulation and no floor insulation.

Input Data	
Tia (F)	70
Tg (F)	40
L (ft)	60
B (ft)	40
Rp (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	0
Calculations	
A (ft2) = L B	2400
U (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.083
Q (Btu/hr) = U A (Tia-Tg)	**5997.60**

b) Calculate the heat loss rate (Btu/hr) if you add R = 5 (hr-ft2-F/Btu) insulation to the perimeter.

Input Data	
Tia (F)	70
Tg (F)	40
L (ft)	60
B (ft)	40
Rp (hr-ft2-F/Btu)	5
Rf (hr-ft2-F/Btu)	0
Calculations	
A (ft2) = L B	2400
U (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.067
Q (Btu/hr) = U A (Tia-Tg)	**4857.60**

c) Determine the R-value of floor insulation, in addition to the R = 5 (hr-ft2-F/Btu) perimeter insulation, needed to reduce the heat loss calculated in part a) to 1/3 of its initial value to achieve an E/3 floor.

Input Data	
Tia (F)	70
Tg (F)	40
L (ft)	60
B (ft)	40
Rp (hr-ft2-F/Btu)	5
Rf (hr-ft2-F/Btu)	**20.65**
Calculations	
A (ft2) = L B	2400
U (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.028
Q (Btu/hr) = U A (Tia-Tg)	**1999.20**

3) (U,G) Consider a house with inside air temperature of 70 F and a basement with floor area 40 ft x 60 ft and 8 ft high walls. The effective ground temperature for basement heat loss is 40 F.

a) Calculate the heat loss rate (Btu/hr) if the basement walls and floor are uninsulated.

Input Data	
Tia (F)	70
Tg (F)	40
L (ft)	60
B (ft)	40
H (ft)	8
Rw (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	0
Calculations	
Afloor (ft2) = L B	2400
Awalls (ft2) = 2(L H) + 2(B H)	1600
Af1 = Afloor/(Awalls+Afloor)	0.60
Af2 = Awalls/(Awalls+Afloor)	0.40
U (Btu/hr-ft2-F) = [Af1/(44.8+Rf)] + [Af2/(4.6+Rw)]	0.100
Q (Btu/hr) = U A (Tia-Tg)	**12041.93**

b) Calculate the heat loss rate (Btu/hr) if R = 12 hr-ft2-F/Btu insulation is added to the basement walls (with no insulation on the basement floor).

Input Data	
Tia (F)	70
Tg (F)	40
L (ft)	60
B (ft)	40
H (ft)	8
Rw (hr-ft2-F/Btu)	12
Rf (hr-ft2-F/Btu)	0
Calculations	
Afloor (ft2) = L B	2400
Awalls (ft2) = 2(L H) + 2(B H)	1600
Af1 = Afloor/(Awalls+Afloor)	0.60
Af2 = Awalls/(Awalls+Afloor)	0.40
U (Btu/hr-ft2-F) = [Af1/(44.8+Rf)] + [Af2/(4.6+Rw)]	0.037
Q (Btu/hr) = U A (Tia-Tg)	**4498.71**

c) Calculate the heat loss rate (Btu/hr) if R = 12 hr-ft2-F/Btu insulation is added to the basement floor (with no insulation on the basement walls)

Input Data	
Tia (F)	70
Tg (F)	40
L (ft)	60
B (ft)	40
H (ft)	8
Rw (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	12
Calculations	
Afloor (ft2) = L B	2400
Awalls (ft2) = 2(L H) + 2(B H)	1600
Af1 = Afloor/(Awalls+Afloor)	0.60
Af2 = Awalls/(Awalls+Afloor)	0.40
U (Btu/hr-ft2-F) = [Af1/(44.8+Rf)] + [Af2/(4.6+Rw)]	0.098
Q (Btu/hr) = U A (Tia-Tg)	**11702.39**

d) Which is more effective at reducing heat loss, adding insulation to the basement walls or floor? Why?

Adding insulation to the basement walls, is more effective at reducing heat loss. Because the rate of heat loss is greatest where the thermal resistance is smallest. Heat loss through slab-on-grade floors is greatest along the edge of the slab and heat loss from basements is greatest at the upper part of the basement walls, where the length of travel from the warm inside air to the cold outside air is smallest.

