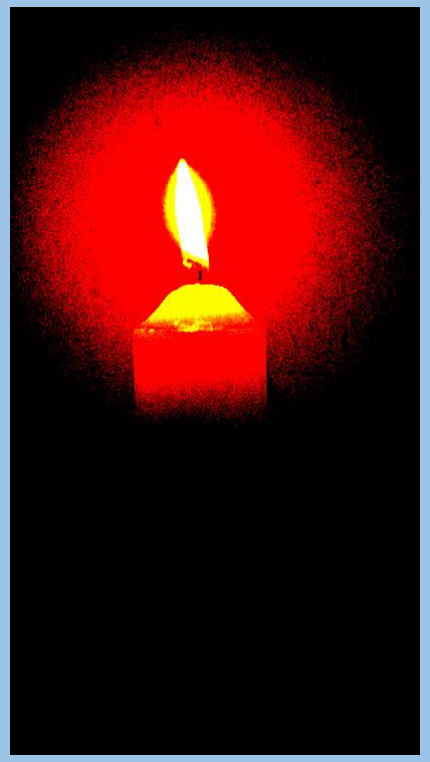
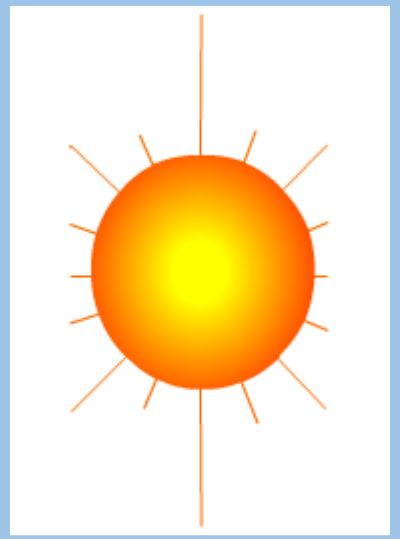
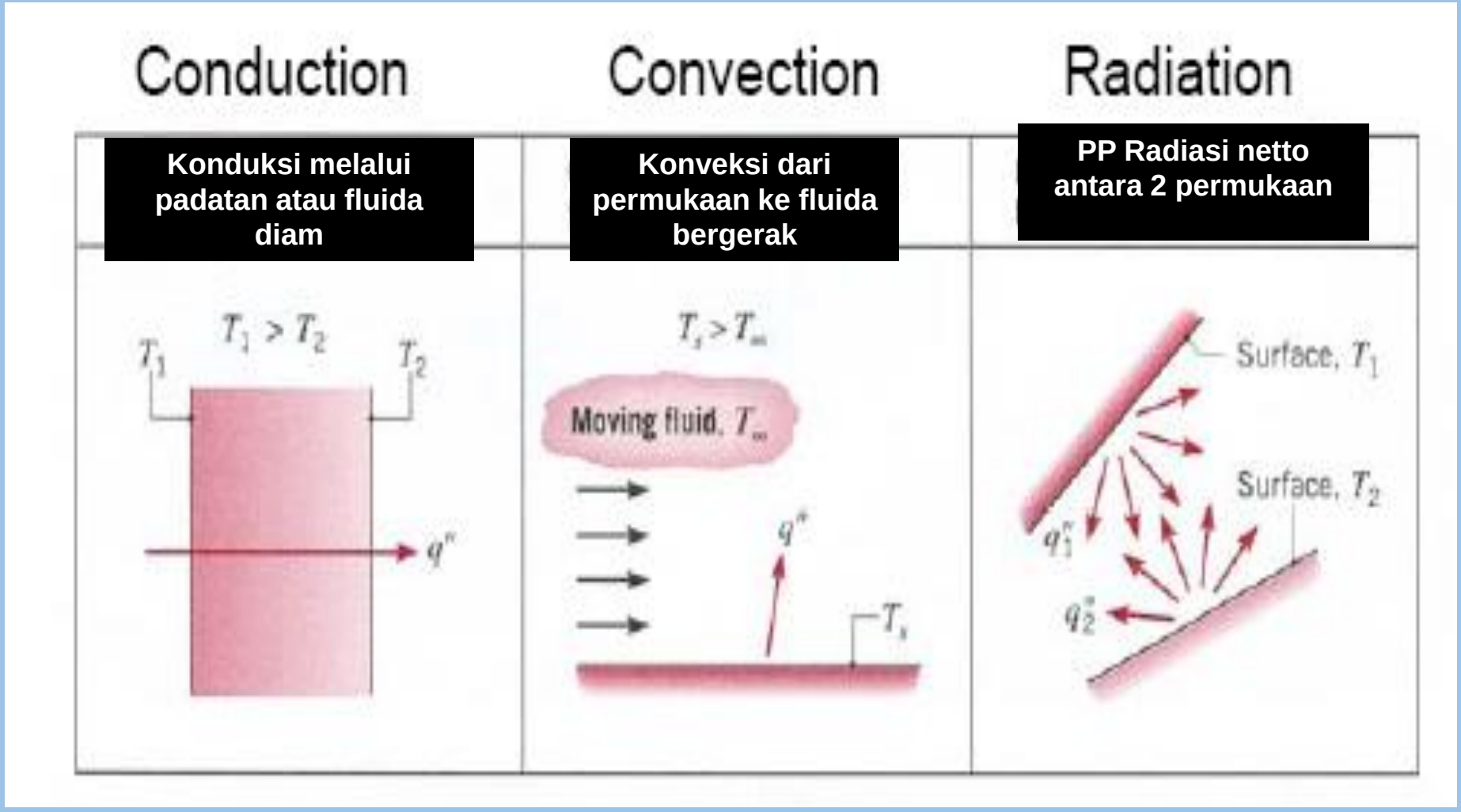
THERMAL RADIATION





Review


Conduction
Convection
Radiation
Konduksi melalui padatan atau fluida diam
Konveksi dari permukaan ke fluida bergerak
PP Radiasi netto antara 2 permukaan
$T_1 > T_2$
T_1
T_2
q''
$T_s > T_\infty$
Moving fluid, T_∞
q''
T_s
Surface, T_1
Surface, T_2
q_1''
q_2''

