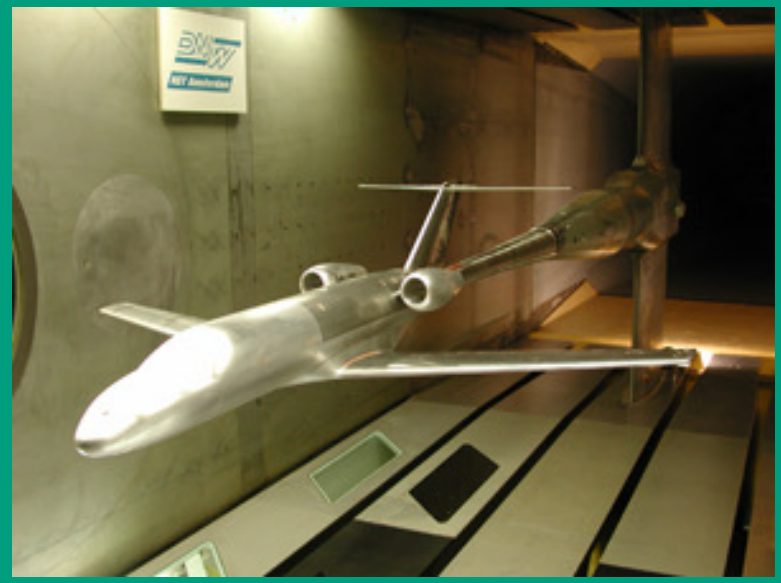
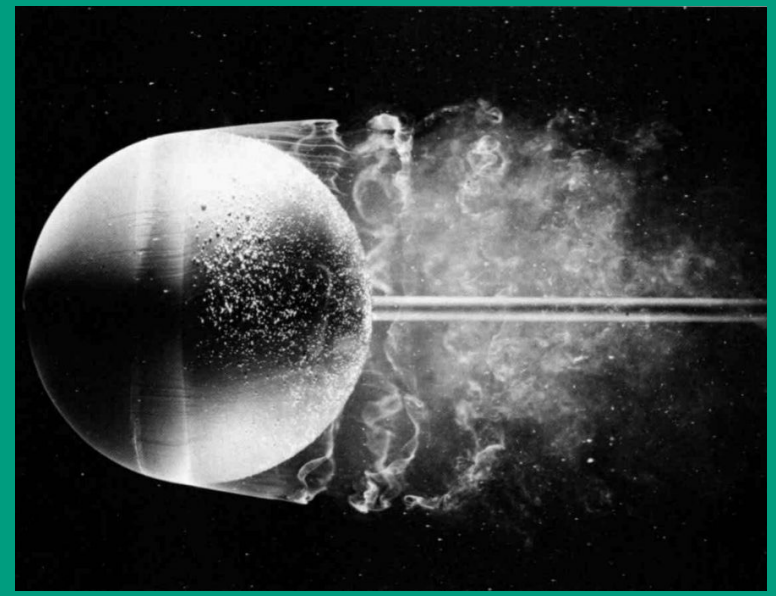
22 – Dimensjonsanalyse

TPS200 – Fluidmekanikk 1: Innføring

20-04-2022 – EFM 8.1-8.3







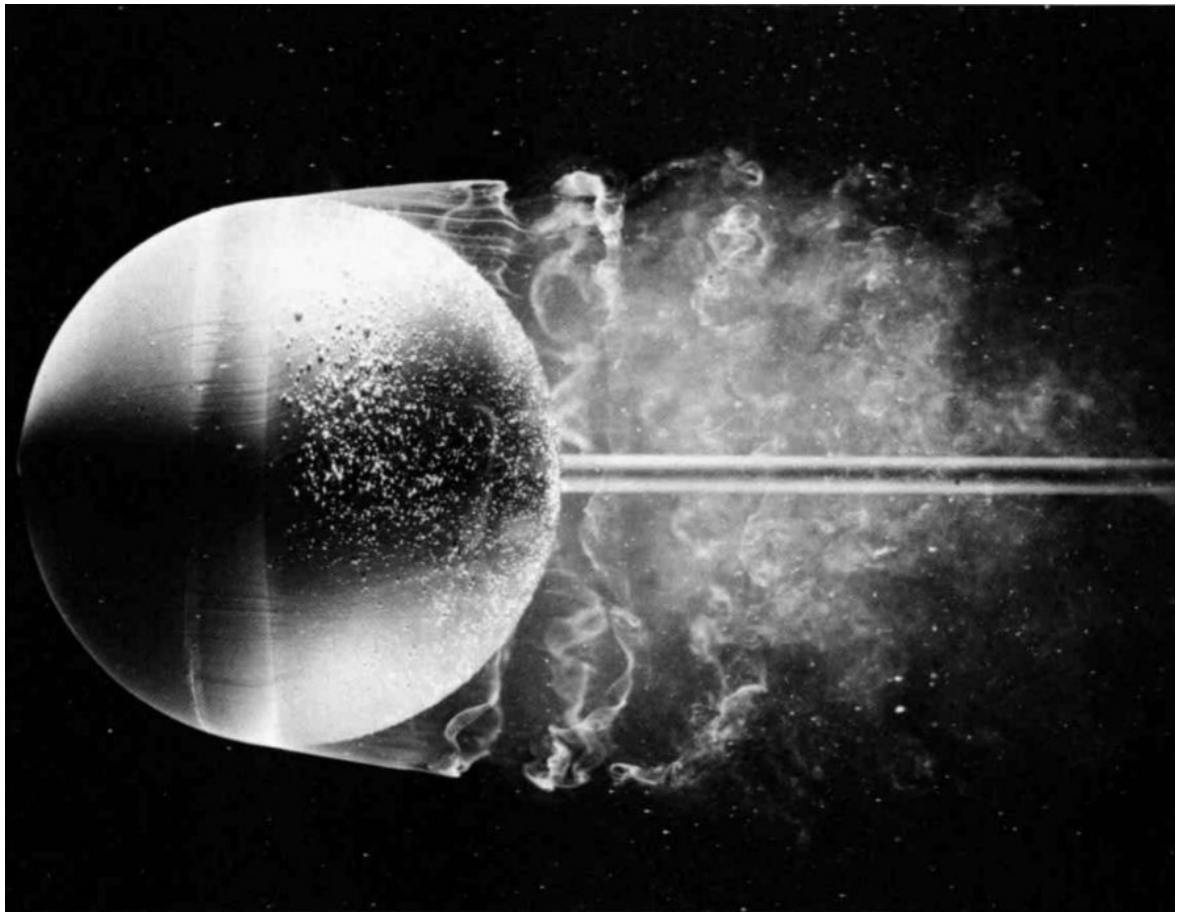
Modelltesting: Hvordan kan vi finne drag og løft på et fullskala fly ved å måle dette på et lite modellfly i vindtunnel?

