Thermodynamic_2026_1

Basic Concepts _ State Property : Pressure

03/2026

UTEC
UNIVERSIDAD DE INGENIERÍA Y TECNOLOGÍA

Recomendaciones generales:

- Leer antes de clase y entender los conceptos o preguntar si es necesario.
- Practicar bastante:
  - *Ejercicios de clase
  - *Asesorías
  - *Ejercicios del libro resueltos y los de final de capitulo
- Los quizzes virtuales y gradescope úsenlos para aprender de forma honesta (se puede inferir)
- Tengan grupos de estudio y apóyense mutuamente.
- Crear sus propias notas estudio y formulario.
- Son 4 horas de clase en la semana (asistir y ser puntuales, perder alguna es atrasarse mucho)
- Cada hora de clase son 3 horas de estudio por fuera mínimo.
- En la ppt de la semana 1 están todos los links claves para el curso.

Instructores del curso y coordinador

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squispe@utec.edu.pe

Guidelines for virtual sessions:

Tiempo aproximado de la sesión 100 minutos

Silenciar su micrófono.

Realizar preguntas a través del chat, habrá un profesor y/o un asistente atento a las dudas planteadas

Levantar la mano si desea hacer uso del micrófono y exponer alguna duda

La grabación de la sesión se cargará a Canvas.

2026

MARZO

	Lu.	Ma.	Mi.	Ju.	Vi.	Sá.	Do.
							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
1	23	24	25	26	27	28	29
2	30	31					

ABRIL

	Lu.	Ma.	Mi.	Ju.	Vi.	Sá.	Do.
2			1	2	3	4	5
3	6	7	8	9	10	11	12
4	13	14	15	16	17	18	19
5	20	21	22	23	24	25	26
6	27	28	29	30			

MAYO

	Lu.	Ma.	Mi.	Ju.	Vi.	Sá.	Do.
6					1	2	3
7	4	5	6	7	8	9	10
8	11	12	13	14	15	16	17
9	18	19	20	21	22	23	24
10	25	26	27	28	29	30	31

JUNIO

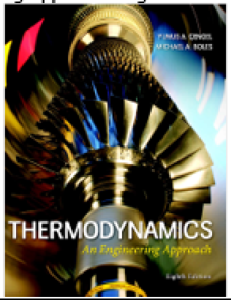
	Lu.	Ma.	Mi.	Ju.	Vi.	Sá.	Do.
11	1	2	3	4	5	6	7
12	8	9	10	11	12	13	14
13	15	16	17	18	19	20	21
14	22	23	24	25	26	27	28
15	29	30					

JULIO

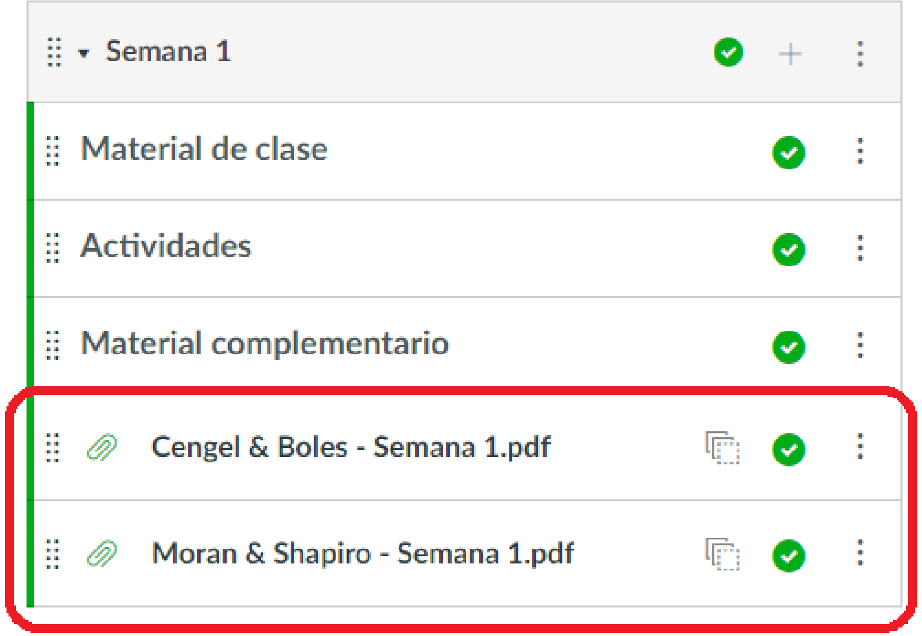
	Lu.	Ma.	Mi.	Ju.	Vi.	Sá.	Do.
15			1	2	3	4	5
16	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31		

Actividades	Inicio		Fin	
	Día	Fecha	Día	Fecha
Inicio de clases UTEC	Lunes 23 de marzo 2026			
Exámenes parciales	Lunes 11 de mayo 2026		Sábado 16 de mayo 2026	
Último día de clases	Sábado 4 de julio 2026			
Exámenes finales	Lunes 6 de julio 2026		Sábado 11 de julio 2026	
Exámenes de rezagados	Jueves 16 de julio 2026		Lunes 20 de julio 2026	

