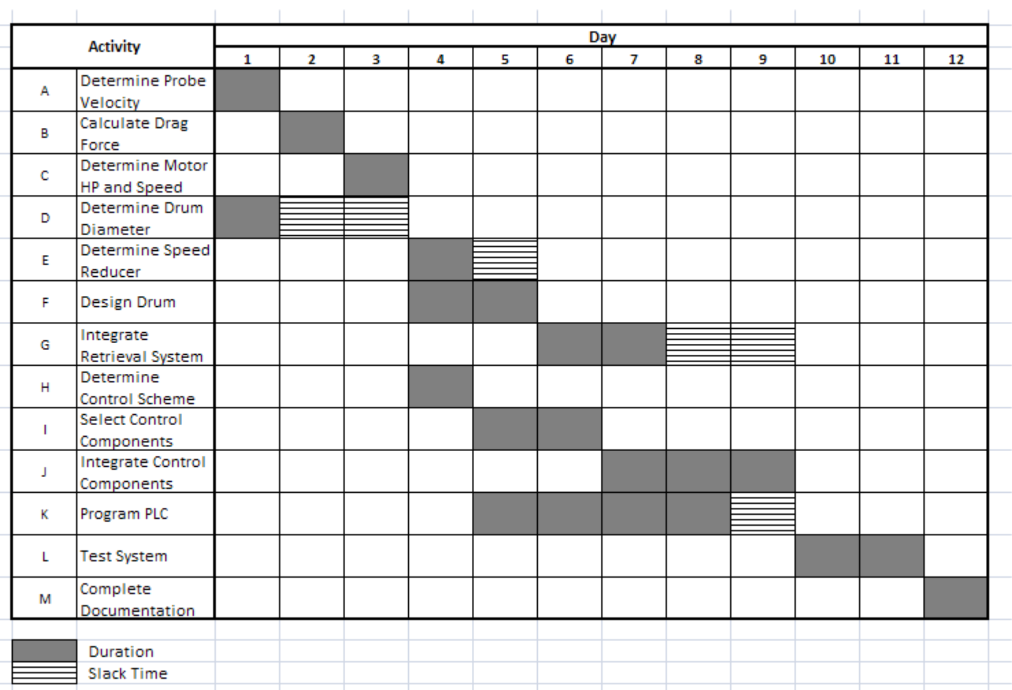
Problem 2.2

Use Excel to create a Gantt chart of the following activities shown in Table P2.2b. Make sure you show duration and slack time. What are the critical path activities?

Activity	Description	Preceding Activity	Duration (days)
A	Determine Probe Velocity		1
B	Calculate Drag Force	A	1
C	Determine Motor HP and Speed	B	1
D	Determine Drum Diameter		1
E	Determine Speed Reducer	C, D	1
F	Design Drum	D	2
G	Integrate Retrieval System	E, F	2
H	Determine Control Scheme	C	1
I	Select Control Components	H	2
J	Integrate Control Components	I	3
K	Program PLC	H	4
L	Test System	G, J, K	2
M	Complete Documentation	L	1

Solution:



Answer:

Critical Path: A-B-C-H-I-J-L-M. Note that F is not critical because on G depends upon its completion and G contains slack time.

Problem 2.3

Lightbulbs are rated by their power consumption in watts (W). Electricity is sold in units of energy, which is power multiplied by time. Electricity costs vary widely across the United States and are on the order of 0.06–0.23 \$/kW-hr for residential customers. Create a spreadsheet that utilizes electricity costs and the number of hours per day that a lightbulb is on as input variables. Then calculate the annual cost to operate a 60-W, 75-W, and 100-W incandescent bulb and a 15-W compact fluorescent bulb. Assuming the average household operates six 60-W, four 75-W, and two 100-W incandescent bulbs for 6 hours a day, how much money can they save by changing all the bulbs to compact fluorescent?

Solution:

	A	B	C	D	E	F
1	Time Per Day (hours)	6				
2	Electricity Cost (\$/kW-hr)	0.06				
3						
4		Bulb	Power	Number Used	Annual kW-hr	Annual Cost
5		60 W Incandescent	60	6	788.4	\$ 47.30
6		75 W Incandescent	75	4	657	\$ 39.42
7		100 W Incandescent	100	2	438	\$ 26.28
8		15 W Compact Fluorescent	15	12	394.2	\$ 23.65
9						
10				Cost Incandescent		\$ 113.00
11				Cost Compact Fluorescent		\$ 23.65
12						
13					**Savings**	**\$ 89.35**
14						

Answer:

Annual Savings: \$89.35 (\$0.06/kW-hr) - \$342.52 (\$0.23/kW-hr).