Modellreduksjon: Hvordan redusere antall tester fra 10,000 til 10 for å finne ut hvordan draget avhenger av
viskositet, hastighet, diameter, fluidets tetthet?

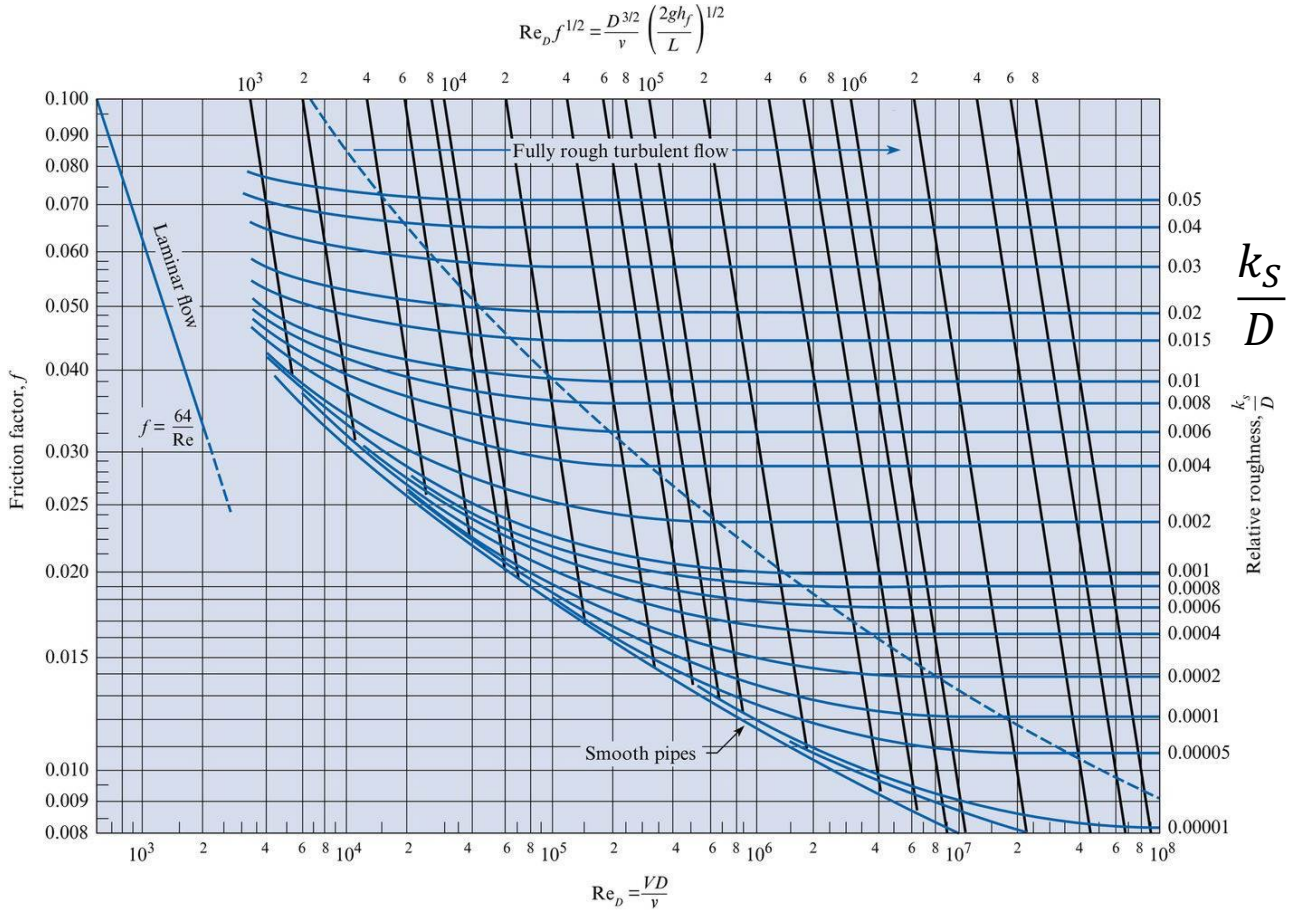
Bilder fra Creative Commons

Hvordan finne ut hvordan dragkraften på en kule avhenger av eksperimentelle parametere (viskositet, diameter, hastighet, tetthet)