4) (U,G) Consider a house with inside air temperature of 70 F and a 40 ft x 60 ft floor above a ventilated, uninsulated crawl space. The floor has thermal resistance of R = 4 hr-ft2-F/Btu including convection coefficients. The crawlspace wall height is 2 feet. The rate of air leaking into and from the crawlspace is 100 ft3/min. The outside air temperature is 30 F. The effective ground temperature for slab heat loss is 40 F.

a) Calculate the heat loss rate (Btu/hr) from the floor.

Input Data	
Tia (F)	70
Toa (F)	30
Tg (F)	40
Lf (ft)	60
Wf (ft)	40
Hcsw (ft)	2
Rfloor (hr-ft2-F/Btu)	4
Rcsw,ins (hr-ft2-F/Btu)	0
V (ft3/min)	100
Rp (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	0
pcp (Btu/ft3-F)	0.018
Calculations	
Ufloor (Btu/hr-ft2-F) = 1 / Rfloor	0.25
Afloor (ft2) = Lf Wf	2400
UAfloor (Btu/hr-F) = Ufloor Afloor	600
Ucsw (Btu/hr-ft2-F) = 1 /(1.36+Rcsw,ins)	0.735294118
Acsw (ft2) = Perimeter Hcsw	400
UAcsw (Btu/hr-F) = Ucsw Acsw	294.12
Ugrnd (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.083
UAgrnd (Btu/hr-F) = Ugrnd Afloor	199.92
Vpcp (Btu/hr-F) = V pcp 60 min/hr	108.000
Tcs (F) = (Uafloor Tia + Uacsw Toa +Uagrnd Tg + Vpcp Toa) / (Uafloor + Uacsw + Uagrnd + Vpcp)	51.63
Q (Btu/hr) = UAfloor (Tia-Tcs)	11022.44

b) To reduce the rate of heat loss, the crawlspace is sealed so that the rate of ventilation is 0 ft3/min and R = 12 hr-ft2-F/Btu insulation is added to the crawlspace wall and extends below grade. Calculate the heat loss rate (Btu/hr) from the floor.

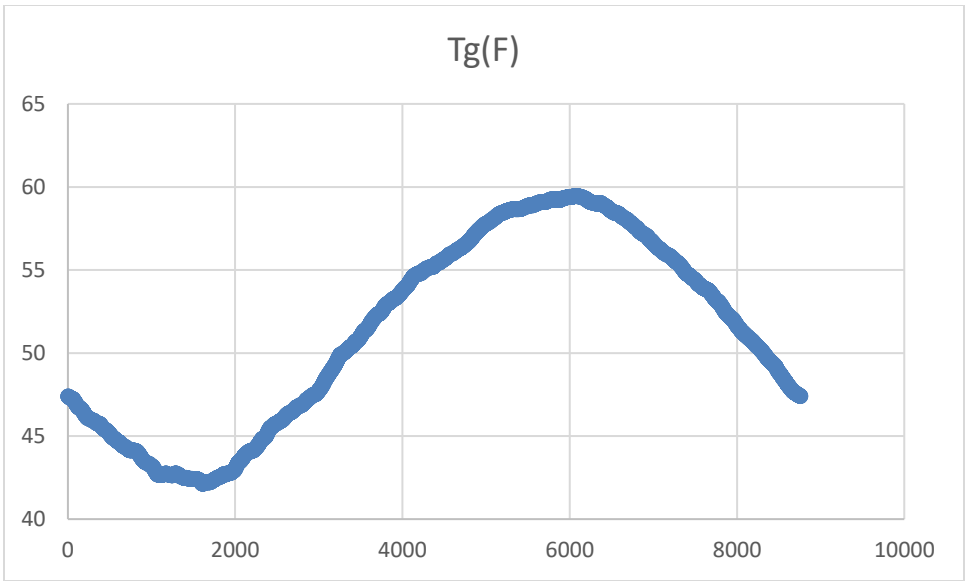
Input Data	
Tia (F)	70
Toa (F)	30
Tg (F)	40
Lf (ft)	60
Wf (ft)	40
Hcsw (ft)	2
Rfloor (hr-ft2-F/Btu)	4
Rcsw,ins (hr-ft2-F/Btu)	12
V (ft3/min)	0
Rp (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	0
pcp (Btu/ft3-F)	0.018
Calculations	
Ufloor (Btu/hr-ft2-F) = 1 / Rfloor	0.25
Afloor (ft2) = Lf Wf	2400
UAfloor (Btu/hr-F) = Ufloor Afloor	600
Ucsw (Btu/hr-ft2-F) = 1 /(1.36+Rcsw,ins)	0.074850299
Acsw (ft2) = Perimeter Hcsw	400
UAcsw (Btu/hr-F) = Ucsw Acsw	29.94
Ugrnd (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.083
UAgrnd (Btu/hr-F) = Ugrnd Afloor	199.92
Vpcp (Btu/hr-F) = V pcp 60 min/hr	0.000
Tcs (F) = (Uafloor Tia + Uacsw Toa +Uagrnd Tg + Vpcp Toa) / (Uafloor + Uacsw + Uagrnd + Vpcp)	61.33
Q (Btu/hr) = UAfloor (Tia-Tcs)	**5202.23**