RADIASI TERMAL

- Berlangsung tanpa perlu media dengan gelombang elektromagnetis

- Hubungan panjang gelombang vs frekuensi

$$\lambda = \frac{c}{\nu} = \frac{1}{\eta}$$

, η = wave number

c = 3 . 10 ^{8} m/s2

v = frekuensi

- Teori kuantum (paket energi foton), Planck

$$\epsilon = h\nu \qquad h = 6.626 \times 10^{-34}\ \mathrm{J \cdot s}$$

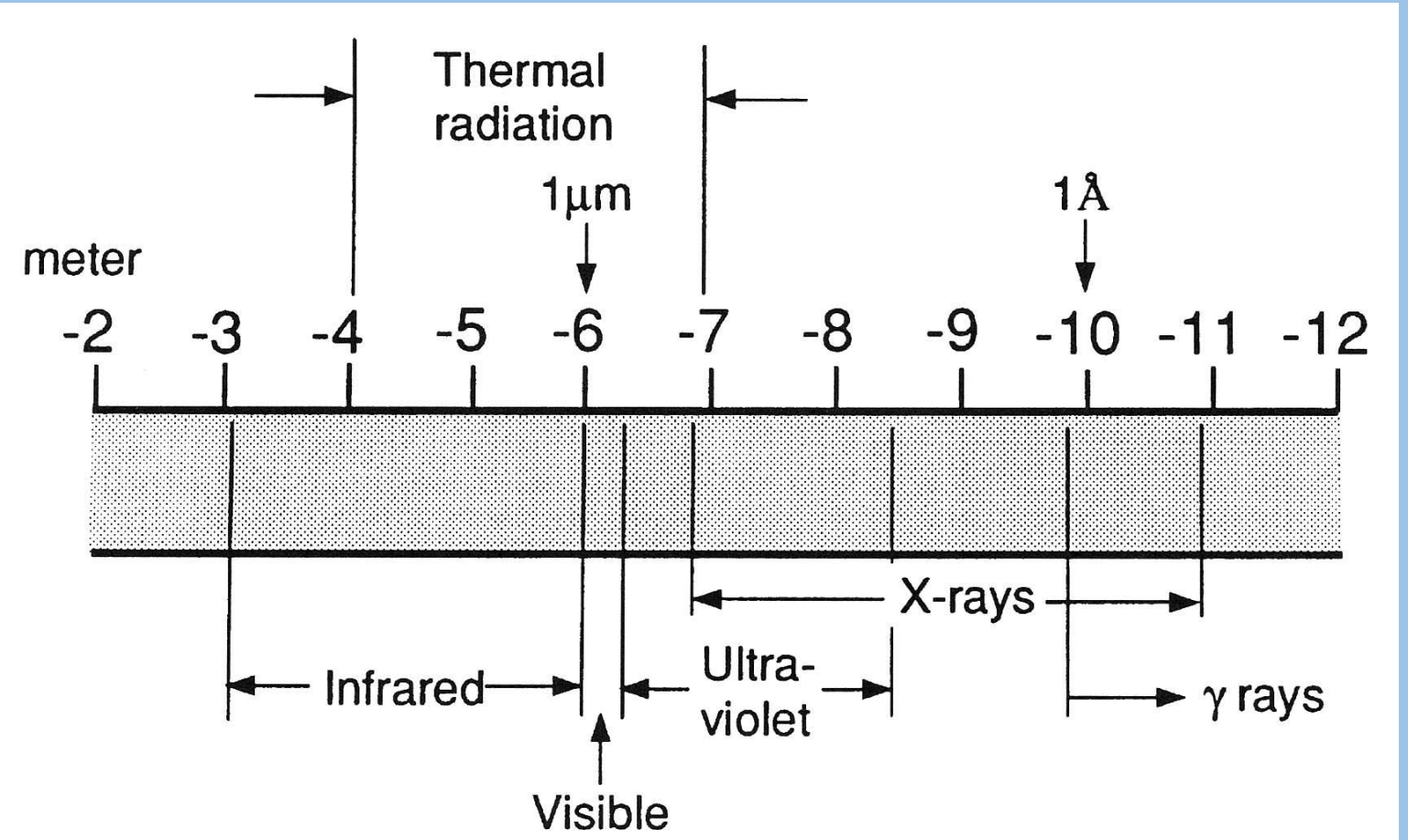


Fig. 2.7-1 Spectrum of electromagnetic radiation.

Cont’d

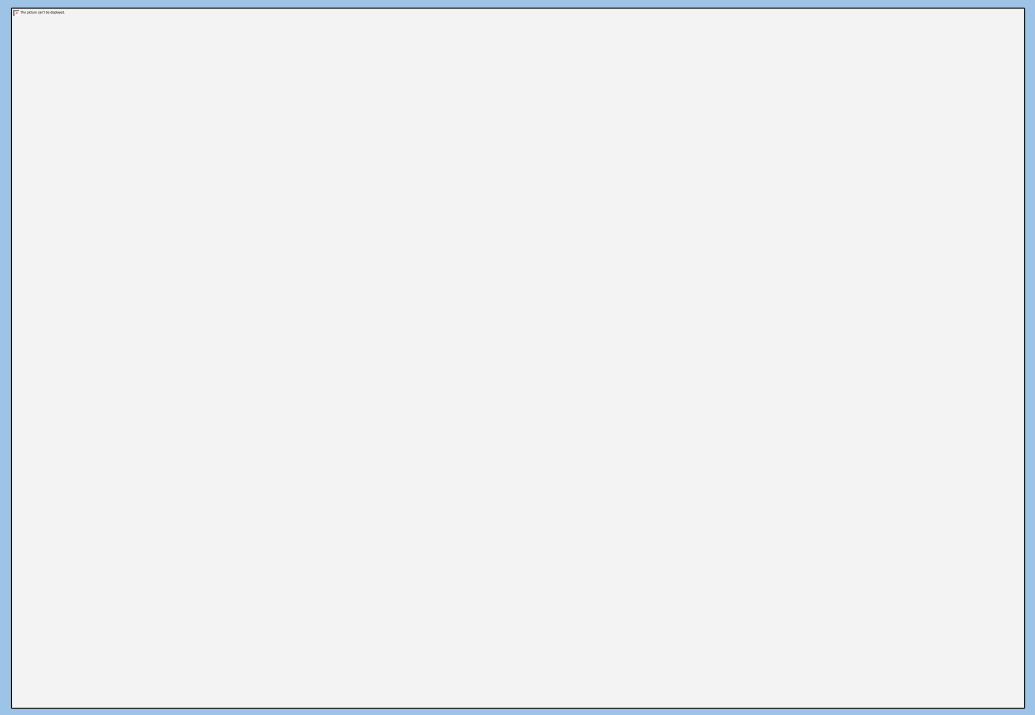
- Energi persatuan luas persatuan waktu (Hukum Stefan Boltzmann)