- **Hvordan ville du gått frem?**
- **Hvor mange målinger må vi ta?**



Moody-diagrammet – et høydepunkt for dimensjonsanalyse!



$$\frac{k_S}{D}$$

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{k_s/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

$$\mathrm{Re} = \frac{VD}{\nu}$$

- Variabelreduksjon: En (ofte ukjent) funksjonssammenheng mellom et sett med fysiske variabler som beskriver et fenomen må oppfylle kravet om dimensjonsmessig konsistens. Vi skal se at antall effektive variabler kan *reduseres* ved å innføre dimensjonsløse variabler.

Særlig denne identifiseres med dimensjonsanalyse

Konsekvenser

- Effektivisere eksperimenter ved å variere på noen få dimensjonsløse variabler i stedet for å variere på alle variablene som inngår i eksperimentet
- Avgjøre hvilke krefter/effekter som er viktige i en gitt situasjon ved å se på verdien til dimensjonsløse variabler → Kan forenkle likninger ved å fjerne ledd som er små
- Oversette resultater fra småskala modellforsøk til anvendelser i stor skala (f.eks. forsøk i vindtunnel) – de dimensjonsløse variablene må ha samme verdi i modell og stor skala
- Effektivisere likningsløsning og presentasjon (løse én gang for dimensjonsløse variabler i stedet for mange ganger for variabler med dimensjoner)

Finne π'ene: Steg-for-steg-metoden

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one $(m + 1)$.
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when

EFM Eksempel 8.1

- For et objekt som faller fritt i vakuum er det tre variabler som er relevant for å beskrive bevegelsen
  - Tyngdeakselerasjonen g
  - Hastigheten V
  - Fallavstanden h
- Vi har $f(g, V, h) = 0$
- Bruk steg-for-steg-metoden til å finne de dimensjonsløse gruppene som beskriver sammenhengen mellom de tre

$$\phi(\pi_1, \ldots, \pi_{n-m}) = 0$$

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one ($m + 1$).
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when dividing (or multiplying) by a given variable. See Ipsen (2) for an example of this.

Oppgave: Hvor mange dimensjonsløse Pi-grupper forventer vi?

- For et objekt som faller fritt i vakuum er det tre variabler som er relevant for å beskrive bevegelsen
  - Tyngdeakselerasjonen g
  - Hastigheten V
  - Fallavstanden h
- Vi har $f(g, V, h) = 0$
- Bruk steg-for-steg-metoden til å finne de dimensjonsløse gruppene som beskriver sammenhengen mellom de tre

$$\phi(\pi_1, \ldots, \pi_{n-m}) = 0$$

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one ($m + 1$).
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when dividing (or multiplying) by a given variable. See Ipsen (2) for an example of this.

Tips: Uttrykk variablene V,g,h ved masse [M], lengde [L] og tid [T]

EFM Eksempel 8.2: Dragkraften på en kule

- Litt større eksempel: Drag-kraften F_D på en kule forventes å avhenge av
  - Viskositeten μ
  - Tettheten ρ
  - Hastighet V
  - Diameteren D
- Finn dimensjonsløse grupper
- Først: Hva er dimensjonene tilde 5 variablene i problemet?

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one $(m + 1)$.
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when dividing (or multiplying) by a given variable. See Ipsen (2) for an example of this.

Oppgave: Eliminer lengde, L, ved å gange eller dele variablene i første kolonne på D [L].

- Vi har $f(F_d, \mu, \rho, V, D) = 0$
- To dimensjonsløse grupper

Variable []	Variable []	Variable []	Variable []
F_D $\frac{ML}{T^2}$			
V $\frac{L}{T}$			
ρ $\frac{M}{L^3}$			
μ $\frac{M}{LT}$			
D L			

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one $(m + 1)$.
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when dividing (or multiplying) by a given variable. See Ipsen (2) for an example of this.

Oppgave: Multipliser eller divider variablene i andre kolonne med ρD^3 for å eliminere massen M fra variablene i tredje kolonne

- Vi vil eliminere massen, M.
- Massen, M, kan uttrykkes ved ρD^3.

Variable []		Variable []		Variable []	Variable []
F_D	$\frac{ML}{T^2}$	$\frac{F_D}{D}$	$\frac{M}{T^2}$		
V	$\frac{L}{T}$	$\frac{V}{D}$	$\frac{1}{T}$		
ρ	$\frac{M}{L^3}$	ρD^3	M		
μ	$\frac{M}{LT}$	μD	$\frac{M}{T}$		
D	L				

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one ($m + 1$).
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when dividing (or multiplying) by a given variable. See Ipsen (2) for an example of this.