TEMAS SEMANA X SEMANA

Semana	Moran M.J. & Shapiro H.N. (2004). Fundamentos de la termodinámica Técnica. 2da edición (español). 	Cengel, Y.A. & Boles, M.A. (2015). Thermodynamics: An Engineering Approach. Eighth Edition (inglés). 
1	Capítulo 1: secciones 1.1 – 1.6 Ejercicios: 1.1 – 1.28	Capítulo 1: 1.3 – 1.9
2	Capítulo 3: secciones 3.1 – 3.2, 3.3.1 – 3.3.2, 3.3.6 Ejercicios: 3.1 – 3.26	Capítulo 3: 3.1 – 3.5 Capítulo 4: 4.1, 4.5
3	Capítulo 3: 3.3.5, 3.4 – 3.8 Ejercicios: 3.40 – 3.51	Capítulo 3: 3.6 – 3.7 Capítulo 4: 4.4
4	Capítulo 12: 12.1 – 12.4 Ejercicios: 12.1 – 12.6	Capítulo 13: 13.1 – 13.3
5	Capítulo 2: 2.1 – 2.6	Capítulo 2: 2.1 – 2.5
6	Capítulo 3: ejemplos 3.2 – 3.4, 3.8 – 3.11 Ejercicios: 2.1 – 2.10, 2.12 – 2.13, 2.21 – 2.40, 3.27 – 3.39, 3.52 – 3.58, 12.7 – 12.8, 12.10, 12.16 – 12.19	Capítulo 2: 2.6 Capítulo 4: 4.1 – 4.2
7 8	Capítulo 4: 4.1 – 4.4 Ejercicios: 4.1 – 4.33	Capítulo 5: 5.1 – 5.5
9	Capítulo 5: 5.1 – 5.4 Ejercicios: 5.1 – 5.11, 5.14 – 5.33	Capítulo 6: 6.1 – 6.4, 6.6
10	Capítulo 5: 5.2, 5.6 – 5.7 Ejercicios: 5.14 – 5.33	Capítulo 6: 6.7 – 6.8, 6.10 – 6.11
11	Capítulo 6: 6.1 – 6.5 Ejercicios: 6.1 – 6.31	Capítulo 7: 7.1 – 7.10
12	Capítulo 6: 6.6 Ejercicios: 6.32 – 6.43	Capítulo 7: 7.13
13 14	Capítulo 6: 6.7 – 6.8 Ejercicios: 6.44 – 6.56	Capítulo 7: 7.12

Importante: Las lecturas señaladas en este documento deben ser leídas antes de la semana indicada, en preparación para la tarea semanal de dicha semana. Ambos libros cubren aproximadamente el mismo contenido, pero con enfoques y niveles de profundidad distintos. Los estudiantes podrán alcanzar la comprensión del curso empleando solo una de las referencias. Sin embargo, se invita a contrastar semanalmente los temas en ambos textos, como método para alcanzar la compresión máxima del contenido. Tener en cuenta que los subcapítulos indicados en esta guía corresponden a las ediciones de los libros especificadas.



Horas de atención - Jhordy Manrique
(Dudas del curso-Tareas - notas)
LUNES 11-1 PM - Oficina P311

Horas de atención - Prof. Naudy Lopez
nlopez@utec.edu.pe
Previa coordinación con el profesor

Horas de atención - Jhordy Manrique
(Dudas del curso-Tareas - notas)
JUEVES 10-12 AM - Oficina P311

Horas de atención - Prof. Nedher Sánchez Ramírez

JUEVES: 9-12 pm....1-2pm - Oficina P311

Horas de asesoría 2026-1

Hora	Lunes	Martes	Miércoles	Jueves	Viernes	Sábado	Hora
7AM - 8AM		Clases		Clases			7AM-8AM
8AM - 9AM		Clases		Clases			8AM - 9AM
9AM - 10AM		Clases	Clases				9AM - 10AM
10AM - 11AM		Clases	Clases				10AM - 11AM
11AM - 12PM			Clases				11AM-12PM
12PM - 1PM			Clases				12PM-1PM
1PM - 2PM			Clases				1PM - 2PM
2PM - 3PM			Clases	CT: https://utec.zoom.us/j/97371427800			2PM - 3PM
3PM - 4PM	Clases					FR: https://utec.zoom.us/j/95953412067	3PM - 4PM
4PM - 5PM	Clases						4PM - 5PM
5PM - 6PM	Clases	Clases	Clases				5PM - 6PM
6PM - 7PM	Clases	Clases	Clases				6PM - 7PM
7PM - 8PM							7PM - 8PM
8PM - 9PM	ASESORÍA DE DUDAS: https://utec.zoom.us/j/97136492520	JG: https://utec.zoom.us/j/92301579107		RV: https://utec.zoom.us/j/92982722393			8PM - 9PM
9PM - 10PM							9PM - 10PM

RV: Rosario Vidal	Todas las sesiones serán grabadas.
CT: Cristian Tobias	*Varia según disponibilidad
FR: Franklin Rosas	
JG: Jose Gamero	

Link de WhatsApp de Termodinámica:

https://chat.whatsapp.com/Iu3b3wnWFuY2Zvamn89NNa

Thermodynamics _ Evaluation

S8

S16

COMPONENTE	%
EXAMEN PARCIAL	20
EXAMEN FINAL	30
C	50
APROBACIÓN: 11/20	

EXÁMENES	FECHAS
EXAMEN PARCIAL	(MAYO 8)
EXAMEN FINAL	(JULIO 6)

EXAMEN 1: Todos los temas vistos hasta la semana 6.

EXAMEN 2: Todos los temas vistos hasta la semana 15

Thermodynamics _ Evaluation

COMPONENTE	%
EXAMEN PARCIAL	20
EXAMEN FINAL	30
C	50
APROBACIÓN: 11/20	

EVALUACIÓN CONTINUA (C) :

La evaluación continua vale un 50% de la nota final

-5 % corresponde a **tareas virtuales ..**Son de corrección automática

-10 % corresponde a **tareas individulales** (ejercicios que los alumnos hacen y suben a la plataforma gradescope) …. ..Ver rúbrica

-17 % corresponde a una **tarea grupal** (proyecto)…..Ver rúbrica

-18% restante corresponde **actividades en aula** (quizes de 20 min aprox)..Ver rúbrica

Thermodynamics _ Evaluation

COMPONENTE	%
PARCIAL	20
FINAL	30
C	50
APROBACIÓN: 11/20	

SEMANA 1	TAREA VIRTUAL	SE CALIFICA AUTOMATICO NO NECESITA PROCEDIMIENTO
SEMANA 2	TAREA VIRTUAL	
SEMANA 3	TAREA VIRTUAL	.
SEMANA 4	**TAREA INDIVIDUAL 1** + EVALUACION_ AULA1	TAREA INDIVIDUAL: Esta parte incluye subir un archivo con la solución EVALUACION_ AULA: SEMANAS 1-2
SEMANA 5	TAREA VIRTUAL+ EVALUACION_ AULA2	EVALUACION_ AULA: SEMANAS 1-3
SEMANA 6	TAREA VIRTUAL+**TAREA INDIVIDUAL 2**	
SEMANA 7	TAREA VIRTUAL+ EVALUACION_ AULA3	EVALUACION_ AULA: SEMANAS 1-6
SEMANA 8	**PARCIAL**	
SEMANA 9	EVALUACION_ AULA4+**TAREA INDIVIDUAL 3** **+Tarea grupal 1**	EVALUACION_ AULA: SEMANAS 1-8
SEMANA 10	TAREA VIRTUAL	
SEMANA 11	TAREA VIRTUAL	
SEMANA 12	TAREA VIRTUAL+ EVALUACION_ AULA5	EVALUACION_ AULA: SEMANAS 1-11
SEMANA 13	TAREA VIRTUAL+**TAREA INDIVIDUAL 4** **+ Tarea grupal 2**	
SEMANA 14	TAREA VIRTUAL+EVALUACION_ AULA6	EVALUACION_ AULA : SEMANAS 1-13
SEMANA 15		
SEMANA 16	**FINAL**	

