<u>Numerical problems of "Applied Physics"</u>

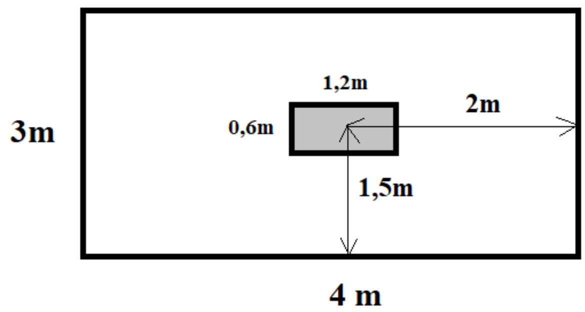
(*The solutions should be handed to the teacher in laboratory classes*.)

1) Find the matrix of view factors of a room whose shape is specified as the hollow half-sphere, i.e. a circular floor and a half-sphere copula above the floor. The floor is numbered 1, the copula as 2 (Follow strictly this numbering!) (*Hint: see the textbook concerning radiation, "two-surface" room. Employ the three basic rules that are valid for view factors. <u>Further explanations will be presented at the lectures.</u>*)

2) Find the matrix of view factors belonging to the room with a circular floor ($r = 3\,\text{m}$) and above the floor there is a hollow cone (side length = 5 m). The floor is numbered as 1, the copula as 2 (Follow strictly this numbering!). (*Hint: see the textbook concerning radiation, "two-surface" room. Employ the three basic rules that are valid for view factors. <u>Further explanations will be presented at the lectures</u>.*)

3) Find the matrix of view factors of a small room shaped as the hollow rectangular parallelepiped with the floor dimensions 3m x 4m and height 3m. Because all of the side walls have the same temperature and emissivity, these four walls may be considered as a single continuous wall. Thus, the room has three inner surfaces" the floor no. 1, the side walls no. 2 and ceiling no. 3. (Follow strictly this numbering!) An input view factor is available: $F_{13} = 0.2374$. (*Hint: see the textbook concerning radiation, "three-surface" room. Employ the three basic rules that are valid for view factors. <u>Further explanations will be presented at the lectures</u>.*)

4) The room shaped as a hollow rectangular parallelepiped with height of 3m and a floor with dimensions 3m x 4m contains a small plate heating panel (0.6m x 1.2m) mounted on the ceiling. The panel forms a part of the surface of the ceiling, that is, it is placed in the same level as the surfaces of the ceiling and thus it does not protrude from the ceiling. The centre of the panel coincides with the center of the ceiling, as shown in the picture. The four side walls have identical temperatures and emissivity, and thus they may be considered as a single continuous surface which is numbered **2**. The floor is marked as **1** and the ceiling without the panel is marked as **3** and the panel as **4**. (Follow strictly this numbering!) The room looks like a "four-surface" object and ***your task is to find its corresponding matrix of view factors***. There are two view factors for your disposal: $F_{41} = 0,29230$ a $F_{13} = 0,21986$.



(*Hint: see the textbook concerning radiation, the solution is similar to the case of the "three-surface" room. Employ the three basic rules that are valid for view factors. <u>Further explanations will be presented at the lectures</u>.*)

5) In the room shaped as the hollow half-sphere described in the numerical problem no. **1)** has a heated circular floor (r = 3m). The room is in the stationary thermal state. The temperature parameters are specified in the following table. Follow the surface numbering given in the numerical problem no. **1)**.

Table: Input parameters

Parameter	Surface no. 1	Surface no. 2
S (m^2)	28.2745	56.5490
T (K)	303 (floor)	291 (copula)
ε (emissivity)	0.95	0.5
$\rho = 1 - \varepsilon$ (reflectivity)	0.05	0.5
$\varepsilon \cdot \sigma \cdot T^4$ (W/ m^2) $\sigma = 5.67 \cdot 10^{-8} (Wm^{-2}K^{-4})$	454.022	203.294

<u>Solve the problem according to the following points:</u>

a) Specify the matrix of view factors (it was determined within Example **1)**).

b) Form the system of algebraic equations for radiosities of both surfaces.

c) Calculate the densities of heat flows (W/m^2) of both surfaces.

d) Calculate the radiant heat powers in Watts for both the surfaces and specify which surface radiates heat into the room and which takes heat from the room.

e) Check the correctness of the radiant heat powers according to the compensation theorem and decide whether they may be numerically acceptable.

(*Hint: see the textbook concerning radiation, "two-surface" room. Approximate radiant power of the floor ~1299 W. <u>Further explanations will be presented at the lectures</u>.*)

6) The room is shaped as the hollow cone described in the numerical problem no. **2)** has a heated circular floor. The room is in the stationary thermal state. The temperature parameters are specified in the following table. Follow the surface numbering given in Example **2)**.