Problem 2.4

Create a spreadsheet that calculates the $\log_{10}$ and $\log_e$ (natural log) of integers from 1 to 100.

Answer:

Integer	Log 10	Log e	Integer	Log 10	Log e	Integer	Log 10	Log e	Integer	Log 10	Log e
1	0.00000	0.00000	26	1.41497	3.25810	51	1.70757	3.93183	76	1.88081	4.33073
2	0.30103	0.69315	27	1.43136	3.29584	52	1.71600	3.95124	77	1.88649	4.34381
3	0.47712	1.09861	28	1.44716	3.33220	53	1.72428	3.97029	78	1.89209	4.35671
4	0.60206	1.38629	29	1.46240	3.36730	54	1.73239	3.98898	79	1.89763	4.36945
5	0.69897	1.60944	30	1.47712	3.40120	55	1.74036	4.00733	80	1.90309	4.38203
6	0.77815	1.79176	31	1.49136	3.43399	56	1.74819	4.02535	81	1.90849	4.39445
7	0.84510	1.94591	32	1.50515	3.46574	57	1.75587	4.04305	82	1.91381	4.40672
8	0.90309	2.07944	33	1.51851	3.49651	58	1.76343	4.06044	83	1.91908	4.41884
9	0.95424	2.19722	34	1.53148	3.52636	59	1.77085	4.07754	84	1.92428	4.43082
10	1.00000	2.30259	35	1.54407	3.55535	60	1.77815	4.09434	85	1.92942	4.44265
11	1.04139	2.39790	36	1.55630	3.58352	61	1.78533	4.11087	86	1.93450	4.45435
12	1.07918	2.48491	37	1.56820	3.61092	62	1.79239	4.12713	87	1.93952	4.46591
13	1.11394	2.56495	38	1.57978	3.63759	63	1.79934	4.14313	88	1.94448	4.47734
14	1.14613	2.63906	39	1.59106	3.66356	64	1.80618	4.15888	89	1.94939	4.48864
15	1.17609	2.70805	40	1.60206	3.68888	65	1.81291	4.17439	90	1.95424	4.49981
16	1.20412	2.77259	41	1.61278	3.71357	66	1.81954	4.18965	91	1.95904	4.51086
17	1.23045	2.83321	42	1.62325	3.73767	67	1.82607	4.20469	92	1.96379	4.52179
18	1.25527	2.89037	43	1.63347	3.76120	68	1.83251	4.21951	93	1.96848	4.53260
19	1.27875	2.94444	44	1.64345	3.78419	69	1.83885	4.23411	94	1.97313	4.54329
20	1.30103	2.99573	45	1.65321	3.80666	70	1.84510	4.24850	95	1.97772	4.55388
21	1.32222	3.04452	46	1.66276	3.82864	71	1.85126	4.26268	96	1.98227	4.56435
22	1.34242	3.09104	47	1.67210	3.85015	72	1.85733	4.27667	97	1.98677	4.57471
23	1.36173	3.13549	48	1.68124	3.87120	73	1.86332	4.29046	98	1.99123	4.58497
24	1.38021	3.17805	49	1.69020	3.89182	74	1.86923	4.30407	99	1.99564	4.59512
25	1.39794	3.21888	50	1.69897	3.91202	75	1.87506	4.31749	100	2.00000	4.60517

Problem 2.5

Create a spreadsheet that calculates the square root and cube root of integers from 1 to 100.

Answer:

Integer	Sqrt	Cube Root	Integer	Sqrt	Cube Root	Integer	Sqrt	Cube Root	Integer	Sqrt	Cube Root
1	1.00000	1.00000	26	5.09902	2.96250	51	7.14143	3.70843	76	8.71780	4.23582
2	1.41421	1.25992	27	5.19615	3.00000	52	7.21110	3.73251	77	8.77496	4.25432
3	1.73205	1.44225	28	5.29150	3.03659	53	7.28011	3.75629	78	8.83176	4.27266
4	2.00000	1.58740	29	5.38516	3.07232	54	7.34847	3.77976	79	8.88819	4.29084
5	2.23607	1.70998	30	5.47723	3.10723	55	7.41620	3.80295	80	8.94427	4.30887
6	2.44949	1.81712	31	5.56776	3.14138	56	7.48331	3.82586	81	9.00000	4.32675
7	2.64575	1.91293	32	5.65685	3.17480	57	7.54983	3.84850	82	9.05539	4.34448
8	2.82843	2.00000	33	5.74456	3.20753	58	7.61577	3.87088	83	9.11043	4.36207
9	3.00000	2.08008	34	5.83095	3.23961	59	7.68115	3.89300	84	9.16515	4.37952
10	3.16228	2.15443	35	5.91608	3.27107	60	7.74597	3.91487	85	9.21954	4.39683
11	3.31662	2.22398	36	6.00000	3.30193	61	7.81025	3.93650	86	9.27362	4.41400
12	3.46410	2.28943	37	6.08276	3.33222	62	7.87401	3.95789	87	9.32738	4.43105
13	3.60555	2.35133	38	6.16441	3.36198	63	7.93725	3.97906	88	9.38083	4.44796
14	3.74166	2.41014	39	6.24500	3.39121	64	8.00000	4.00000	89	9.43398	4.46475
15	3.87298	2.46621	40	6.32456	3.41995	65	8.06226	4.02073	90	9.48683	4.48140
16	4.00000	2.51984	41	6.40312	3.44822	66	8.12404	4.04124	91	9.53939	4.49794
17	4.12311	2.57128	42	6.48074	3.47603	67	8.18535	4.06155	92	9.59166	4.51436
18	4.24264	2.62074	43	6.55744	3.50340	68	8.24621	4.08166	93	9.64365	4.53065
19	4.35890	2.66840	44	6.63325	3.53035	69	8.30662	4.10157	94	9.69536	4.54684
20	4.47214	2.71442	45	6.70820	3.55689	70	8.36660	4.12129	95	9.74679	4.56290
21	4.58258	2.75892	46	6.78233	3.58305	71	8.42615	4.14082	96	9.79796	4.57886
22	4.69042	2.80204	47	6.85565	3.60883	72	8.48528	4.16017	97	9.84886	4.59470
23	4.79583	2.84387	48	6.92820	3.63424	73	8.54400	4.17934	98	9.89949	4.61044
24	4.89898	2.88450	49	7.00000	3.65931	74	8.60233	4.19834	99	9.94987	4.62607
25	5.00000	2.92402	50	7.07107	3.68403	75	8.66025	4.21716	100	10.00000	4.64159

Problem 2.6

Create a spreadsheet that calculates the circumference and area of circles with diameters ranging from 1 cm to 100 cm in 1-cm increments.

Answer:

Circles: Diameter (cm), Circumference (cm), Area (cm^2)											
Diameter	Circum	Area	Diameter	Circum	Area	Diameter	Circum	Area	Diameter	Circum	Area
1	3.14	0.79	26	81.68	530.93	51	160.22	2042.82	76	238.76	4536.46
2	6.28	3.14	27	84.82	572.56	52	163.36	2123.72	77	241.90	4656.63
3	9.42	7.07	28	87.96	615.75	53	166.50	2206.18	78	245.04	4778.36
4	12.57	12.57	29	91.11	660.52	54	169.65	2290.22	79	248.19	4901.67
5	15.71	19.63	30	94.25	706.86	55	172.79	2375.83	80	251.33	5026.55
6	18.85	28.27	31	97.39	754.77	56	175.93	2463.01	81	254.47	5153.00
7	21.99	38.48	32	100.53	804.25	57	179.07	2551.76	82	257.61	5281.02
8	25.13	50.27	33	103.67	855.30	58	182.21	2642.08	83	260.75	5410.61
9	28.27	63.62	34	106.81	907.92	59	185.35	2733.97	84	263.89	5541.77
10	31.42	78.54	35	109.96	962.11	60	188.50	2827.43	85	267.04	5674.50
11	34.56	95.03	36	113.10	1017.88	61	191.64	2922.47	86	270.18	5808.80
12	37.70	113.10	37	116.24	1075.21	62	194.78	3019.07	87	273.32	5944.68
13	40.84	132.73	38	119.38	1134.11	63	197.92	3117.25	88	276.46	6082.12
14	43.98	153.94	39	122.52	1194.59	64	201.06	3216.99	89	279.60	6221.14
15	47.12	176.71	40	125.66	1256.64	65	204.20	3318.31	90	282.74	6361.73
16	50.27	201.06	41	128.81	1320.25	66	207.35	3421.19	91	285.88	6503.88
17	53.41	226.98	42	131.95	1385.44	67	210.49	3525.65	92	289.03	6647.61
18	56.55	254.47	43	135.09	1452.20	68	213.63	3631.68	93	292.17	6792.91
19	59.69	283.53	44	138.23	1520.53	69	216.77	3739.28	94	295.31	6939.78
20	62.83	314.16	45	141.37	1590.43	70	219.91	3848.45	95	298.45	7088.22
21	65.97	346.36	46	144.51	1661.90	71	223.05	3959.19	96	301.59	7238.23
22	69.12	380.13	47	147.65	1734.94	72	226.19	4071.50	97	304.73	7389.81
23	72.26	415.48	48	150.80	1809.56	73	229.34	4185.39	98	307.88	7542.96
24	75.40	452.39	49	153.94	1885.74	74	232.48	4300.84	99	311.02	7697.69
25	78.54	490.87	50	157.08	1963.50	75	235.62	4417.86	100	314.16	7853.98

Problem 2.7

Create a spreadsheet that calculates the perimeter and area of squares with side lengths ranging from 1 cm to 100 cm in 1-cm increments.