$$E_b = \sigma T^4$$

$$\sigma = 5.670 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}$$

Eb [=] W/m^2

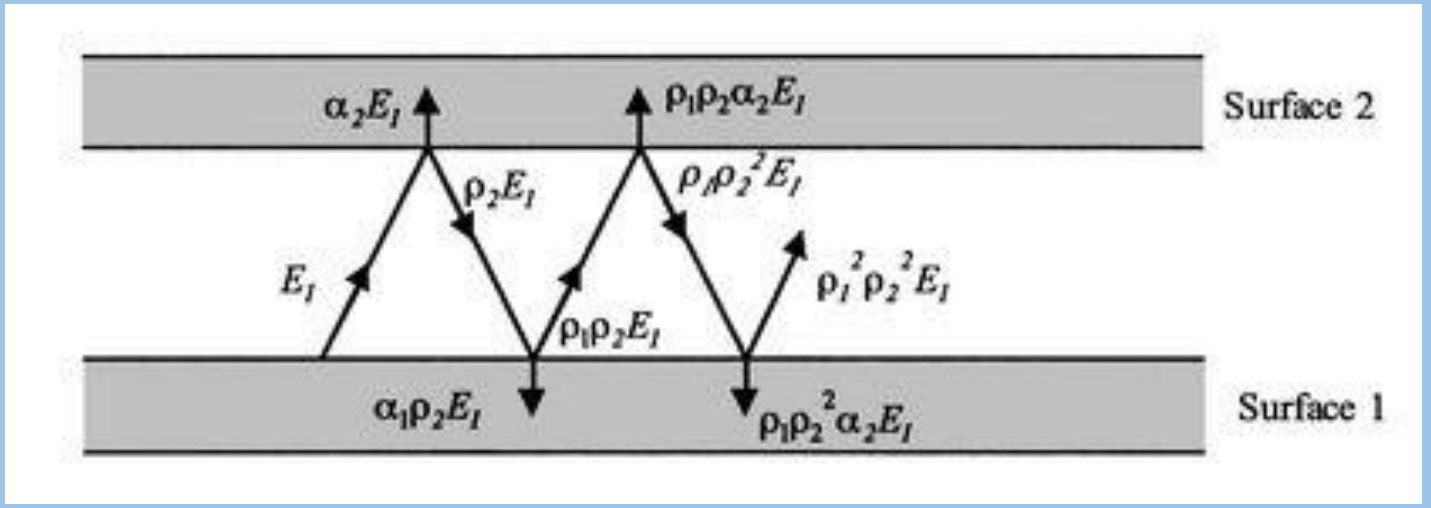
Sifat-sifat PP Radiasi



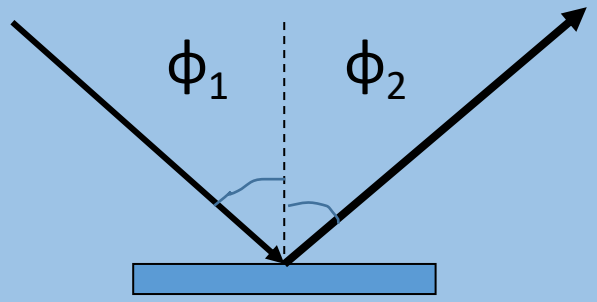
r = reflektivitas, α = absorptivitas, τ = transmisivitas,

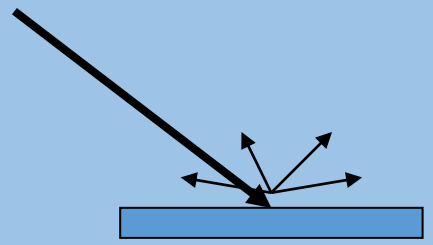
r + α + τ = 1

- Kebanyakan benda padat tidak mentransmisi radiasi termal, sehingga $\tau = 0$ (benda suram / opaque)
- $\rho + \alpha = 1$



Fenomena refleksi





Pemantulan energi:

1. Spekular

   seperti cermin,

   sudut datang = sudut pantul

2. Diffus:

   kesegala arah

Hukum Kirchoff

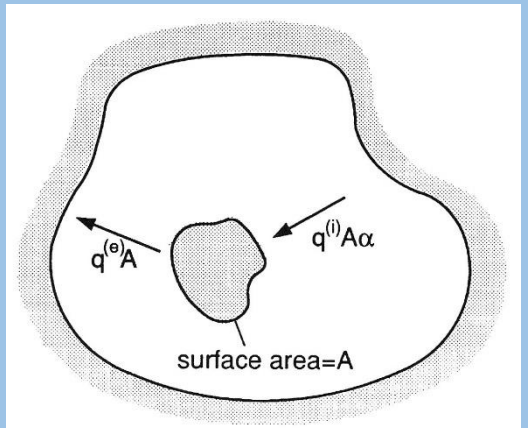


Fig. 2.7-2 A body enclosed in a cavity.

Tenaga emisi = tenaga yang dipancarkan oleh sebuah benda persatuan luas, persatuan waktu

Emisivitas total = perbandingan tenaga yang dipancarkan benda pada suhu T terhadap tenaga yang dipancarkan benda hitam pada suhu yang sama

$$\epsilon(T) = \frac{E(T)}{E_b(T)}$$

$$\frac{E}{E_b} = \alpha = \varepsilon.$$

Faktor yang mempengaruhi Emisivitas dan absorptivitas

- Temperatur, konduktor emisivitas naik dengan suhu naik
- Keadaan permukaan, makin kasar emisivitas naik
- Struktur benda dan ukuran butir
- Arah pancaran panas
- Panjang gelombang