Oppgave: Eliminer T i fjerde kolonne ved å bruke at $\frac{V}{D} = 1/T$

- Vi har $f(F_d, \mu, \rho, V, D) = 0$
- To dimensjonsløse grupper

Variable []		Variable []		Variable []		Variable []
F_D	$\frac{ML}{T^2}$	$\frac{F_D}{D}$	$\frac{M}{T^2}$	$\frac{F_D}{\rho D^4}$	$\frac{1}{T^2}$	
V	$\frac{L}{T}$	$\frac{V}{D}$	$\frac{1}{T}$	$\frac{V}{D}$	$\frac{1}{T}$	
ρ	$\frac{M}{L^3}$	ρD^3	M			
μ	$\frac{M}{LT}$	μD	$\frac{M}{T}$	$\frac{\mu}{\rho D^2}$	$\frac{1}{T}$	
D	L					

TABLE 8.1 The Step-by-Step Approach

Step	Action Taken during This Step
1	Identify the significant dimensional variables and write out the primary dimensions of each.
2	Apply the Buckingham Π theorem to find the number of π-groups.*
3	Set up a table with the number of rows equal to the number of dimensional variables and the number of columns equal to the number of basic dimensions plus one ($m + 1$).
4	List all the dimensional variables in the first column with primary dimensions.
5	Select a dimension to be eliminated, choose a variable with that dimension in the first column, and combine with remaining variables to eliminate the dimension. List combined variables in the second column with the remaining primary dimensions.
6	Select another dimension to be eliminated, choose from variables in the second column that have that dimension, and combine with the remaining variables. List the new combinations with the remaining primary dimensions in the third column.
7	Repeat Step 6 until all dimensions are eliminated. The remaining dimensionless groups are the π-groups. List the π-groups in the last column.

*Note that, in rare instances, the number of π-groups may be one more than predicted by the Buckingham Π theorem. This anomaly can occur because it is possible that two dimensional categories can be eliminated when dividing (or multiplying) by a given variable. See Ipsen (2) for an example of this.

Du skal nå stå igjen med to dimensjonsløse Pi-grupper

Oppgave: Hva kalles π_1 – gruppen?

- Vi har $f(F_d, \mu, \rho, V, D) = 0$
- To dimensjonsløse grupper

$$\pi_1 = \frac{F_D}{\rho V^2 D^2}; \pi_2 = \frac{\mu}{\rho V D}$$

- Kan også skrives

$$\frac{F_D}{\rho V^2 D^2} = g\left(\frac{\rho V D}{\mu}\right) = g(Re)$$

Hva kalles denne?

Variable []		Variable []		Variable []		Variable []	
F_D	$\frac{ML}{T^2}$	$\frac{F_D}{D}$	$\frac{M}{T^2}$	$\frac{F_D}{\rho D^4}$	$\frac{1}{T^2}$	$\frac{F_D}{\rho V^2 D^2}$	0
V	$\frac{L}{T}$	$\frac{V}{D}$	$\frac{1}{T}$	$\frac{V}{D}$	$\frac{1}{T}$		
ρ	$\frac{M}{L^3}$	ρD^3	M				
μ	$\frac{M}{LT}$	μD	$\frac{M}{T}$	$\frac{\mu}{\rho D^2}$	$\frac{1}{T}$	$\frac{\mu}{\rho V D}$	0
D	L						

Agenda

- Introduksjon og anvendelser
- Buckingham's Π-teorem
- Finne π´ene: Steg-for-steg-metoden
- Finne π´ene: Eksponentmetoden



Eksponentmetoden

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $$[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ \ldots \ y_n^k$ and identify the π-groups.

EFM Eksempel 8.3: Dragkraft på en kule ved eksponentmetoden

- Som Eksempel 8.2: Drag-kraften F_D på en kule forventes å avhenge av
  - Viskositeten μ; $[\mu] = M/LT$
  - Tettheten ρ; $[\rho] = M/L^3$
  - Hastighet V; $[V] = L/T$
  - Diameteren D; $[D] = L$
- $[F_D] = ML/T^2$
- Finn dimensjonsløse grupper ved hjelp av eksponentmetoden

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ \ldots \ y_n^k$ and identify the π-groups.

EFM Eksempel 8.3

- Vi har $F_d = f(V, \rho, \mu, D)$
- Fem variabler, tre dimensjoner → To dimensjonsløse grupper

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ \ldots \ y_n^k$ and identify the π-groups.

EFM Eksempel 8.3

- Vi har $F_d = f(V, \rho, \mu, D)$
- Fem variabler, tre dimensjoner → To dimensjonsløse grupper

$$[\mu] = \frac{M}{LT}, [\rho] = \frac{M}{L^3}, [V] = \frac{L}{T}, [D] = L, [F_D] = \frac{ML}{T^2}$$

$$[F_d] = [V]^a \cdot [\rho]^b \cdot [\mu]^c \cdot [D]^d$$

$$\frac{ML}{T^2} = \left(\frac{L}{T}\right)^a \cdot \left(\frac{M}{L^3}\right)^b \cdot \left(\frac{M}{LT}\right)^c \cdot L^d$$

$$MLT^{-2} = M^{b+c} L^{a-3b-c+d} T^{-a-c}$$

Vi utnytter her at hvis funksjonen f kan skrives på formen

$$F_d = CV^a \rho^b \mu^c D^d$$

der C er en dimensjonsløs konstant, så må dimensjonene på høyre og venstre side være like

$$[F_d] = [V^a \rho^b \mu^c D^d]$$

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ldots y_n^k$ and identify the π-groups.

EFM Eksempel 8.3

- Vi har $F_d = f(V, \rho, \mu, D)$
- Fem variabler, tre dimensjoner → To dimensjonsløse grupper

$$MLT^{-2} = M^{b+c} L^{a-3b-c+d} T^{-a-c}$$

- Dimensjonsmessig konsistens krever:

M: $b + c = 1$

L: $a - 3b - c + d = 1$

T: $-a - c = -2$

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ \ldots \ y_n^k$ and identify the π-groups.