***LAS TAREAS VIRTUALES O LOS GRADESCOPE (TAREA INDIVIDAL) se abren lunes 2pm y se cierran sábado media noche. La tarea virtual se presenta hasta un máximo de 3 veces.**

EVALUACION_ AULA: es un quiz de 20 min aprox. en aula.

Thermodynamics _ Evaluation

EVALUACIÓN CONTINUA (C) :

COMPONENTE	%
C	50

25 %
- 3 actividades en aula→ 9 %
- 2 tareas individuales→ 5 %
- ½ tareas virtuales → 2.5 %
- 1ra entrega tarea grupal → 8.5 %

25 %
- 3 actividades en aula→ 9 %
- 2 tareas individuales→ 5 %
- ½ tareas virtuales → 2.5 %
- 2da entrega tarea grupal → 8.5 %

Se subirá al EDU En dos bloques de 25% c/v

Thermodynamics _ Evaluation

Tarea grupal (proyecto)…..

La actividad consta del análisis de una sistema, dicho análisis puede requerir elementos de programación.

Fechas de entrega del laboratorio:
1ra entrega - 18/05/2026 a las 9 am (jueves de la semana 9)
2da entrega - 15/06/2026 a las 9am (lunes de la semana 13)
coevaluación - 16/06/2026 a las 11:59pm (martes de la semana 13)

Link con toda la información de la tarea grupal :

https://docs.google.com/spreadsheets/d/1DMrZjoEaRlHfZPbrFa5q84ha0ElWJQS1zmyLanvjGcw/edit?gid=0#gid=0

Thermodynamics _ Evaluation

Link con las rubricas de actividad de aula y tarea individual:

https://docs.google.com/spreadsheets/d/1iLMFoTAZiUBYuD8fGZFW4d0pF0-UBt8f/edit?gid=85594443#gid=85594443

	CURSO	SESION_GRUPO	AULA	FECHA	HORA	PROFESOR
0	Termodinámica	Teo. V.1.00	Virtual 103	Lun	03:00 p.m.	Nedher
1	Termodinámica	Lab.13.00	A803	Mar	09:00 a.m.	Nedher
2	Termodinámica	Lab.11.00	A708	Mie	11:00 a.m.	Nedher
3	Termodinámica	Lab.22.00	A904	Mar	07:00 a.m.	Nedher
4	Termodinámica	Lab.23.00	A903	Mie	09:00 a.m.	Nedher
5	Termodinámica	Lab.24.00	A202	Jue	07:00 a.m.	Nedher
7	Termodinámica	Lab. 12.00	A901	Mar	05:00 p.m.	Naudy
8	Termodinámica	Lab. 14.00	A707	Mie	05:00 p.m.	Naudy
9	Termodinámica	Teo. V. 2.00	Virtual 101	Lun	05:00 p.m.	Naudy
10	Termodinámica	Lab. 21.00	A704	Mie	01:00 p.m.	Naudy

Session 2: Review, pressure, absolute pressure, gauge pressure (sometimes requires the concept of hydrostatic pressure).

How can a doctor save lives without sophisticated technology tools?

- **Temperatures (T)**

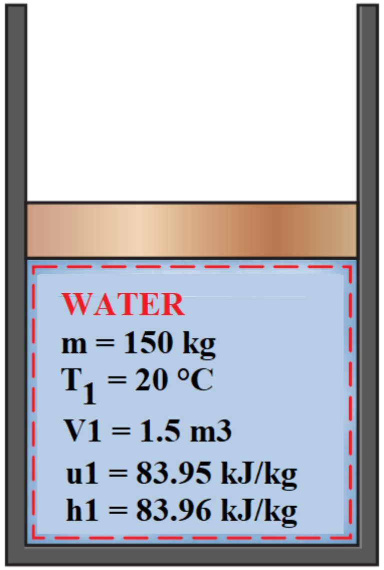
- **Pressure (P)**

Macroscopic view of a system:

- **Temperatures (T)**
- **Pressure (P)**
- v
- h
- u

The State Postulate

The state of a simple compressible system, **the state**, is completely specified by two independent, intensive properties.