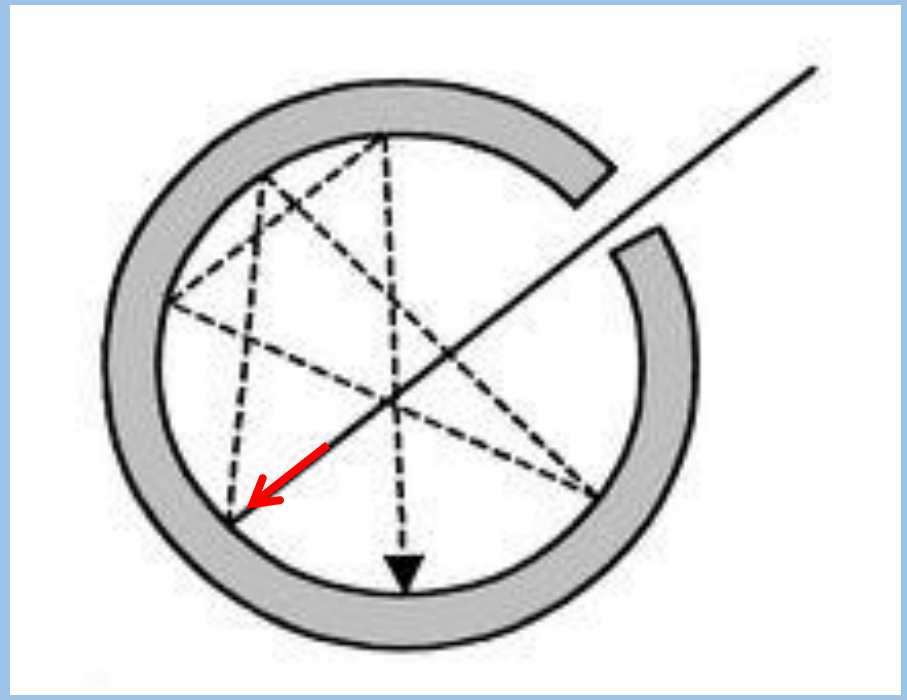
Total Emisivitas beberapa benda

TABLE 8.2 Total Emittance and Solar Absorptance of Selected Surfaces

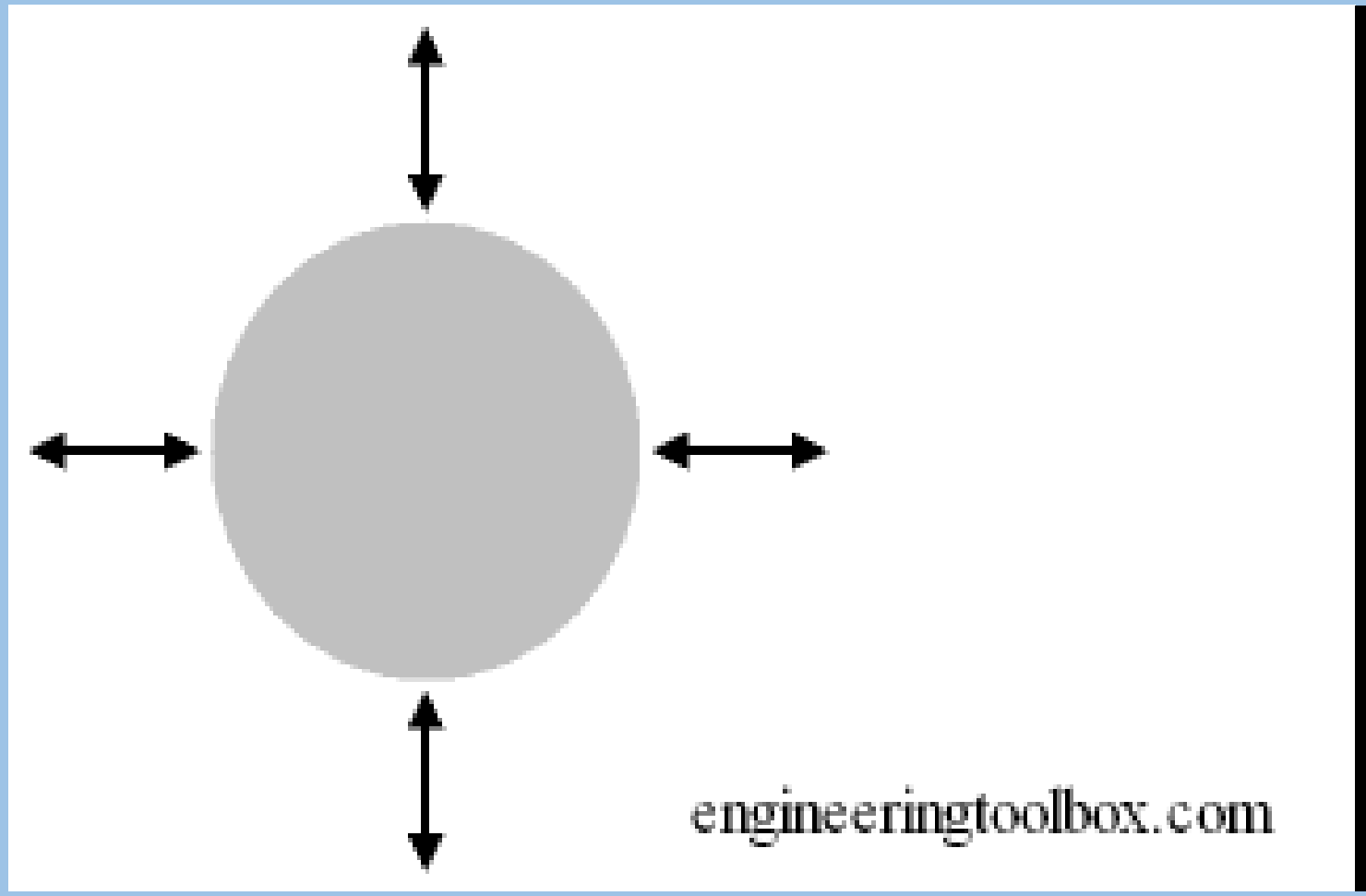
	Temperature (°C)	Total, Normal Emittance	Solar Absorptance
Alumina, flame-sprayed	−25	0.80	0.28
Aluminum foil			
As received	20	0.04	
Bright dipped	20	0.025	0.10
Aluminum, vacuum-deposited	20	0.025	0.10
Hard-anodized	−25	0.84	0.92
Highly polished plate, 98.3% pure	225–575	0.039–0.057	
Commercial sheet	100	0.09	
Rough polish	100	0.18	
Rough plate	40	0.055–0.07	
Oxidized at 600°C	200–600	0.11–0.19	
Heavily oxidized	95–500	0.20–0.31	

Benda hitam

- A cavity with a small hole (approximate black body)



Benda Abu-abu / Gray Body



$q = \varepsilon \sigma T^4 A$ (2)

Dimana
ε = emisivitas

ε = 1 untuk black body
0 < ε < 1 untuk benda abu-abu

Contoh :
oxidized Iron pada *390 °F (199 °C) > ε = 0.64*
polished Copper pada *100 °F (38 °C) > ε = 0.03*

Faktor Bentuk Radiasi (View Factor)

- Fraksi energi yang meninggalkan permukaan m dan mencapai permukaan n ($F_{m,n}$)
- Energi yang meninggalkan permukaan 1 dan mencapai permukaan 2 = $Eb_1.A_1.F_{12}$
- Utk benda hitam, seluruh radiasi yang menimpa akan diserap dan terjadi pertukaran panas netto sebesar :