Table: Input parameters

Parameter	Surface no. 1	Surface no. 2
S (m^2)	28,2745	47.124
T (K)	305 (floor)	289 (copula)
ε (emissivity)	0.91	0.8
$\rho = 1 - \varepsilon$ (reflectivity)	0.09	0.2
$\varepsilon \cdot \sigma \cdot T^4$ (W/ m^2) $\sigma = 5.67 \cdot 10^{-8}$(Wm^{-2}K^{-4})	446.5024	316.4204

Solve the problem according to the following points:

a) Specify the matrix of view factors (it was determined within Example **2)**).

b) Form the system of algebraic equations for radiosities of both surfaces.

c) Calculate the densities of heat flows (W/m^2) of both surfaces.

d) Calculate the radiant heat powers in Watts for both surfaces and specify which surface radiates heat into the room and which takes heat from the room.

e) Check the correctness of the radiant heat powers according to the compensation theorem and decide whether they may be numerically acceptable.

(*Hint: see the textbook concerning radiation, "two-surface" room. Approximate radiant power of the floor ~2154 W. Further explanations will be presented at the lectures.*)

7) The room shaped as the rectangular parallelepiped described in the numerical problem no. **3)** has a heated floor. The room is in the stationary thermal state. Temperature parameters are specified in the following table. Follow the surface numbering given in Example **3)**.

Table: Input parameters

Parameter	Surface no. 1	Surface no. 2	Surface no. 3
S (m^2)	12	42	12
T (K)	304 (floor)	290 (walls)	291 (ceiling)
ε (emissivity)	0.94	0.88	0.89
$\rho = 1 - \varepsilon$ (reflectivity)	0.06	0.12	0.11
$\varepsilon \cdot \sigma \cdot T^4$ (W/ m^2) $\sigma = 5.67 \cdot 10^{-8} (Wm^{-2}K^{-4})$	455.2031	352.9049	361.8637

Solve the problem according to the following points:

a) Specify the matrix of view factors (it was determined within Example **3)**).

b) Form the system of algebraic equations for radiosities of both surfaces.

c) Calculate the densities of heat flows (W/m^2) of both surfaces.

d) Calculate the radiant heat powers in Watts for both surfaces and specify which surface radiates heat into the room and which takes heat from the room.

e) Check the correctness of the radiant heat powers according to the compensation theorem and decide whether they may be numerically acceptable.

(*Hint: see the textbook concerning radiation, "three-surface" room. Approximate radiant power of the floor ~899 W. Further explanations will be presented at the lectures.*)

8) The room shaped as the rectangular parallelepiped has a heating panel mounted on the ceiling as has been described in the numerical problem no. **4)**. The room is in the stationary thermal state. The temperature parameters are specified in the following table. Follow the surface numbering given in Example **4)**.

Table: Input parameters

Parameter	Surface no. 1	Surface no. 2	Surface no. 3	Surface no. 4
S (m^2)	12	42	11,28	0,72
T (K)	295 (floor)	290 (walls)	291 (ceiling)	343 (panel)
ε (emissivity)	0.92	0.85	0.90	0.98
$\rho = 1 - \varepsilon$ (reflectivityt)	0.08	0.15	0.10	0.02
$\varepsilon \cdot \sigma \cdot T^4$ (W/ m^2) $\sigma = 5.67 \cdot 10^{-8} (Wm^{-2}K^{-4})$	395.0563	340.8741	365.9296	769.1850

<u>**Solve the problem according to the following points:**</u>

a) Specify the matrix of view factors (it was determined within Example **4)**).

b) Form the system of algebraic equations for radiosities of both surfaces.

c) Calculate the densities of heat flows (W/m^2) of both surfaces.

d) Calculate the radiant heat powers in Watts for both surfaces and specify which surface radiates heat into the room and which takes heat from the room.

e) Check the correctness of the radiant heat powers according to the compensation theorem and decide whether they may be numerically acceptable.

f) What will happen with the radiant heat power of the panel, if the floor is cooler?

g) Compare the calculated power of the panel installed inside the room (P_{inside}) with the power of the same panel placed in the absolutely open space ($P_{outside} = S\varepsilon\sigma T^4$). Determine the percentage of heat power savings when the panel is placed inside the room. *A note: Savings in heat energy stimulate savings in electricity that supplies the panel.*

(*Hint: see the textbook concerning radiation and look at a similar solution as in the case of a "three-surface" room. Approximate radiant power of the panel ~264 W. <u>Further explanations will be presented at the lectures</u>.*)

9) Within assignment **7)**, the radiant heat powers of all surfaces of the room *(rectangular parallelepiped*) were found. Thus, the radian heat power of the floor is known. The present task is to calculate the convective heat power of the floor and, finally, its total heat power (*convective power plus radiant power*). The room is in the stationary thermal state. The temperature of the air inside the room is $T_\infty = 293\,\mathrm{K}$ (~20 °C). Dimensions and temperature of the floor are given within assignment **7)**.

A note: To determine the temperature parameters of convective flows, you may use the table which is enclosed at the end of this text (if necessary, use interpolation). Inspiration for solution could be found in the textbook (see chapters about natural convection with horizontal surfaces). Be careful, the surface of the floor is the so-called "upper warm". The approximate total heat power of the floor is ~1422 W. <u>Further explanations will be presented at the lectures</u>.