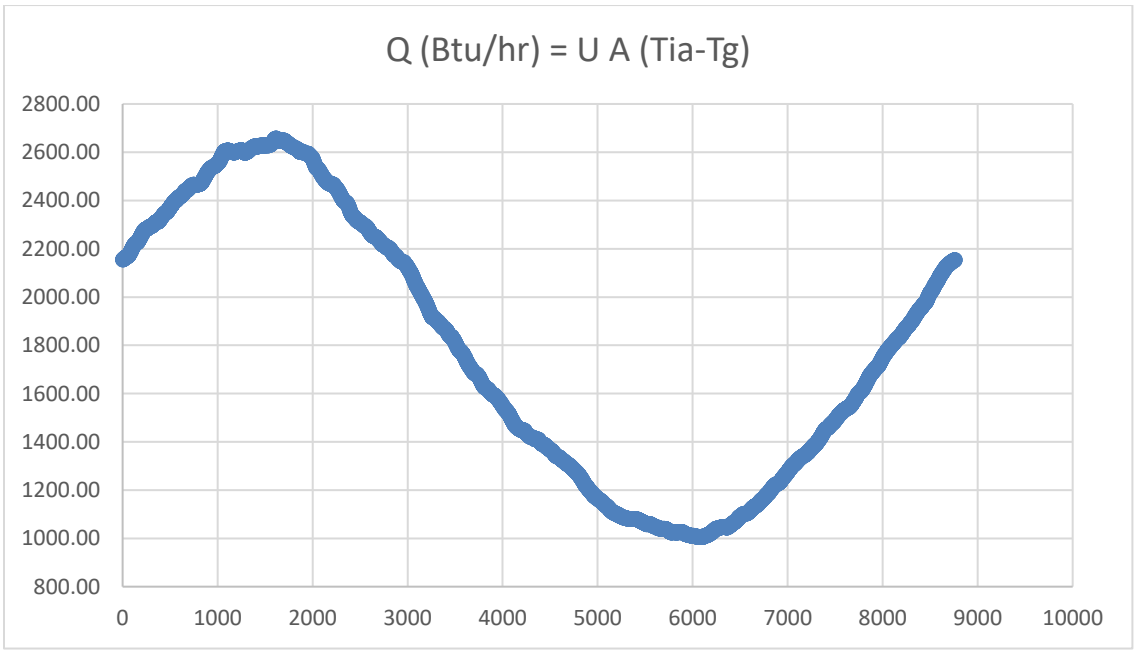
Input Data	
Tia (F)	70
Toa (F)	30
Tg (F)	40
Lf (ft)	60
Wf (ft)	40
Hcsw (ft)	2
Rfloor (hr-ft2-F/Btu)	16
Rcsw,ins (hr-ft2-F/Btu)	12
V (ft3/min)	0
Rp (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	0
pcp (Btu/ft3-F)	0.018
Calculations	
Ufloor (Btu/hr-ft2-F) = 1 / Rfloor	0.0625
Afloor (ft2) = Lf Wf	2400
UAfloor (Btu/hr-F) = Ufloor Afloor	150
Ucsw (Btu/hr-ft2-F) = 1 /(1.36+Rcsw,ins)	0.074850299
Acsw (ft2) = Perimeter Hcsw	400
UAcsw (Btu/hr-F) = Ucsw Acsw	29.94
Ugrnd (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.083
UAgrnd (Btu/hr-F) = Ugrnd Afloor	199.92
Vpcp (Btu/hr-F) = V pcp 60 min/hr	0.000
Tcs (F) = (Uafloor Tia + Uacsw Toa +Uagrnd Tg + Vpcp Toa) / (Uafloor + Uacsw + Uagrnd + Vpcp)	51.06
Q (Btu/hr) = UAfloor (Tia-Tcs)	**2841.26**