Answer:

Squares: Side (cm), Perimeter (cm), Area (cm^2)											
Side	**Perim**	**Area**	**Side**	**Perim**	**Area**	**Side**	**Perim**	**Area**	**Side**	**Perim**	**Area**
1	4	1	26	104	676	51	204	2601	76	304	5776
2	8	4	27	108	729	52	208	2704	77	308	5929
3	12	9	28	112	784	53	212	2809	78	312	6084
4	16	16	29	116	841	54	216	2916	79	316	6241
5	20	25	30	120	900	55	220	3025	80	320	6400
6	24	36	31	124	961	56	224	3136	81	324	6561
7	28	49	32	128	1024	57	228	3249	82	328	6724
8	32	64	33	132	1089	58	232	3364	83	332	6889
9	36	81	34	136	1156	59	236	3481	84	336	7056
10	40	100	35	140	1225	60	240	3600	85	340	7225
11	44	121	36	144	1296	61	244	3721	86	344	7396
12	48	144	37	148	1369	62	248	3844	87	348	7569
13	52	169	38	152	1444	63	252	3969	88	352	7744
14	56	196	39	156	1521	64	256	4096	89	356	7921
15	60	225	40	160	1600	65	260	4225	90	360	8100
16	64	256	41	164	1681	66	264	4356	91	364	8281
17	68	289	42	168	1764	67	268	4489	92	368	8464
18	72	324	43	172	1849	68	272	4624	93	372	8649
19	76	361	44	176	1936	69	276	4761	94	376	8836
20	80	400	45	180	2025	70	280	4900	95	380	9025
21	84	441	46	184	2116	71	284	5041	96	384	9216
22	88	484	47	188	2209	72	288	5184	97	388	9409
23	92	529	48	192	2304	73	292	5329	98	392	9604
24	96	576	49	196	2401	74	296	5476	99	396	9801
25	100	625	50	200	2500	75	300	5625	100	400	10000

Problem 2.8

Create a spreadsheet that calculates the surface area and volume of cubes with side lengths ranging from 1 inch to 100 inches using 1-inch increments.

Answer:

Cubes: Side (in), Surface Area (in^2), Volume (in^3)											
Side	Surf Area	Volume	Side	Surf Area	Volume	Side	Surf Area	Volume	Side	Surf Area	Volume
1	6	1	26	4056	17576	51	15606	132651	76	34656	438976
2	24	8	27	4374	19683	52	16224	140608	77	35574	456533
3	54	27	28	4704	21952	53	16854	148877	78	36504	474552
4	96	64	29	5046	24389	54	17496	157464	79	37446	493039
5	150	125	30	5400	27000	55	18150	166375	80	38400	512000
6	216	216	31	5766	29791	56	18816	175616	81	39366	531441
7	294	343	32	6144	32768	57	19494	185193	82	40344	551368
8	384	512	33	6534	35937	58	20184	195112	83	41334	571787
9	486	729	34	6936	39304	59	20886	205379	84	42336	592704
10	600	1000	35	7350	42875	60	21600	216000	85	43350	614125
11	726	1331	36	7776	46656	61	22326	226981	86	44376	636056
12	864	1728	37	8214	50653	62	23064	238328	87	45414	658503
13	1014	2197	38	8664	54872	63	23814	250047	88	46464	681472
14	1176	2744	39	9126	59319	64	24576	262144	89	47526	704969
15	1350	3375	40	9600	64000	65	25350	274625	90	48600	729000
16	1536	4096	41	10086	68921	66	26136	287496	91	49686	753571
17	1734	4913	42	10584	74088	67	26934	300763	92	50784	778688
18	1944	5832	43	11094	79507	68	27744	314432	93	51894	804357
19	2166	6859	44	11616	85184	69	28566	328509	94	53016	830584
20	2400	8000	45	12150	91125	70	29400	343000	95	54150	857375
21	2646	9261	46	12696	97336	71	30246	357911	96	55296	884736
22	2904	10648	47	13254	103823	72	31104	373248	97	56454	912673
23	3174	12167	48	13824	110592	73	31974	389017	98	57624	941192
24	3456	13824	49	14406	117649	74	32856	405224	99	58806	970299
25	3750	15625	50	15000	125000	75	33750	421875	100	60000	1000000

Problem 2.9

Create a spreadsheet that calculates the surface area and volume of spheres with diameters ranging from 1 inch to 100 inches using 1-inch increments.