<u>Solve the problem according to the following points:</u>

a) Calculate the characteristic dimension of the floor $L = S / O$ (area divided by perimeter).

b) Determine the average temperature of the convective flow (convective film) T_f nearby the floor.

c) Near the floor, determine the temperature parameters β, ν, λ, α, Pr (*see the table at the end of this text).*

d) Calculate the value of the Rayleigh number Ra_L *(upper warm surface!).*

f) Calculate the convective heat power of the floor Φ_c.

g) Calculate the total heat power of the floor Φ_t (radiant plus convective powers).

h) Determine the heat percentages that go into convection and radiation. Decide whether the floor is a convective or radiant heater.

10) Within assignment **8)**, the radiant heat powers of all surfaces of a room shaped as the rectangular parallelepiped possessing ceiling heating panel were found. Thus, the radian heat power of the panel is known. The present task is to calculate the convective heat power of the panel and, finally, its total heat power (*convective power plus radiant power*). The room is in the stationary thermal state. The temperature of the air inside the room is $T_\infty = 293\,\text{K}$ (~20 °C). The dimensions of the floor and its temperature are given within assignment **8)**.

A note: To determine the temperature parameters of convective flows, you may use the table which is enclosed at the end of this text (if necessary, use interpolation). Inspiration for solution could be found in the textbook (see chapters about natural convection with horizontal surfaces). Be careful, the surface of the panel is the so-called "lower warm". The approximate total heat power of the panel is ~362 W. <u>Further explanations will be presented at the lectures</u>.

<u>Solve the problem according to the following points:</u>

a) Calculate the characteristic dimension of the floor $L = S / O$ (area divided by perimeter).

b) Determine the average temperature of the convective flow (convective film) T_f nearby the floor.

c) Near the floor, determine the temperature parameters β, ν, λ, α, Pr (*see the table at the end of this text).*

d) Calculate the value of the Rayleigh number Ra_L *(lower warm surface!).*

f) Calculate the convective heat power of the panel Φ_c.

g) Calculate the total heat power of the panel Φ_t (radiant plus convective powers).

h) Determine the heat percentages that go into convection and radiation. Decide whether the floor is a convective or radiant heater.

Thermodynamic properties of air at normal atmospheric pressure

T (K)	ρ (kg/m^3)	c_p (kJ/kg · K)	$\mu \cdot 10^7$ (N · s/m^2)	$\nu \cdot 10^6$ (m^2/s)	$\lambda_f \cdot 10^3$ (W/m · K)	$\alpha \cdot 10^6$ (m^2/s)	Pr
Vzduch, $\mathcal{M}$ = 28.97 kg/kmol							
100	3.5562	1.032	71.1	2.00	9.34	2.54	0.786
150	2.3364	1.012	103.4	4.426	13.8	5.84	0.758
200	1.7458	1.007	132.5	7.590	18.1	10.3	0.737
250	1.3947	1.006	159.6	11.44	22.3	15.9	0.720
300	1.1614	1.007	184.6	15.89	26.3	22.5	0.707
350	0.9950	1.009	208.2	20.92	30.0	29.9	0.700
400	0.8711	1.014	230.1	26.41	33.8	38.3	0.690
450	0.7740	1.021	250.7	32.39	37.3	47.2	0.686
500	0.6964	1.030	270.1	38.79	40.7	56.7	0.684
550	0.6329	1.040	288.4	45.57	43.9	66.7	0.683
600	0.5804	1.051	305.8	52.69	46.9	76.9	0.685
650	0.5356	1.063	322.5	60.21	49.7	87.3	0.690
700	0.4975	1.075	338.8	68.10	52.4	98.0	0.695
750	0.4643	1.087	354.6	76.37	54.9	109	0.702
800	0.4354	1.099	369.8	84.93	57.3	120	0.709
850	0.4097	1.110	384.3	93.80	59.6	131	0.716
900	0.3868	1.121	398.1	102.9	62.0	143	0.720
950	0.3666	1.131	411.3	112.2	64.3	155	0.723
1000	0.3482	1.141	424.4	121.9	66.7	168	0.726
1100	0.3166	1.159	449.0	141.8	71.5	195	0.728
1200	0.2902	1.175	473.0	162.9	76.3	224	0.728
1300	0.2679	1.189	496.0	185.1	82	257	0.719
1400	0.2488	1.207	530	213	91	303	0.703
1500	0.2322	1.230	557	240	100	350	0.685
1600	0.2177	1.248	584	268	106	390	0.688
1700	0.2049	1.267	611	298	113	435	0.685
1800	0.1935	1.286	637	329	120	482	0.683
1900	0.1833	1.307	663	362	128	534	0.677
2000	0.1741	1.337	689	396	137	589	0.672
2100	0.1658	1.372	715	431	147	646	0.667
2200	0.1582	1.417	740	468	160	714	0.655
2300	0.1513	1.478	766	506	175	783	0.647
2400	0.1448	1.558	792	547	196	869	0.630
2500	0.1389	1.665	818	589	222	960	0.613
3000	0.1135	2.726	955	841	486	1570	0.536