Input Data	
Tia (F)	70
Toa (F)	30
Tg (F)	40
Lf (ft)	60
Wf (ft)	40
Hcsw (ft)	2
Rfloor (hr-ft2-F/Btu)	4
Rcsw,ins (hr-ft2-F/Btu)	12
V (ft3/min)	0
Rp (hr-ft2-F/Btu)	0
Rf (hr-ft2-F/Btu)	12
pcp (Btu/ft3-F)	0.018
Calculations	
Ufloor (Btu/hr-ft2-F) = 1 / Rfloor	0.25
Afloor (ft2) = Lf Wf	2400
UAfloor (Btu/hr-F) = Ufloor Afloor	600
Ucsw (Btu/hr-ft2-F) = 1 /(1.36+Rcsw,ins)	0.07485
Acsw (ft2) = Perimeter Hcsw	400
UAcsw (Btu/hr-F) = Ucsw Acsw	29.94
Ugrnd (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	0.038
UAgrnd (Btu/hr-F) = Ugrnd Afloor	92.25
Vpcp (Btu/hr-F) = V pcp 60 min/hr	0.000
Tcs (F) = (Uafloor Tia + Uacsw Toa +Uagrnd Tg + Vpcp Toa) / (Uafloor + Uacsw + Uagrnd + Vpcp)	64.51
Q (Btu/hr) = UAfloor (Tia-Tcs)	**3294.32**

5) (G): Consider a house in Dayton, OH with inside air temperature of 70 F and a 40 ft x 60 ft slab-on-grade floor. Calculate the heat loss rate (Btu/hr) if the floor is slab-on-grade with R = 5 (hr-ft^2-F/Btu) insulation on the perimeter and R = 10 (hr-ft^2-F/Btu) insulation on the floor for every hour of the year.

Mo	Dy	Yr	Hr	Ta(F)	Tg(F)	Tia (F)	L (ft)	B (ft)	Rp (hr-ft2-F/Btu)	Rf (hr-ft2-F/Btu)	A (ft2) = L B	U (Btu/hr-ft2-F) = [0.1140/(4+Rf+Rp)] + [0.8768/(16+Rf)]	Q (Btu/hr) = U A (Tia-Tg)
1	1	1995	1	32	47.4	70	60	40	5	10	2400	0.040	**2154.58**
1	1	1995	2	32	47.39	70	60	40	5	10	2400	0.040	**2155.53**
1	1	1995	3	32	47.39	70	60	40	5	10	2400	0.040	**2155.53**
1	1	1995	4	32	47.39	70	60	40	5	10	2400	0.040	**2155.53**
1	1	1995	5	32	47.38	70	60	40	5	10	2400	0.040	**2156.49**
1	1	1995	6	30.92	47.38	70	60	40	5	10	2400	0.040	**2156.49**
1	1	1995	7	30.92	47.38	70	60	40	5	10	2400	0.040	**2156.49**
1	1	1995	8	30.92	47.37	70	60	40	5	10	2400	0.040	**2157.44**
1	1	1995	9	30.02	47.37	70	60	40	5	10	2400	0.040	**2157.44**
1	1	1995	10	30.92	47.37	70	60	40	5	10	2400	0.040	**2157.44**
1	1	1995	11	32	47.36	70	60	40	5	10	2400	0.040	**2158.39**
1	1	1995	12	32	47.36	70	60	40	5	10	2400	0.040	**2158.39**
1	1	1995	13	33.08	47.36	70	60	40	5	10	2400	0.040	**2158.39**
1	1	1995	14	33.98	47.35	70	60	40	5	10	2400	0.040	**2159.35**
1	1	1995	15	33.98	47.35	70	60	40	5	10	2400	0.040	**2159.35**
1	1	1995	16	33.98	47.35	70	60	40	5	10	2400	0.040	**2159.35**
1	1	1995	17	33.08	47.34	70	60	40	5	10	2400	0.040	**2160.30**
1	1	1995	18	33.08	47.34	70	60	40	5	10	2400	0.040	**2160.30**
1	1	1995	19	33.08	47.34	70	60	40	5	10	2400	0.040	**2160.30**
1	1	1995	20	33.08	47.33	70	60	40	5	10	2400	0.040	**2161.25**


Tg(F)
65
60
55
50
45
40
0
2000
4000
6000
8000
10000


Q (Btu/hr) = U A (Tia-Tg)
2800.00
2600.00
2400.00
2200.00
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000