- $Eb_1.A_1.F_{12} - Eb_2.A_2.F_{21} = Q_{12}$

- Bila suhu kedua permukaan sama, maka $Q_{12} = 0$

  dan $Eb_1 = Eb_2$

  dan $A_1F_{12} = A_2\ F_{21}$

- $Q_{12} = A_1F_{12}\ (Eb1 - Eb2)$

  $= A_2\ F_{21}\ (Eb1 - Eb2)$

Hubungan antara berbagai faktor bentuk

- Resiprositas $A_1 F_{12} = A_2 F_{21}$
- $F_{1\text{-}2+3} = F_{12} + F_{13}$

$$F_{1-1} + F_{1-2} + F_{1-3} = 1$$

- Nilai F dapat dilihat pada fig.8-12 smp 8-16 Holman

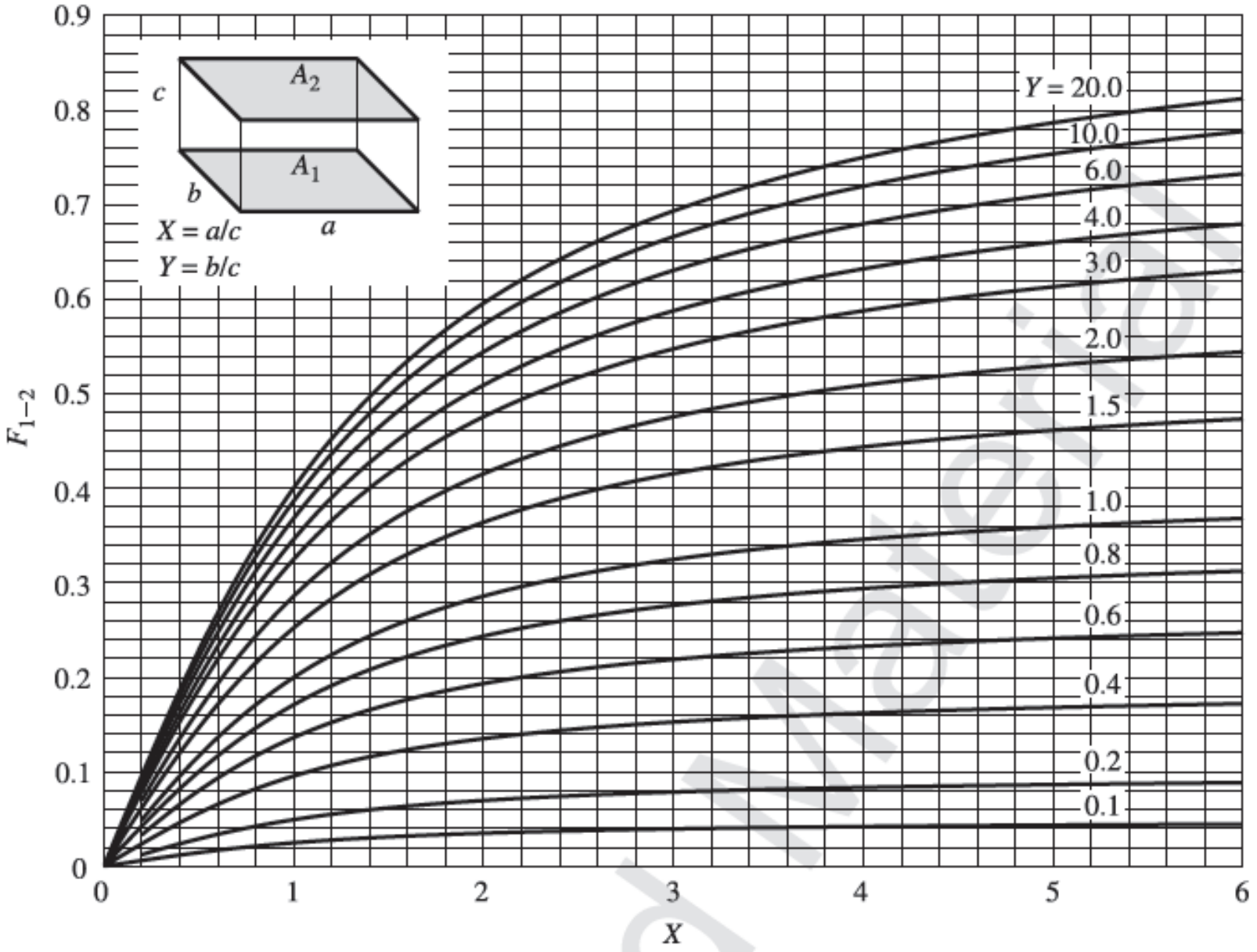
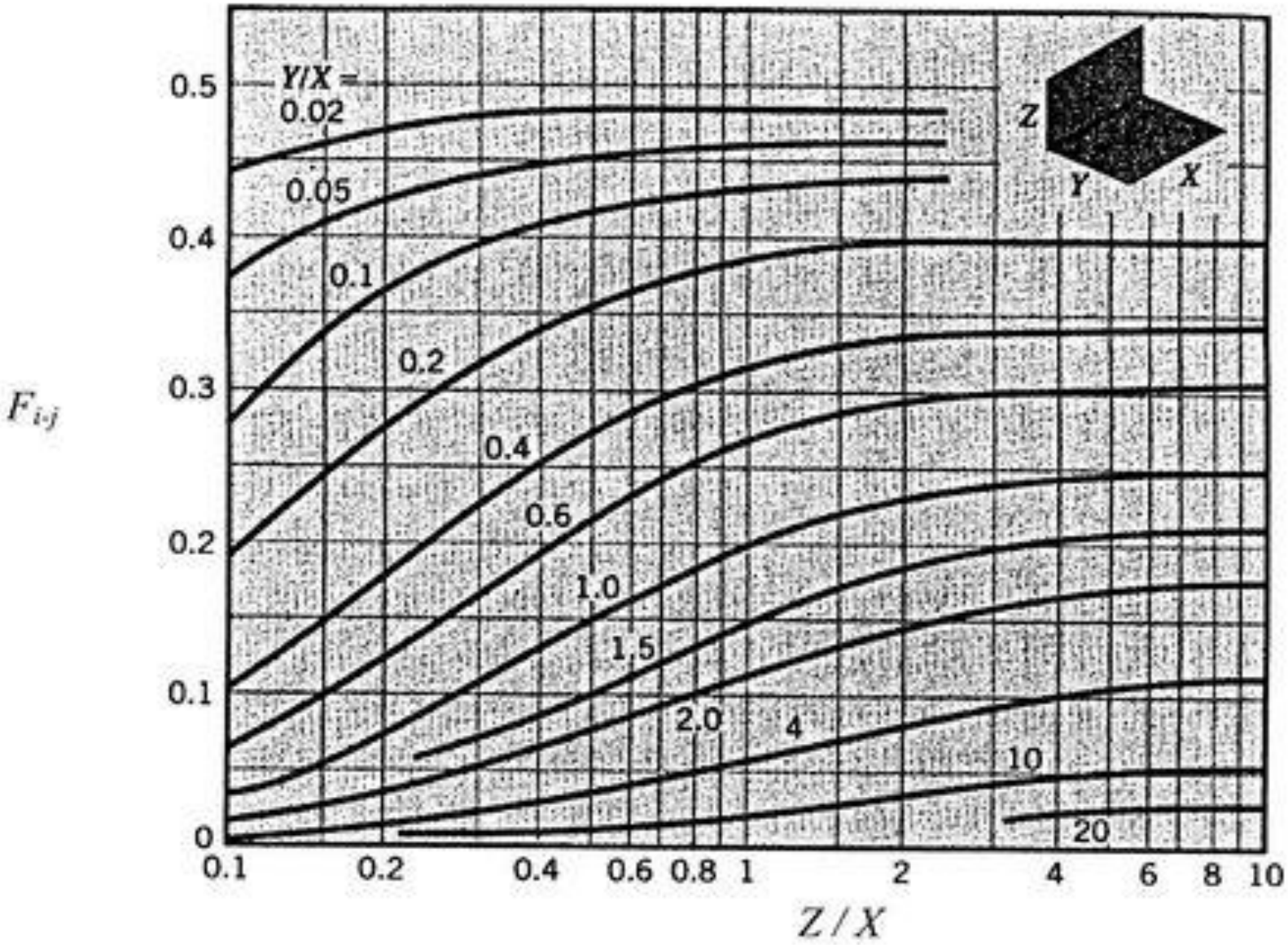


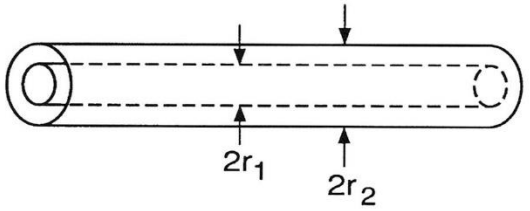
Figure 8.15 View factor between identical, parallel, directly opposed rectangles (configuration 7).