Answer:

Spheres: Diameter (in), Surface Area (in^2), Volume (in^3)											
Diameter	**Surf Area**	**Volume**	**Diameter**	**Surf Area**	**Volume**	**Diameter**	**Surf Area**	**Volume**	**Diameter**	**Surf Area**	**Volume**
1	3.142	0.5236	26	2124	9203	51	8171	69456	76	18146	229847
2	12.57	4.189	27	2290	10306	52	8495	73622	77	18627	239040
3	28.27	14.14	28	2463	11494	53	8825	77952	78	19113	248475
4	50.27	33.51	29	2642	12770	54	9161	82448	79	19607	258155
5	78.54	65.45	30	2827	14137	55	9503	87114	80	20106	268083
6	113.1	113.1	31	3019	15599	56	9852	91952	81	20612	278262
7	153.9	179.6	32	3217	17157	57	10207	96967	82	21124	288696
8	201.1	268.1	33	3421	18817	58	10568	102160	83	21642	299387
9	254.5	381.7	34	3632	20580	59	10936	107536	84	22167	310339
10	314.2	523.6	35	3848	22449	60	11310	113097	85	22698	321555
11	380.1	696.9	36	4072	24429	61	11690	118847	86	23235	333038
12	452.4	904.8	37	4301	26522	62	12076	124788	87	23779	344791
13	530.9	1150	38	4536	28731	63	12469	130924	88	24328	356818
14	615.8	1437	39	4778	31059	64	12868	137258	89	24885	369121
15	706.9	1767	40	5027	33510	65	13273	143793	90	25447	381704
16	804.2	2145	41	5281	36087	66	13685	150533	91	26016	394569
17	907.9	2572	42	5542	38792	67	14103	157479	92	26590	407720
18	1018	3054	43	5809	41630	68	14527	164636	93	27172	421160
19	1134	3591	44	6082	44602	69	14957	172007	94	27759	434893
20	1257	4189	45	6362	47713	70	15394	179594	95	28353	448921
21	1385	4849	46	6648	50965	71	15837	187402	96	28953	463247
22	1521	5575	47	6940	54362	72	16286	195432	97	29559	477874
23	1662	6371	48	7238	57906	73	16742	203689	98	30172	492807
24	1810	7238	49	7543	61601	74	17203	212175	99	30791	508047
25	1963	8181	50	7854	65450	75	17671	220893	100	31416	523599

Problem 2.10

Create a single spreadsheet to perform the following unit conversions, taking a value in SI units as the input and returning the value converted to U.S. Customary units:

a) Centimeters to inches
b) °C to °F
c) Newtons to pounds
d) Meters per second to miles per hour

Use comments in your cells to cite the reference used to determine the unit conversion values.

Answer:

Unit Converter			
1	centimeters =	0.3937	inches
1	°C =	33.8000	°F
1	newtons =	0.2248	pounds
1	m/s =	2.2369	mph

Problem 2.11

Create a single spreadsheet to perform the following unit conversions, taking a value in U.S. Customary units as the input and returning the value converted to SI units:

a) Feet to meters
b) Pounds per square inch (psi) to newtons per square meter (pascals)
c) Horsepower to watts
d) U.S. gallons to cubic meters

Use comments in your cells to cite the reference used to determine the unit conversion values.

Answer:

Unit Converter			
1	feet =	0.3048	m
1	psi =	6894.7573	N/m^2
1	hp =	745.6999	watts
1	gal =	0.0038	m^3

Problem 2.12

Consider the analytic solution of the projectile problem described in Section 1.1.2. Create a spreadsheet that will allow the user to enter the launch speed and angle, and will compute the peak height, flight time, and horizontal distance travelled using the analytic equations. Calculate the peak height, flight time, and horizontal distanced travelled for a launch speed of 150 m/s and an angle of 60°.

Solution:

	A	B	C
1	**User Input**		
2	Launch Speed (m/s)	150	
3	Angle (degrees)	60	
4			
5	**Calculations**		
6	Time to Peak Height (s)	**13.2**	
7	Peak Height (m)	**860.1**	
8	Flight Time (s)	**26.5**	
9	Horizontal Distance (m)	**1986.3**	
10			

Answer: The flight time is 26.5 s, the peak height is 860 m, and the horizontal distance is 1986 m.