$P_1 = 1$ bar

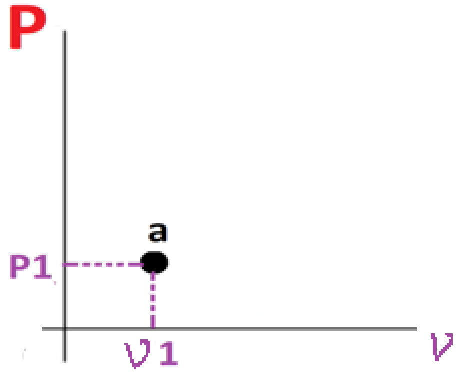
$v_1 = \frac{V_1}{m}$

IF I Know $P_1, v_1 \Rightarrow u_1 = F(P_1, v_1)$

$h_1 = F(P_1, v_1)$ or $h_1 = Fn(P_1, u_1)$

$\vdots$

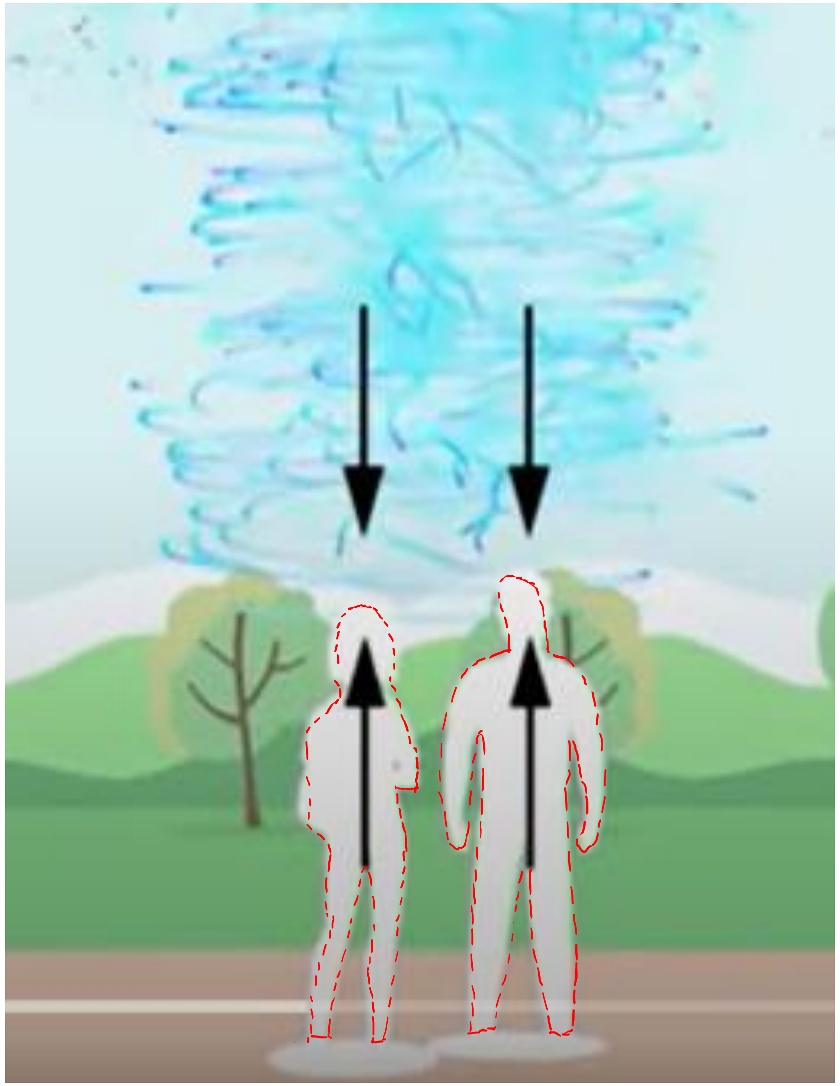
Alternative definition to the postulate: **It is a condition that can be represented on a plane**



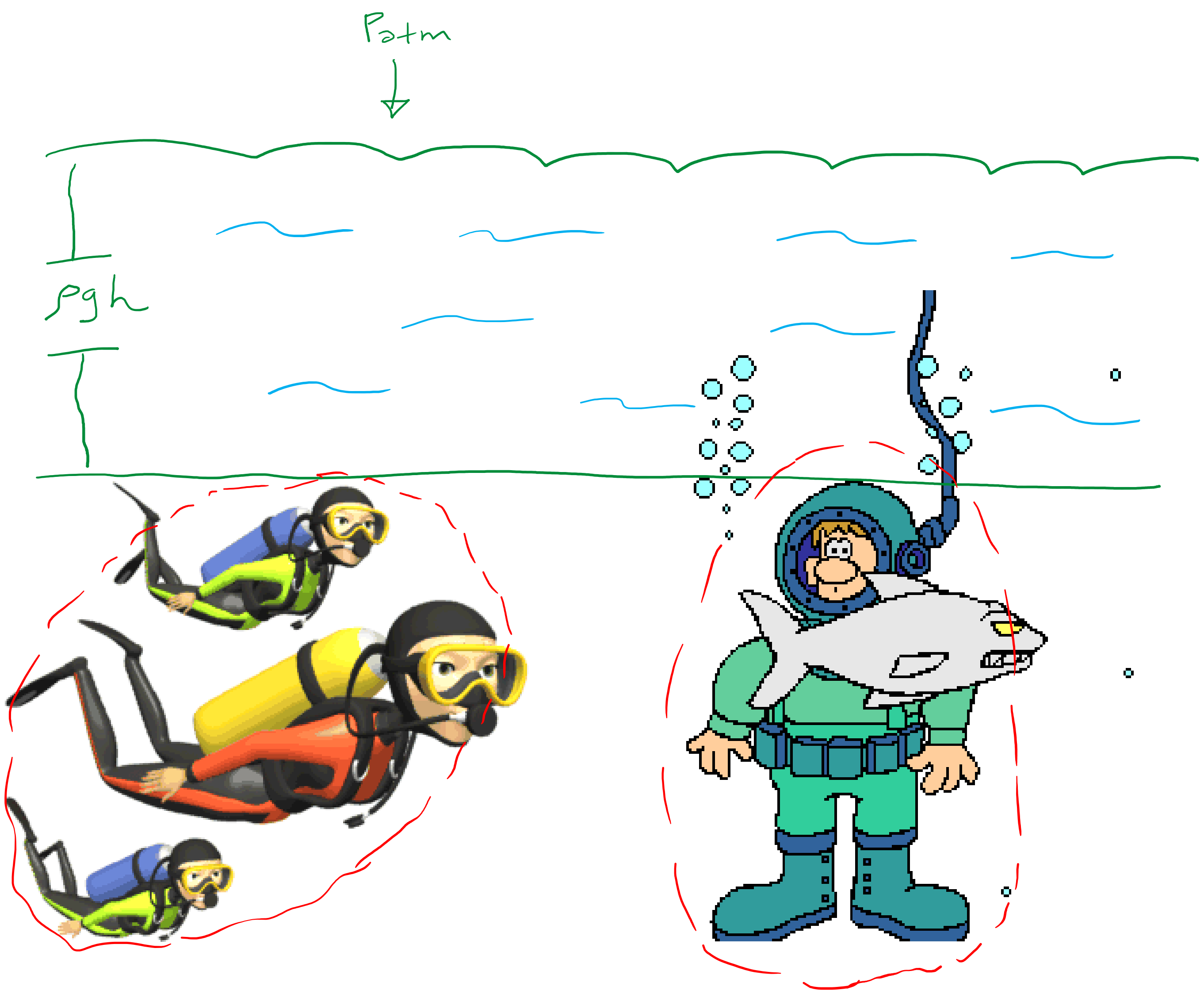
PRESSURE

Pressure is defined as *a* ***normal force*** *exerted* ***by a fluid per unit area***.