$F_{i\text{-}j}$
Y/X =
0.02
0.05
0.1
0.2
0.4
0.6
1.0
1.5
2.0
4
10
20
Z
Y
X
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.4
0.6
0.8
1
2
4
6
8
10
Z / X

Important View Factors

(a) large(infinite) parallel plates :
$F_{12} = 1$

(b) long(infinite) concentric cylinders :
$F_{12} = 1$



(c) concentric spheres :
$F_{12} = 1$

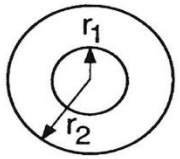
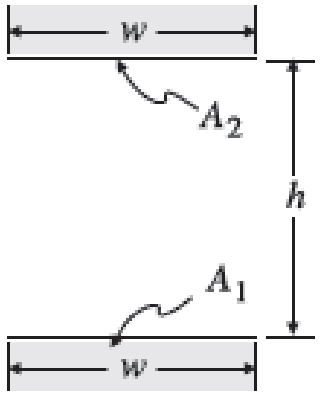


Fig. 2.7-7 Examples of view factors equal to one: (*a*) large parallel plates; (*b*) long concentric cylinders; (*c*) concentric spheres.

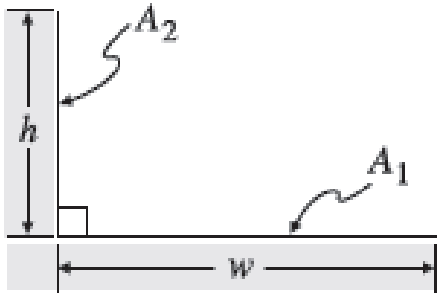
TABLE 8.3 Important View Factors



1. Two infinitely long, directly opposed parallel plates of the same finite width:

$$H = \frac{h}{w}$$

$$F_{1-2} = F_{2-1} = \sqrt{1 + H^2} - H$$



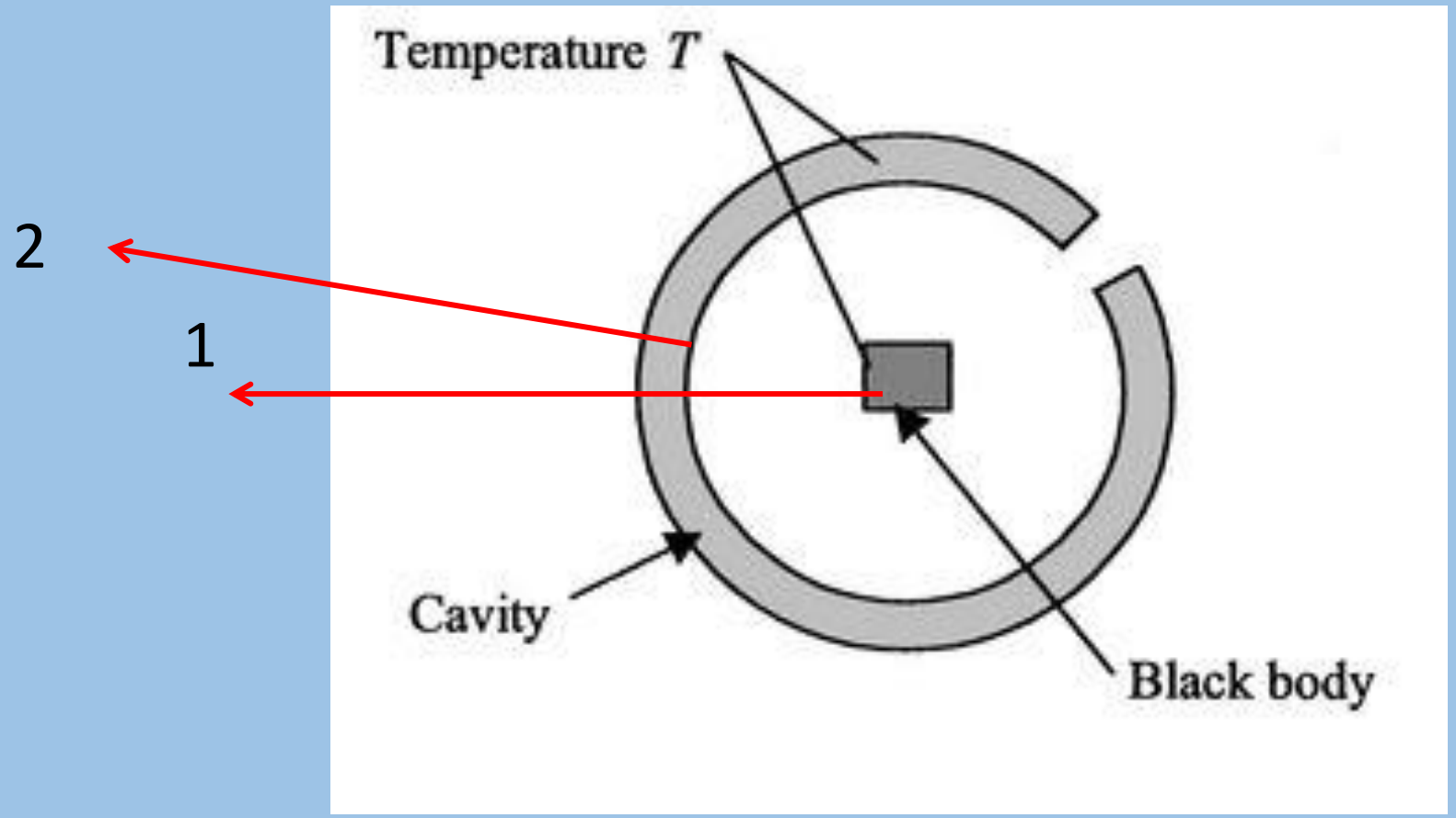
2. Two infinitely long plates of unequal widths h and w, having one common edge, and at an angle of 90° to each other:

$$H = \frac{h}{w}$$

$$F_{1-2} = \frac{1}{2}\left(1 + H - \sqrt{1 + H^2}\right)$$

Black body in a cavity

- $F_{12} = 1$



PP pada benda abu-abu

- Bila semua permukaan dianggap bersifat baur dan suhu uniform, emisivitas dan reflektivitas sama dan tetap, maka muncul 2 besaran :
- Iradiasi (G) :