EFM Eksempel 8.3

- Vi har $F_d = f(V, \rho, \mu, D)$
- Fem variabler, tre dimensjoner → To dimensjonsløse grupper

$$b + c = 1$$
$$a - 3b - c + d = 1$$
$$a + c = 2$$

- Løs for a, b og d mhp. c og finn

$$a = 2 - c$$
$$b = 1 - c$$
$$d = 2 - c$$

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ldots y_n^k$ and identify the π-groups.

Oppgave: Uttrykk F_D på formen $F_D = \rho X^2 Y^2 (\quad)^c$ Hva er X og Y og hva skal stå inni parantesen?

- Vi har $F_d = f(V, \rho, \mu, D)$
- Fem variabler, tre dimensjoner → To dimensjonsløse grupper

$$a = 2 - c$$
$$b = 1 - c$$
$$d = 2 - c$$

- Vår opprinnelige likning:

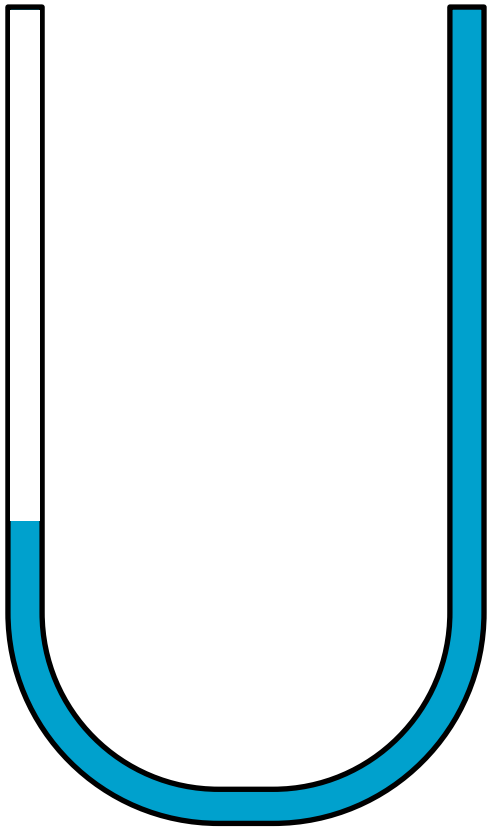
$$[F_d] = [V]^a \cdot [\rho]^b \cdot [\mu]^c \cdot [D]^d$$

TABLE 8.2 The Exponent Method

Step	Action Taken During This Step
1	Identify the significant dimensional variables, y_i, and write out the primary dimensions of each, $[y_i]$.
2	Apply the Buckingham Π theorem to find the number of π-groups.
3	Write out the product of the primary dimensions in the form $[y_1] = [y_2]^a \times [y_3]^b \times \cdots \times [y_n]^k$ where n is the number of dimensional variables and a, b, and so on are exponents.
4	Find the algebraic equations for the exponents that satisfy dimensional homogeneity (same power for dimensions on each side of equation).
5	Solve the equations for the exponents.
6	Express the dimensional equation in the form $y_1 = y_2^a y_3^b \ \ldots \ y_n^k$ and identify the π-groups.

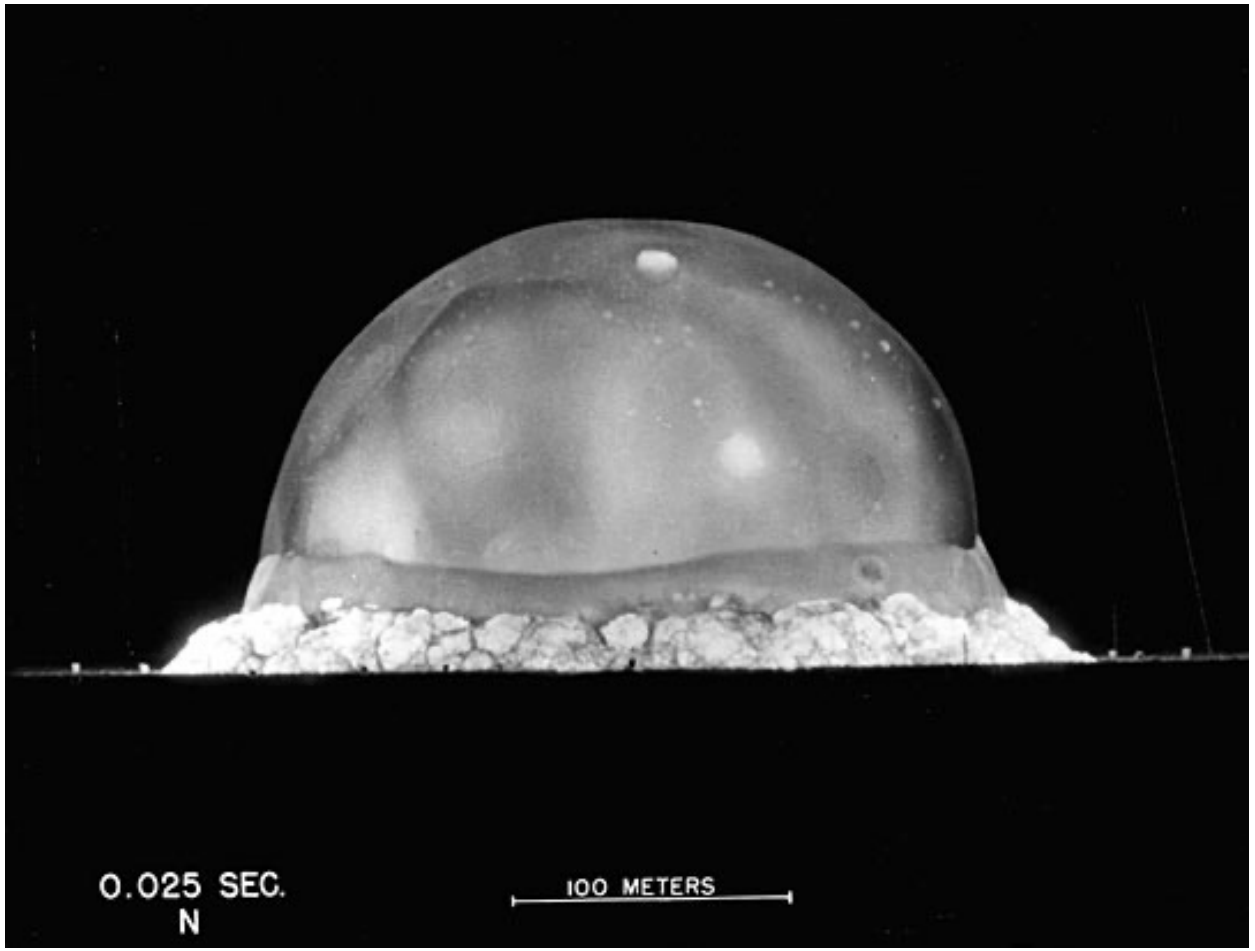
Prøv selv – demo på Multimedia Fluid Mechanics online