$$P = \frac{F_n}{A}$$



https://www.youtube.com/watch?v=3rNQXXuyhMw&ab_channel=La2



Patm
ρgh

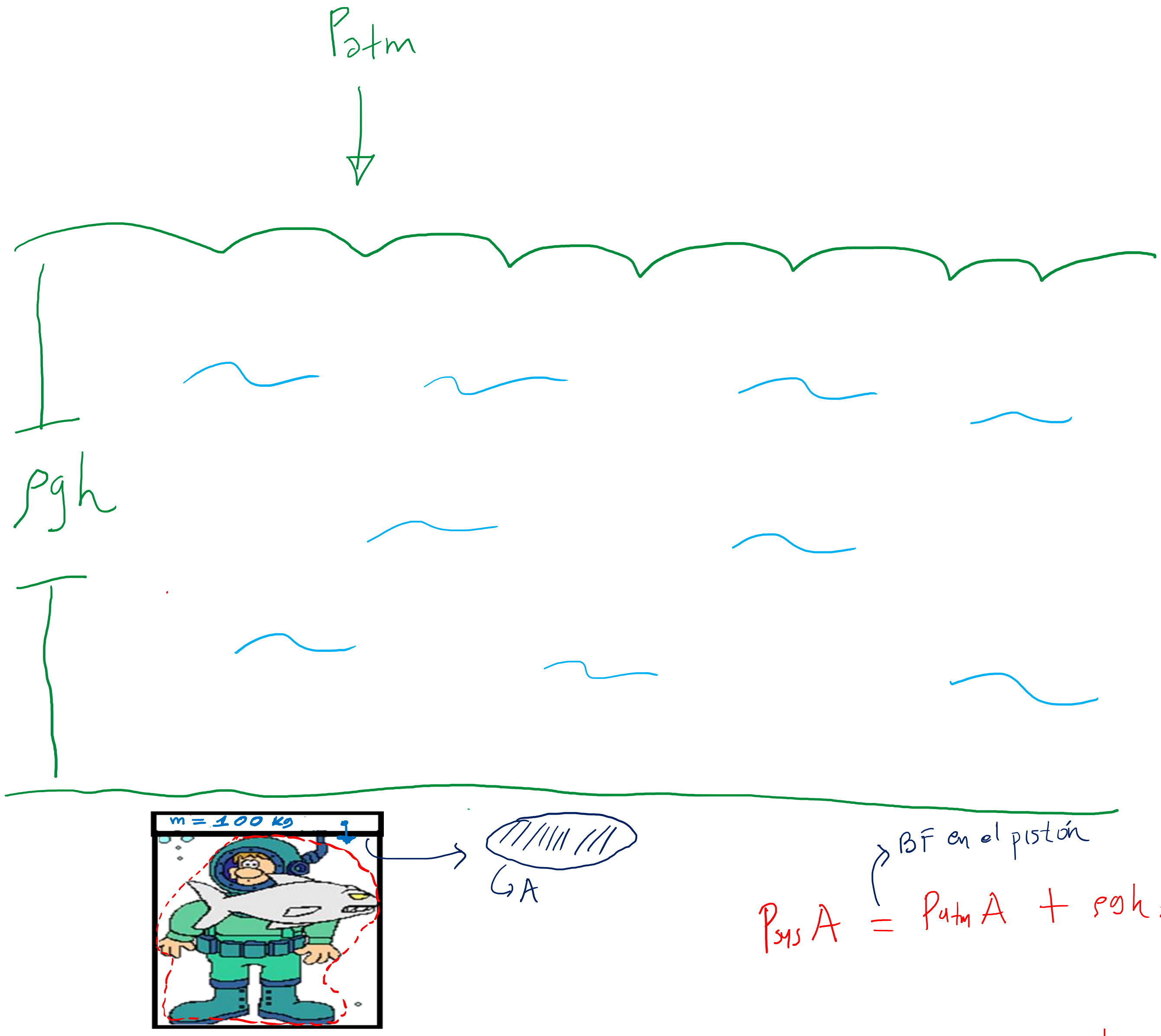
$$P = \frac{F}{A}$$

$$1\ \text{Pa} = 1\ \text{N/m}^2$$

$$1\ \text{N} = \frac{\text{kg}\cdot\text{m}}{\text{s}^2}$$

$$1\ \text{Pa} = \frac{\boxed{\text{kg}\cdot}\ \boxed{\text{m}}\cdot\text{m}}{\boxed{\text{m}^2\cdot\text{m}}\cdot\boxed{\text{s}^2}}$$

$$\boxed{\rho}\quad \boxed{g}\quad \boxed{h}$$



BF en el pistón

$$P_{sys} A = P_{atm} A + \rho g h A + mg$$

$$P_{sys} = P_{atm} + \rho h g + \frac{mg}{A}$$

"La presión manométrica (P_{gage}) es la diferencia entre la presión absoluta del sistema y la presión atmosférica."

$P_{absoluta}$

$$P_{sys} = P_{atm} + \rho h g + \frac{mg}{A}$$

$$P_{sys} - P_{atm} = \rho g h + \frac{mg}{A}$$

$$= P_{gage}$$

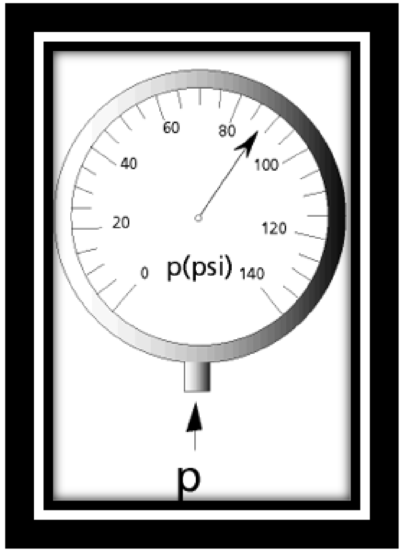
Esta P_{gage} Puede medirse con dispositivos.