  Panas radiasi total yg mengenai permukaan per sat.wkt per sat. luas
- Radiositas (J) :

  Panas radiasi total yg dipancarkan permukaan per sat.wkt per sat. luas

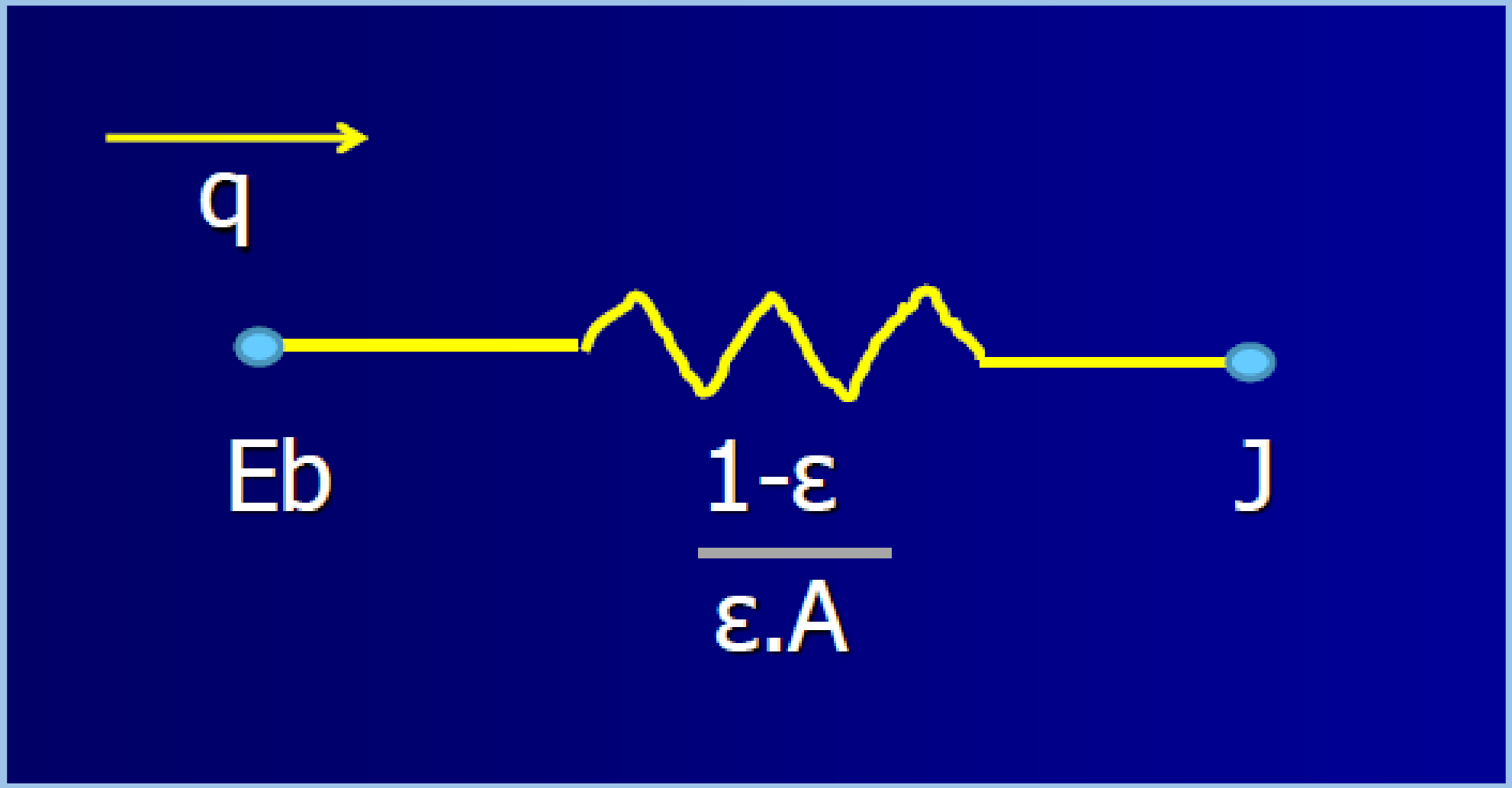
- $J = \varepsilon.Eb + \rho.G$
- $\rho = 1-\alpha = 1 - \varepsilon$
- $Q / A = J - G = [\varepsilon.Eb + (1 - \varepsilon) G] - G$
- $Q = \varepsilon A (Eb - J) / 1- \varepsilon$

  $=(Eb - J) / [(1 - \varepsilon)/ \varepsilon A]$

Analogi dengan aliran listrik ($I = V/R$) :

$(Eb - J)$: beda potensial

$(1 - \varepsilon)/ \varepsilon A$: tahanan permukaan


q
Eb
1-ε
ε.A
J

- Bila view factor terlibat, maka :