- En U-formet slange med konstant diameter inneholder vann
- Ved $t = 0$ opprettholdes en forskjell i vannstand i de to endene vha. en trykkforskjell
- Så slipper vi atmosfæretrykket til i begge ender og det oppstår svingninger uten demping (vi regner friksjonsfritt)
- Hvilke variabler er relevante for svingeperioden og hvordan varierer svingeperioden med disse variablene?



Energien frigjort i Trinity (1945) vha. dette bildet?

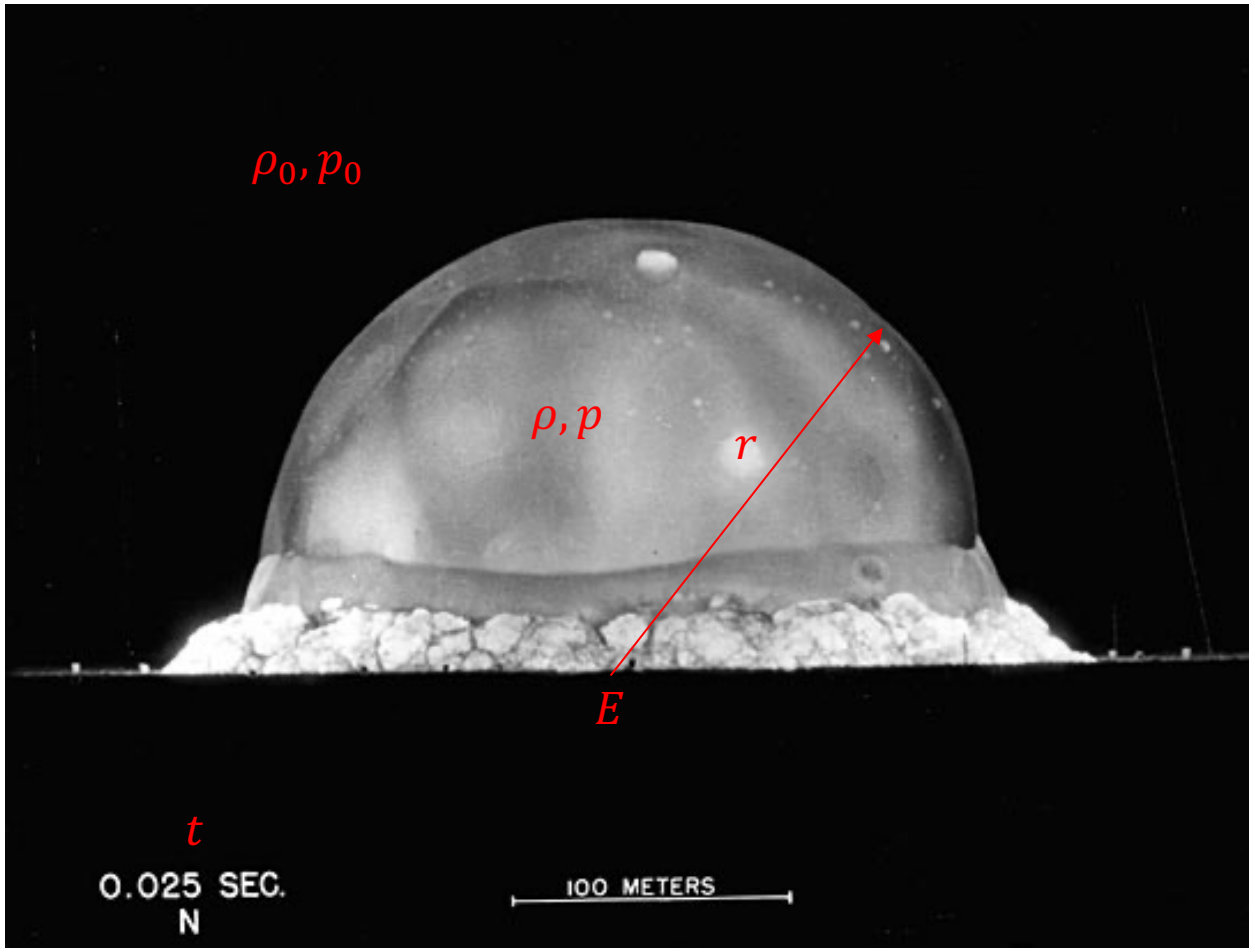
- Fysikeren G.I. Taylor ble engasjert av den britiske regjeringen i 1941 til å rapportere om den fluidmekaniske virkningen av en kjernefysisk eksplosjon
  - Leverte (hemmelig) rapport i 1941 (før Trinity)
  - Publiserte offentlig i 1950 der også bildene fra Trinity ble analysert
- Historien fremlegges ofte som om Taylor benyttet seg av ren dimensjonsanalyse, men i virkeligheten var det mer komplisert