$P_{gage} = P_{manométrica}$

$$P_{sys} = P_{atm} + \rho h g + \frac{mg}{A}$$

Este termino contribuye poco cuando

1. h es pequeño
2. ρ es pequeño (en gases)



$$P_{syst} = P_{atm} + P_{gage}$$

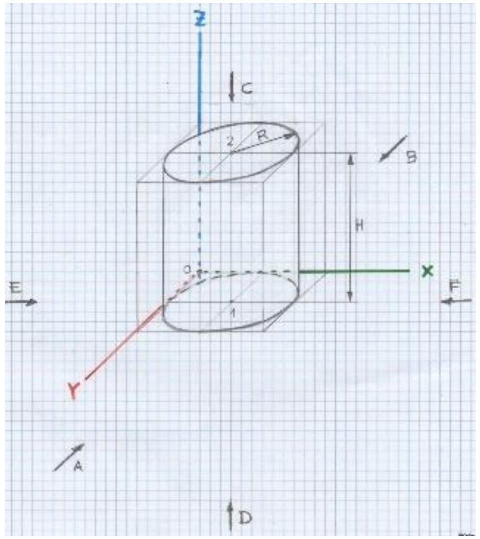
$$P_{syst} > P_{atm}$$

$$P_{syst} = P_{atm} + \overset{<0}{P_{gage}}$$

$$P_{syst} < P_{atm}$$

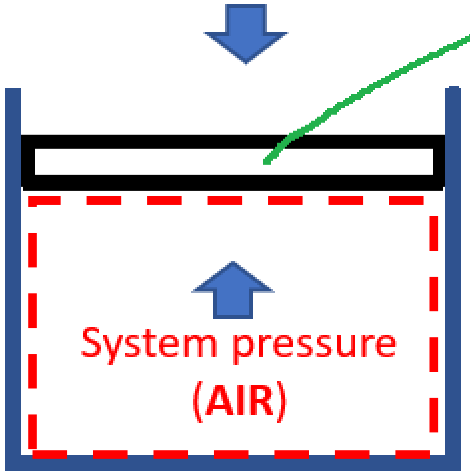
In thermodynamics we work with <u>absolute pressure</u>, which is a function of <u>atmospheric pressure</u> ...

P_{sys}



https://www.aulafacil.com/cursos/maquetas/diseno-y-realizacion-de-maquetas-de-papel-a-partir-de-recortables/perspectiva-y-vistas-de-un-cilindro-de-revolucion-l12090

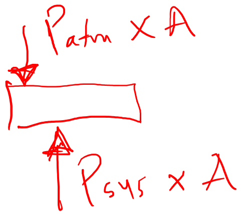
Atmospheric-pressure

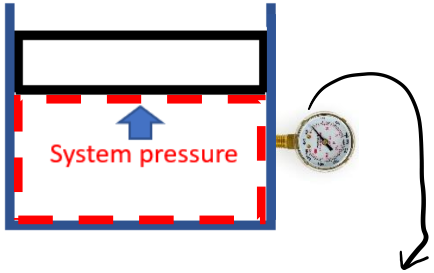


Negligible mass

$$P_{syst} * \cancel{A} = P_{atm} * \cancel{A}$$

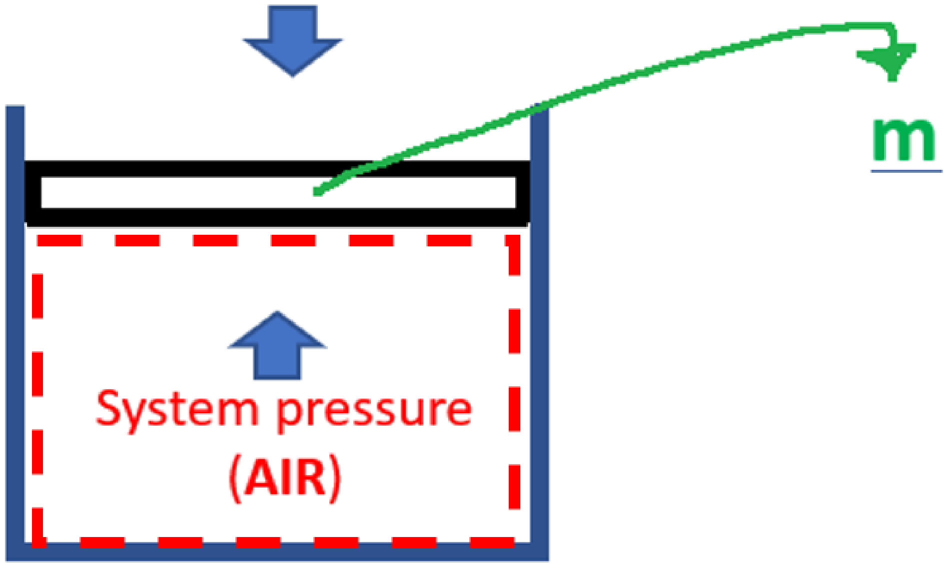
$$\mathbf{P_{syst} = P_{atm}}$$





En este caso $P_{gage} = P_{man} = 0$

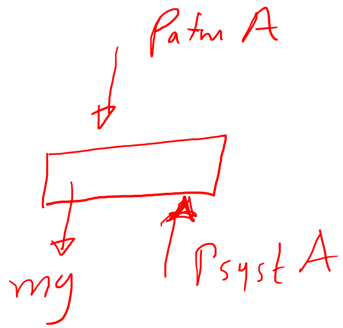
Atmospheric-pressure

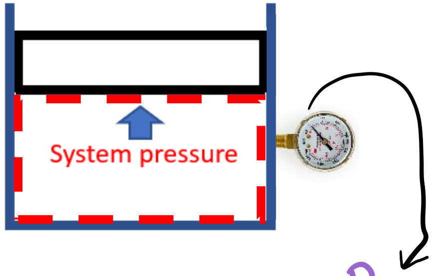


$$P_{syst} * A = P_{atm} * A + mg$$

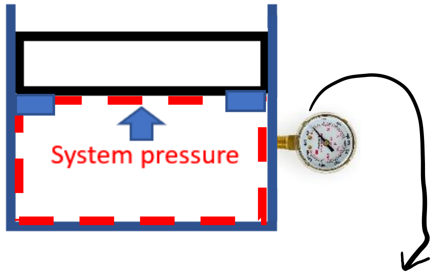
$$P_{syst} = P_{atm} + \underbrace{mg/A}_{P_{gage}}$$