Problem 2.13

A typical thickness for a sheet of paper is 0.004 inches. If you fold a sheet of paper once, the thickness of the folded paper will double to a value of 0.008 inches. A second fold will result in a folded thickness of 0.016 inches. Create a spreadsheet that shows the number of folds from 0 to 50 and the resulting thickness of each fold. Calculate the resulting thickness in units of inches, feet, and miles.

Answer:

Paper Thickness (in)	0.004						
Number of Folds	**inches**	**feet**	**miles**	**Number of Folds**	**inches**	**feet**	**miles**
1	0.008	0.0007	0.00000013	26	268435	22370	4.237
2	0.016	0.0013	0.00000025	27	536871	44739	8.473
3	0.032	0.0027	0.00000051	28	1073742	89478	16.95
4	0.064	0.0053	0.00000101	29	2147484	178957	33.89
5	0.128	0.0107	0.00000202	30	4294967	357914	67.79
6	0.256	0.0213	0.00000404	31	8589935	715828	135.6
7	0.512	0.0427	0.00000808	32	17179869	1431656	271.1
8	1.024	0.0853	0.00001616	33	34359738	2863312	542.3
9	2.048	0.1707	0.00003232	34	68719477	5726623	1085
10	4.096	0.3413	0.00006465	35	137438953	11453246	2169
11	8.192	0.6827	0.00012929	36	274877907	22906492	4338
12	16.38	1.365	0.00025859	37	549755814	45812984	8677
13	32.77	2.731	0.00051717	38	1099511628	91625969	17353
14	65.54	5.461	0.00103434	39	2199023256	183251938	34707
15	131.1	10.92	0.00206869	40	4398046511	366503876	69414
16	262.1	21.85	0.00413737	41	8796093022	733007752	138827
17	524.3	43.69	0.00827475	42	17592186044	1466015504	277654
18	1049	87.38	0.01654949	43	35184372089	2932031007	555309
19	2097	174.8	0.03309899	44	70368744178	5864062015	1110618
20	4194	349.5	0.06619798	45	140737488355	11728124030	2221236
21	8389	699.1	0.13239596	46	281474976711	23456248059	4442471
22	16777	1398	0.26479192	47	562949953421	46912496118	8884942
23	33554	2796	0.52958384	48	1125899906843	93824992237	17769885
24	67109	5592	1.05916768	49	2251799813685	187649984474	35539770
25	134218	11185	2.11833535	50	4503599627371	375299968948	71079540

Problem 2.14

We learned in Example 2.3 that ball bearings are hardened through a process of heating and then rapid cooling or "quenching" by submersion in an oil or water bath. The temperature of the ball as a function of time, $T(t)$, in the bath may be estimated by Equation 2.3, repeated here:

$$T(t) = (T_i - T_\infty)e^{-t/\tau} + T_\infty$$

where t is the time in seconds in the bath; T_i is the initial ball temperature; T_∞ is the oil temperature; and τ is the time constant in seconds that depends upon the material of the ball, the geometry of the ball, and oil properties. Create a spreadsheet that utilizes T_i, T_∞, and τ as input variables and calculates the ball temperature for times from 0 to 180 seconds at 1-second intervals. Assume the time constant τ = 50 s.

Assuming an initial bearing temperature of 800°C and an oil temperature of 40°C, how long does it take for the ball to cool to a temperature of less than 100°C?

Solution:

Input Variables	
Ti, °C	800
Tinf, °C	40
Tau, s	50

Calculations

time, s	Temp, °C	time, s	Temp, °C	time, s	Temp, °C	time, s	Temp, °C	time, s	Temp, °C	time, s	Temp, °C
0	800.0	31	448.8	62	259.9	93	158.3	124	103.6	155	74.2
1	785.0	32	440.7	63	255.6	94	156.0	125	102.4	156	73.6
2	770.2	33	432.8	64	251.3	95	153.7	126	101.1	157	72.9
3	755.7	34	425.0	65	247.1	96	151.4	127	99.9	158	72.2
4	741.6	35	417.4	66	243.0	97	149.2	128	98.8	159	71.6
5	727.7	36	409.9	67	239.0	98	147.1	129	97.6	160	71.0
6	714.1	37	402.6	68	235.1	99	144.9	130	96.4	161	70.4
7	700.7	38	395.4	69	231.2	100	142.9	131	95.3	162	69.8
8	687.6	39	388.4	70	227.4	101	140.8	132	94.2	163	69.2
9	674.8	40	381.5	71	223.7	102	138.8	133	93.2	164	68.6
10	662.2	41	374.7	72	220.1	103	136.9	134	92.1	165	68.0
11	649.9	42	368.1	73	216.5	104	134.9	135	91.1	166	67.5
12	637.8	43	361.6	74	213.0	105	133.1	136	90.1	167	66.9
13	626.0	44	355.2	75	209.6	106	131.2	137	89.1	168	66.4
14	614.4	45	349.0	76	206.2	107	129.4	138	88.1	169	65.9
15	603.0	46	342.9	77	202.9	108	127.6	139	87.1	170	65.4
16	591.9	47	336.9	78	199.7	109	125.9	140	86.2	171	64.9
17	580.9	48	331.0	79	196.5	110	124.2	141	85.3	172	64.4
18	570.2	49	325.2	80	193.4	111	122.5	142	84.4	173	63.9
19	559.7	50	319.6	81	190.4	112	120.9	143	83.5	174	63.4
20	549.4	51	314.1	82	187.4	113	119.3	144	82.7	175	63.0
21	539.4	52	308.6	83	184.5	114	117.7	145	81.8	176	62.5
22	529.5	53	303.3	84	181.6	115	116.2	146	81.0	177	62.1
23	519.8	54	298.1	85	178.8	116	114.7	147	80.2	178	61.6
24	510.3	55	293.0	86	176.1	117	113.2	148	79.4	179	61.2
25	501.0	56	288.0	87	173.4	118	111.8	149	78.6	180	60.8
26	491.8	57	283.1	88	170.8	119	110.3	150	77.8	181	60.4
27	482.9	58	278.2	89	168.2	120	108.9	151	77.1	182	60.0
28	474.1	59	273.5	90	165.6	121	107.6	152	76.4	183	59.6
29	465.5	60	268.9	91	163.1	122	106.2	153	75.6	184	59.2
30	457.1	61	264.4	92	160.7	123	104.9	154	74.9	185	58.8

Answer: The ball cools to less than 100 °C after about 127 s.

Problem 2.15

Numerical grades for 5 students and 7 assignments are shown in Table P2.15. Create a spreadsheet that determines the average numerical grade for each of the students and then assigns a letter grade (A, B, C, D, F) based on a 10-point scale (greater than or equal to 90 equals an A, greater than or equal to 80 and less than 90 equals a B, etc.).

Table P2.15 Student Grades

Student	Assignment Grade						
	1	2	3	4	5	6	7
A	95	60	89	90	92	80	87
B	92	100	93	87	90	85	90
C	88	60	76	89	70	40	60
D	90	87	70	89	92	85	85
E	78	90	94	89	98	95	97

Answer:

Student	Assignment Grade							Final Grade	
	1	2	3	4	5	6	7	Average	Letter Grade
A	95	60	89	90	92	80	87	84.7	**B**
B	92	100	93	87	90	85	90	91.0	**A**
C	88	60	76	89	70	40	60	69.0	**D**
D	90	87	70	89	92	85	85	85.4	**B**
E	78	90	94	89	98	95	97	91.6	**A**

Problem 2.16

The time constant in Problem 2.14 is given by:

$$\tau = \frac{\rho D c_P}{6h}$$

where ρ is the material density of the ball in g/cm^3, D is the diameter of the ball in cm, c_p is the specific heat capacity of the material in J/g°C, and h is the heat transfer coefficient between the ball and the oil in W/cm^2°C. Table P2.16 lists the material properties for aluminum, copper, gold, nickel, and steel.

Table P2.16 Thermal Properties of Selected Metals

	Aluminum	Copper	Gold	Nickel	Steel
Density (g/cm^3)	2.77	8.92	19.30	8.90	7.83
Specific Heat Capacity (J/g°C)	0.875	0.385	0.129	0.444	0.434

Assume a convective heat transfer coefficient of 0.3 W/cm^2°C. Create a spreadsheet that utilizes the material, the ball diameter D, the convective heat transfer coefficient h, and the temperatures T_i and T_∞, as input variables. Use a lookup table to look up the thermal properties based upon the material and then calculate the temperature of the ball for times from 0 to 600 seconds in 1-second increments. Assume the initial ball temperature is 400°C, the oil temperature is 100°C, and the ball diameter is 0.5 cm. Which material cools the fastest?

Solution: Note: Only the first 6 seconds are shown. The quenching is very fast and a better analysis would be to calculate 0 – 10 s at 0.1 second increments

User Input

Material	**Nickel**
Diameter (cm)	0.5
Heat Transfer Coef (W/cm^2°C)	0.3
Ti (°C)	400
Tinf (°C)	100

Property Table

Property	Aluminum	Copper	Gold	Nickel	Steel
Density (g/cm^3)	2.77	8.92	19.3	8.9	7.83
Specific Heat Capacity (J/g°C)	0.875	0.385	0.129	0.444	0.434

Material Properties and Calculation of Tau

Density (g/cm3)	8.9
Specific Heat (J/g°C)	0.444
Tau (s)	1.098

Calculation of Cooling

Time (s)	Temperature (°C)
0	400.0
1	220.6
2	148.5
3	119.5
4	107.8
5	103.2
6	101.3

Temperature After 2 s (°C)

Al	167.9
Cu	136.9
Ag	**116.6**
Ni	148.5
Steel	136.1

Answer: Based upon the first two seconds of cooling, the **gold cools the fastest**.
Note: There is an error in the property table for the tabulated properties of copper. The properties shown here are correct. This error does not change the answer.