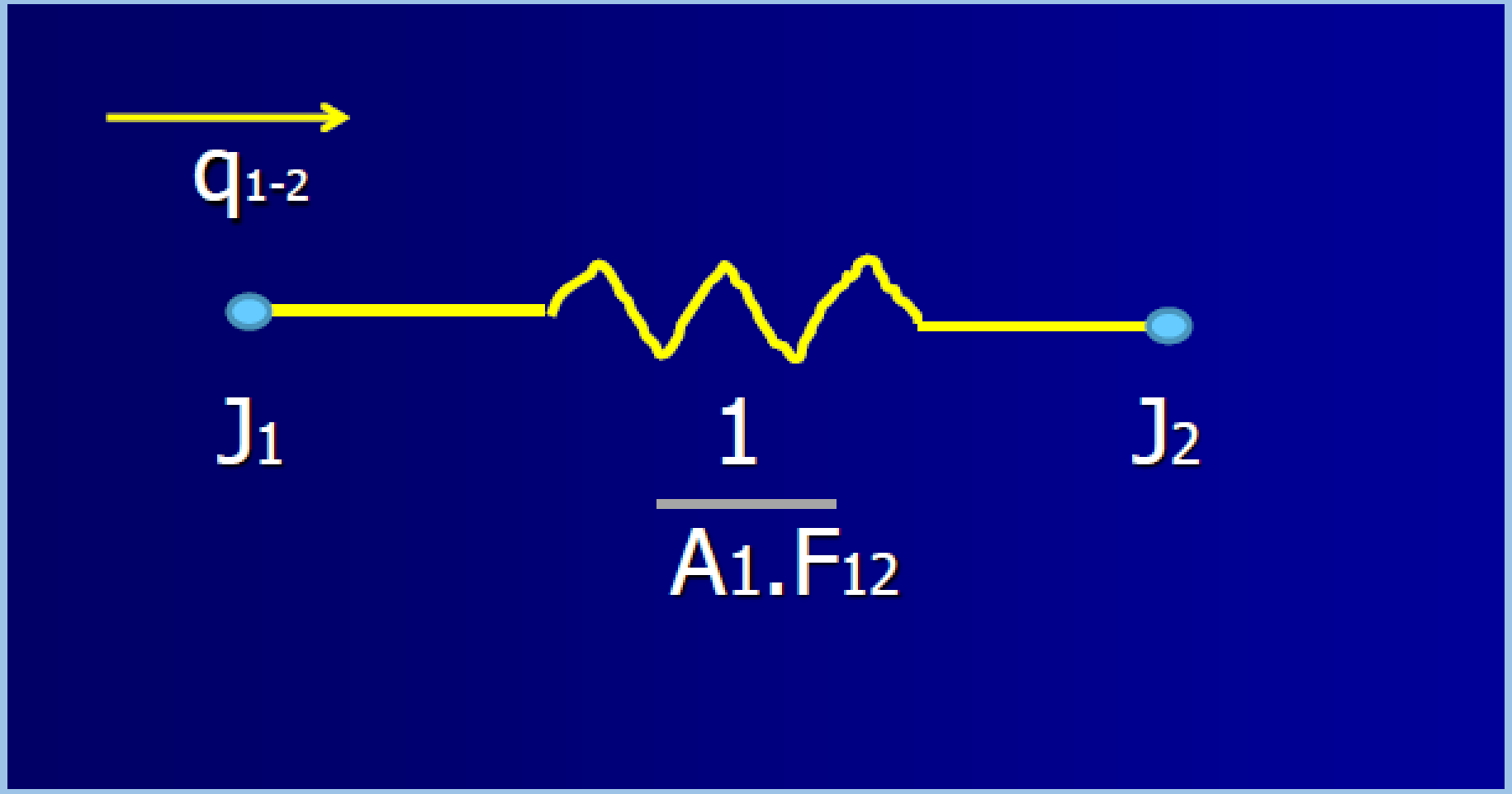
$Q_{12} = J_1 A_1 F_{12} - J_2 A_2 F_{21}$

$= A_1 F_{12} (J_1 - J_2)$

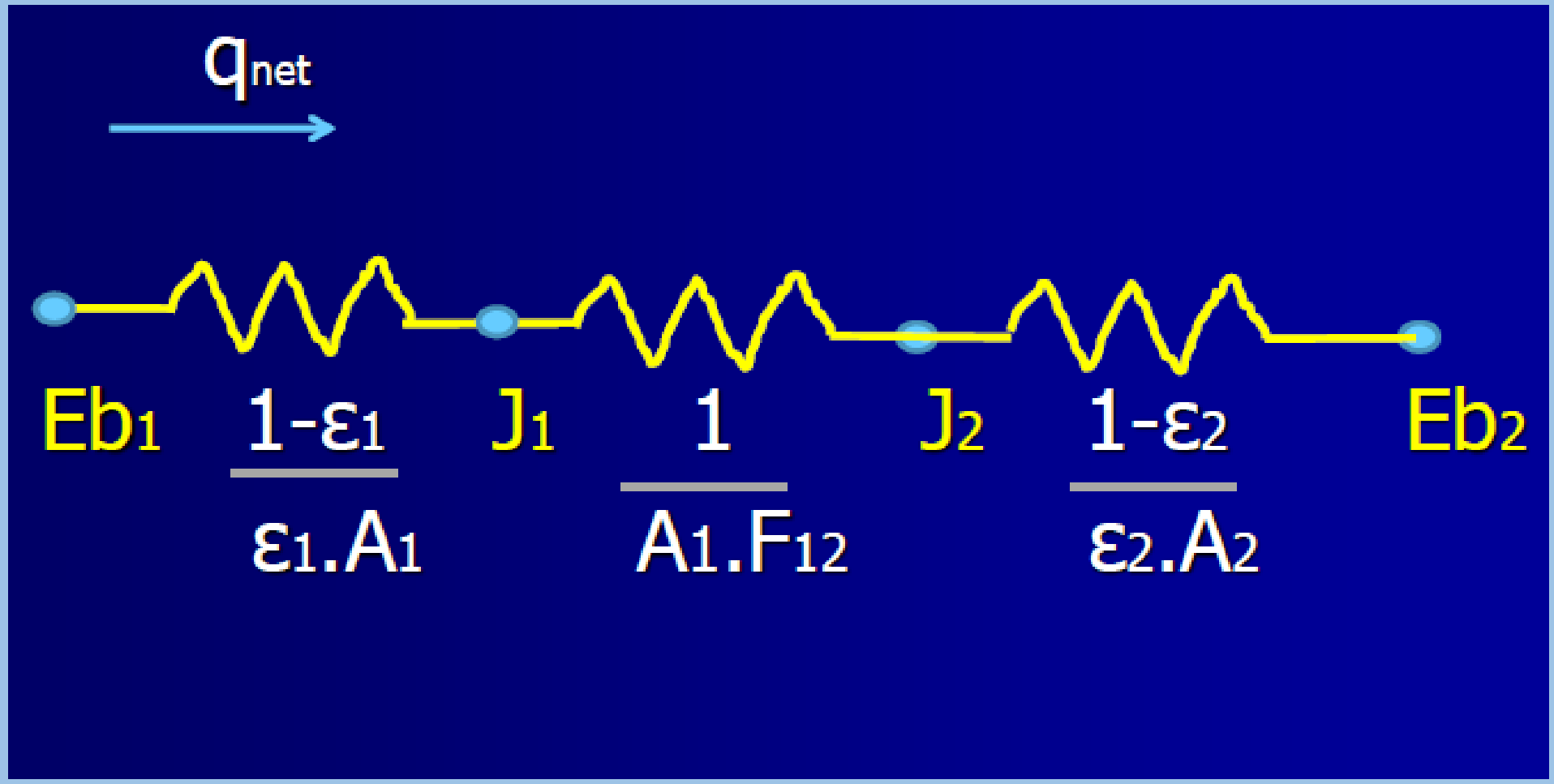
$= A_2 F_{21} (J_1 - J_2)$

$= (J_1 - J_2) / [1 / A_1 F_{12}]$

$[1 / A_1 F_{12}]$: tahanan kedudukan (tahanan ruang)


$q_{1\text{-}2}$
J_1
1
$A_1.F_{12}$
J_2

Jaringan radiasi utk 2 permukaan benda abu-abu



Kasus-kasus khusus

- Permukaan sangat besar (misal : ruangan besar)

  $A >>$ sehingga $(1 - \varepsilon)/ \varepsilon A \approx 0$

  (tahanan permukaan)

- Permukaan diisolasi

  $q = 0$ sehingga $J = Eb$

Contoh soal

- Pelajari contoh 8-2, 8-3 dan 8-6 Holman

- PR :
- Kerjakan 8-14, 8-17