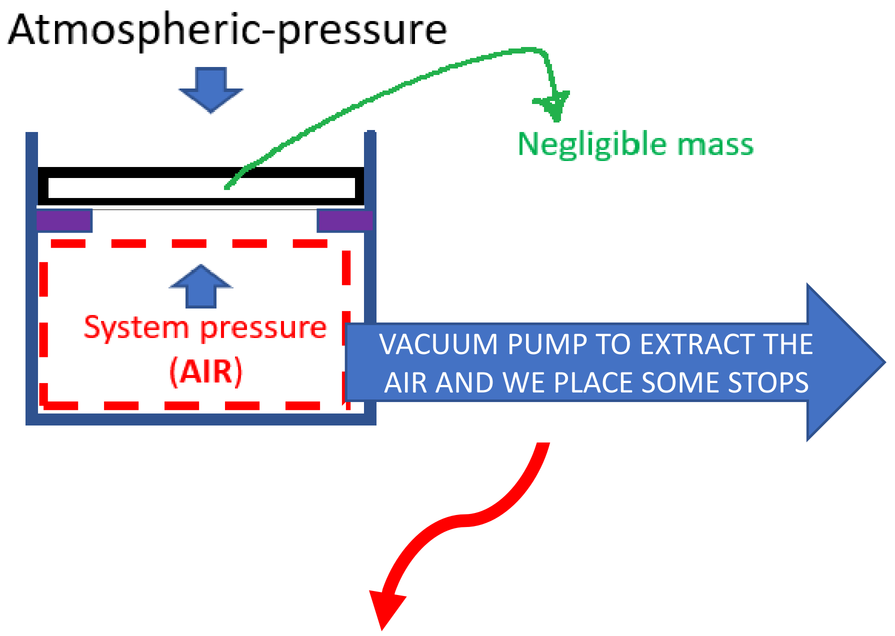
$$\mathbf{P_{syst} > P_{atm}}$$





$P_{gage} = \frac{mg}{A}$





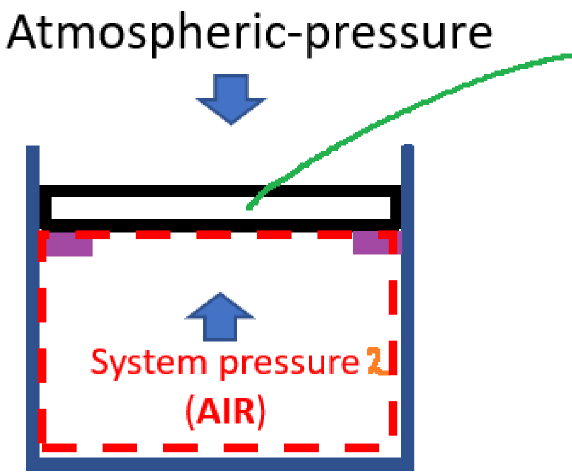
$P_{vacuum\ gage} < 0$

$P_{vacuum\ gage}$

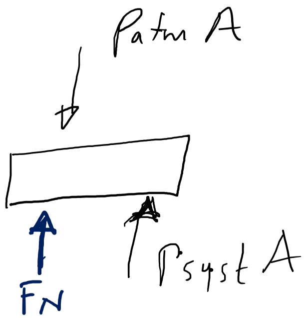
$P_{syst} = P_{atm} + P_{vacuum}$

< 0

$P_{syst} < P_{atm}$



$P_{syst} = P_{atm} - \frac{F_N}{A}$



$P_{vacuum\ gage}$

1:15 o 10 s

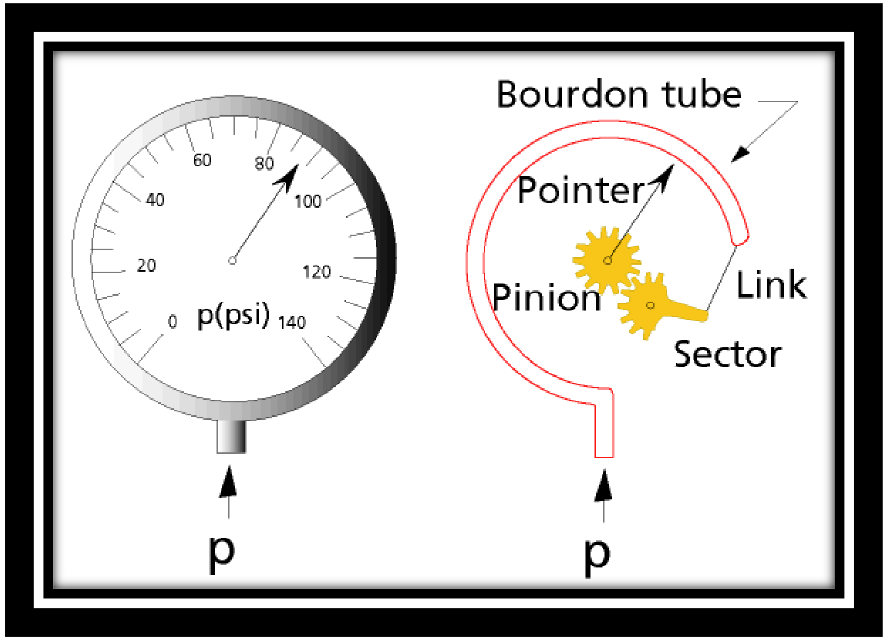
https://www.youtube.com/watch?v=MYAmPRQ4eWo

1.33

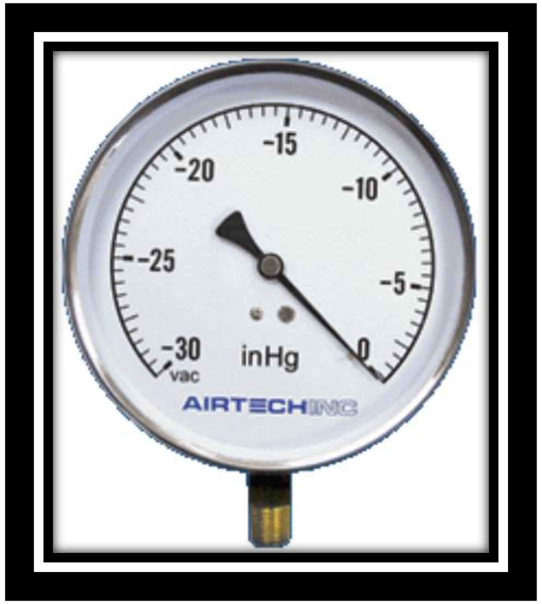
https://www.youtube.com/watch?v=ShSxUg4Yyws&t=537s

https://www.youtube.com/watch?v=iPSz5mia9J0

How we measure the gauge pressure?