Wikipedia

Energien frigjort i Trinity (1945) vha. dette bildet?

- Eksplosjonen skjer så å si ila. null tid
- De første millisekundene etter eksplosjonen: En sjokkbølge (dvs. hastighet > lydhastighet) brer seg utover i omtrent uforstyrret luft
- Det er lett å tenke seg at radien r ved tiden t avhenger av energien som ble frigjort, E, og tettheten til luften (som bølgefronten må dytte på), ρ_0
- Men hvorfor ikke trykket p_0 eller tettheten ρ? Eller viskositet?
  - Fysisk intuisjon!



Wikipedia

Energien frigjort i Trinity (1945) vha. dette bildet?

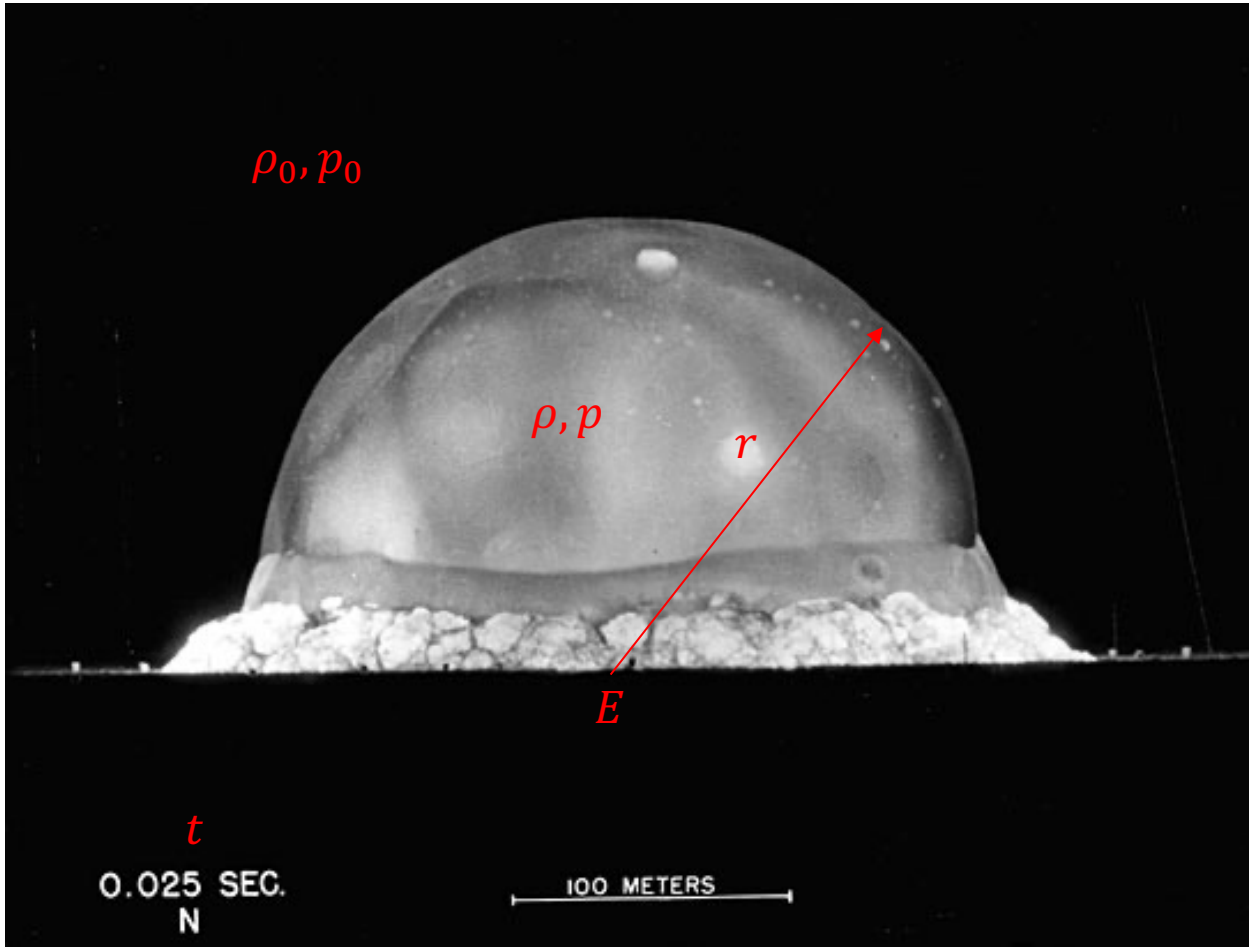
- Altså

$$E = g(r, t, \rho_0)$$

$$[E] = ML^2T^{-2}$$
$$[r] = L$$
$$[t] = T$$
$$[\rho_0] = ML^{-3}$$

- Eksponentmetoden

$$E = Cr^a t^b \rho_0^c$$
$$[E] = [r^a t^b \rho_0^c]$$
$$ML^2T^{-2} = L^a T^b M^c L^{-3c}$$
$$ML^2T^{-2} = M^c L^{a-3c} T^b$$
$$c = 1; a = 5; b = -2$$



Wikipedia

Energien frigjort i Trinity (1945) vha. dette bildet?