Problem 2.17

Create a spreadsheet to calculate the weight of a sphere in pounds. Inputs will be the diameter of the sphere (in inches) and the material. Use a lookup table to find the specific weight (weight/volume) of the material chosen from the list in Figure P2.17. Use Figure P2.17 to check your formula for the weight of the sphere.

	A	B	C	D	E	F
1	Diameter, inches	3.0				
2	Material	Aluminum		WEIGHT, lb	1.43	
3	Specific Weight, lb per cubic inch	0.101				
4						
5						
6		Aluminum	Steel	Brass	Titanium	Concrete
7	Specific Weight, lb per cubic inch	0.101	0.284	0.316	1.160	0.086
8						

Figure P2.17

Answer:

User Input

Diameter (in)	3
Material	Steel

Property Table

	Aluminum	Steel	Brass	Titanium	Concrete
Specific Weight (lb/in^3)	0.101	0.284	0.316	0.160	0.086

Calculations

Specific Weight (lb/in^3)	0.284
Weight (lb)	4.015

Notes:

1. The specific weight of titanium in the table is incorrect. The correct value is shown in the answer.
2. For the lookup table to function properly, the parameter *range_lookup* must be set to false. This is necessary because the materials are not listed in alphabetical order.

Problem 2.18

Solve the boiling temperature problem from Example 2.7 in the chapter using linear interpolation in place of the lookup table.

Answer:

User Input	
Temperature (°C)	260
Mass (kg)	5

Calculated Values	
Pressure (kPa)	**4760.60**
Heat Required (kJ)	**8298**

	Tabulated Properties		Interpolated Properties	
Temperature (°C)	Saturation Pressure (kPa)	Enthalpy of Vaporization (kJ/kg)	Saturation Pressure (kPa)	Enthalpy of Vaporization (kJ/kg)
0	0.6113	2501		
25	3.169	2442		
50	12.35	2383		
75	38.58	2321		
100	101.3	2257		
125	232.1	2189		
150	475.8	2114		
175	892.0	2032		
200	1554	1941		
225	2548	1837		
250	3973	1716		
275	5942	1575	4760.6	1659.6
300	8581	1405		
325	12060	1190		
350	16513	893		
374	22090	0		

Problem 2.19

At sea level, average atmospheric pressure is about 14.7 pounds per square inch (psi). At altitude, pressure decreases. As the pressure decreases, there are fewer air molecules in a given volume. Therefore, baseballs fly further at Coors Field in Denver (elevation = 5280 feet), and it is very difficult to breathe on Mt. Everest (elevation = 29,035 feet). Create a spreadsheet that allows a user to input an elevation between 0 and 50,000 feet and estimates the atmospheric pressure based on Table P2.19. Use linear interpolation to estimate values between the data points shown in the table. If a value of less than 0 or greater than 50,000 feet is entered, then "Out of Range" should be displayed in the spreadsheet.

Table P2.19 Air Pressure as a Function of Altitude

Altitude, feet	Air Pressure, psi
0	14.70
1,000	14.16
2,000	13.66
3,000	13.17
4,000	12.69
5,000	12.23
10,000	10.10
20,000	6.76
30,000	4.37
40,000	2.73
50,000	1.69

Answer:

Altitude, feet	12000	
Pressure, psi	**9.432**	

Tabulated Values		**Interpolated Value**
Altitude, feet	Air Pressure, psi	Air Pressure, psi
0	14.7	
1,000	14.16	
2,000	13.66	
3,000	13.17	
4,000	12.69	
5,000	12.23	
10,000	10.1	
20,000	6.76	9.432
30,000	4.37	
40,000	2.73	
50,000	1.69	

Altitude, feet	60000	
Pressure, psi	Out of Range	

Tabulated Values		**Interpolated Value**
Altitude, feet	Air Pressure, psi	Air Pressure, psi
0	14.7	
1,000	14.16	
2,000	13.66	
3,000	13.17	
4,000	12.69	
5,000	12.23	
10,000	10.1	
20,000	6.76	
30,000	4.37	
40,000	2.73	
50,000	1.69	