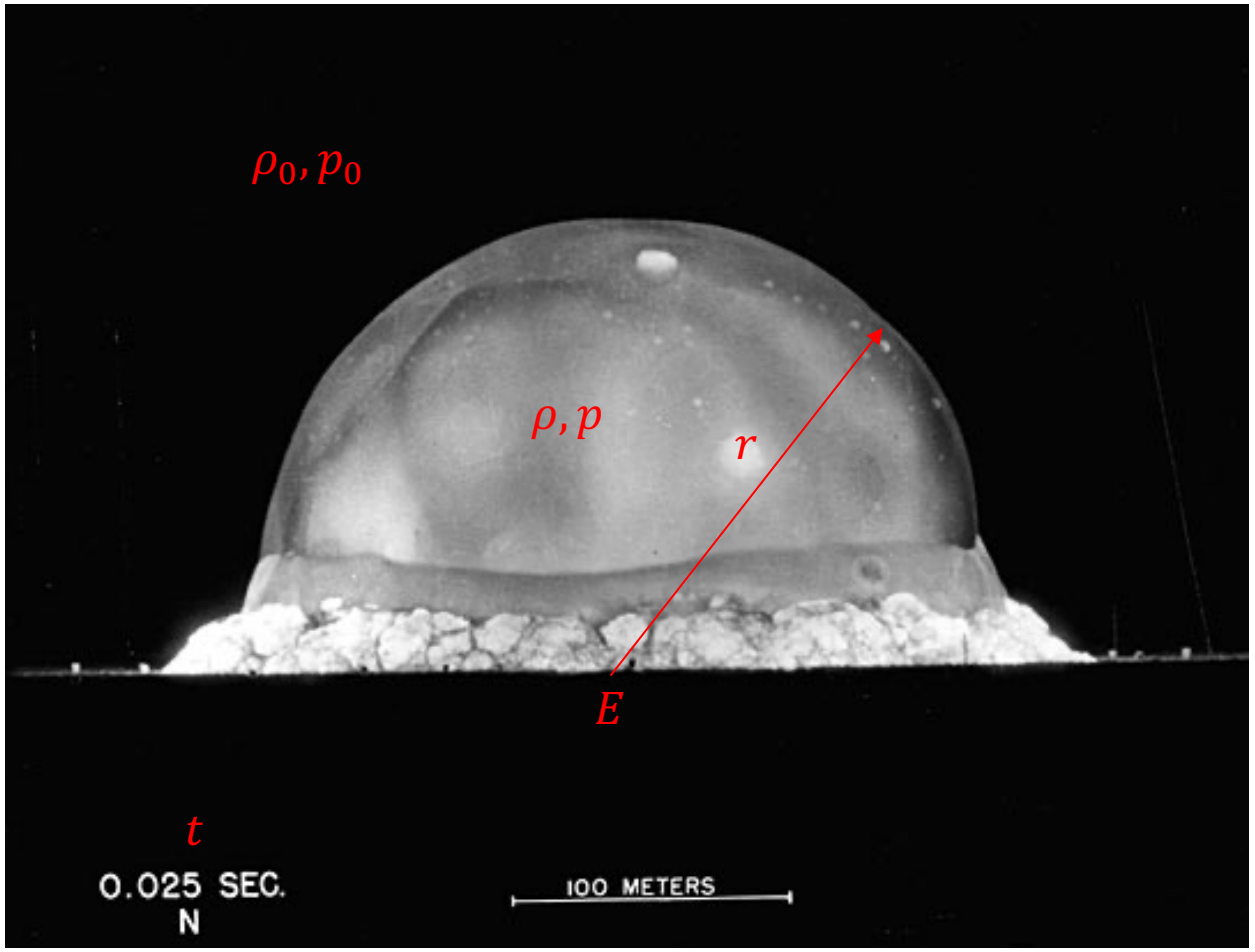
- Eksponentmetoden

$$E = Cr^a t^b \rho_0^c$$
$$c = 1; a = 5; b = -2$$
$$E = Cr^5 t^{-2} \rho_0$$

- Vi kjenner ikke konstanten C, men får betydelig innsikt i hvordan E varierer med r, t og ρ_0
- Taylor m.fl.: C ligger rundt 0.85 og hvis vi tar $\rho_0 = 1.25\ \mathrm{kg/m^3}$ og $r = 140\ \mathrm{m}$ får vi

$$E = 0.85 \cdot 140^5 \cdot 0.025^{-2} \cdot\ 1.25\ \mathrm{J}$$
$$= 9 \cdot 10^{13}\ \mathrm{J}$$

- Ikke langt unna offisielle tall



Wikipedia