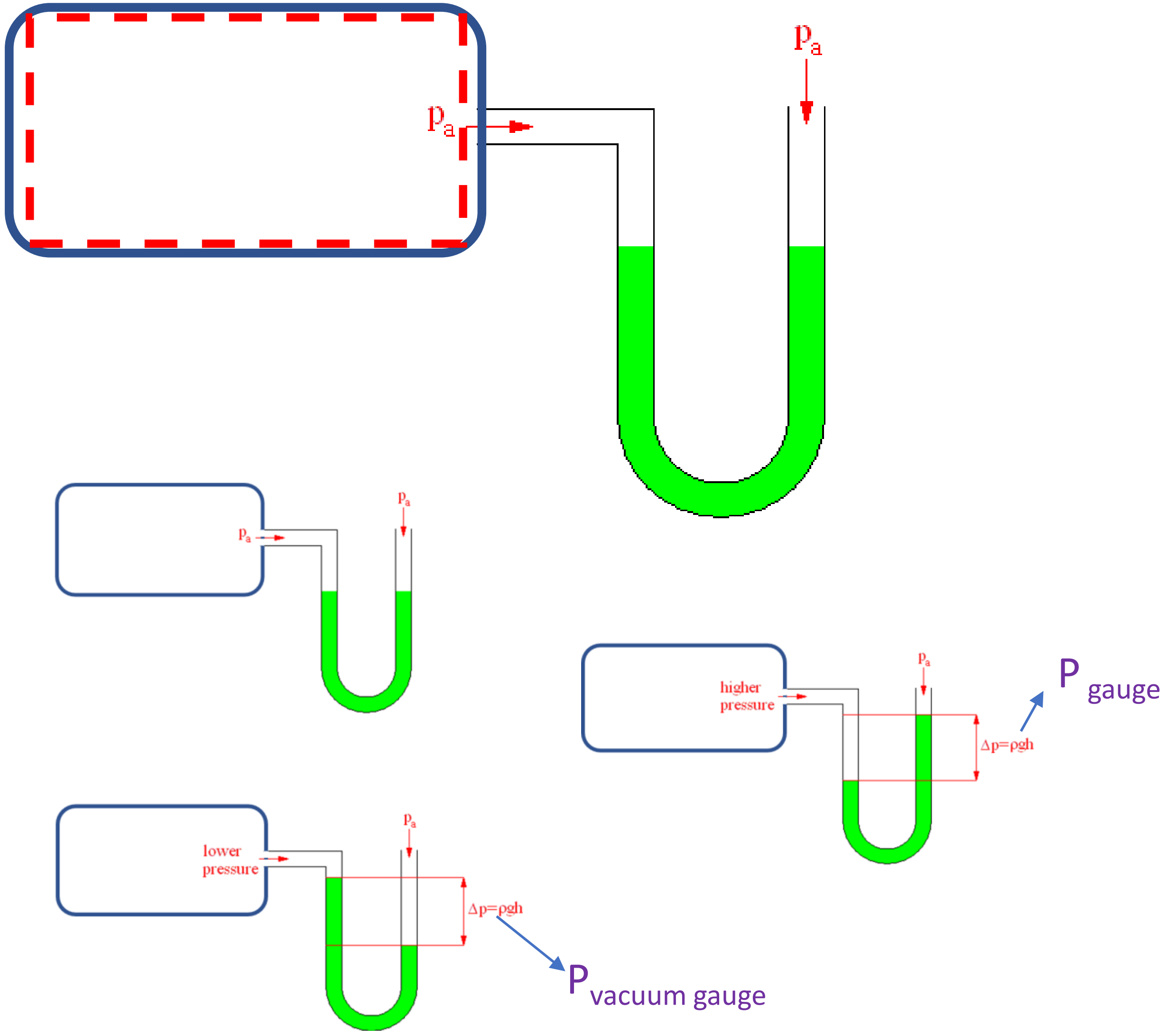


Difference?



In most thermodynamic investigations we are concerned with absolute pressure. Most pressure and vacuum gauges, however, read the difference between the absolute pressure and the atmospheric pressure existing at the gauge. This is referred to as gauge pressure.

How we measure the gauge pressure?



$$P = \frac{F}{A}$$

$$1\ \text{Pa} = 1\ \text{N/m}^2$$

$$1\ \text{N} = \frac{\text{kg} \cdot \text{m}}{\text{s}^2}$$

$$1\ \text{Pa} = \frac{\text{kg} \cdot \text{m} \cdot \text{m}}{\text{m}^2 \cdot \text{m} \cdot \text{s}^2}$$

$\{=\}$

$\frac{Kg}{m.s^2}$

$\boxed{\rho}$ $\boxed{g}$ $\boxed{h}$

Obtaining the pressure by a balance of forces is not always possible, or being possible sometimes it is impractical, that's why we use: pressure gauges!

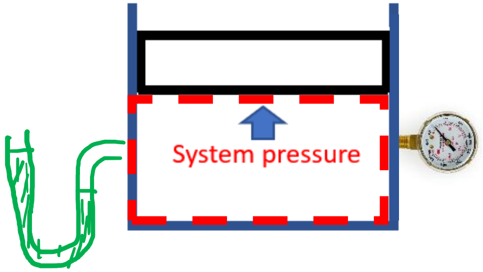
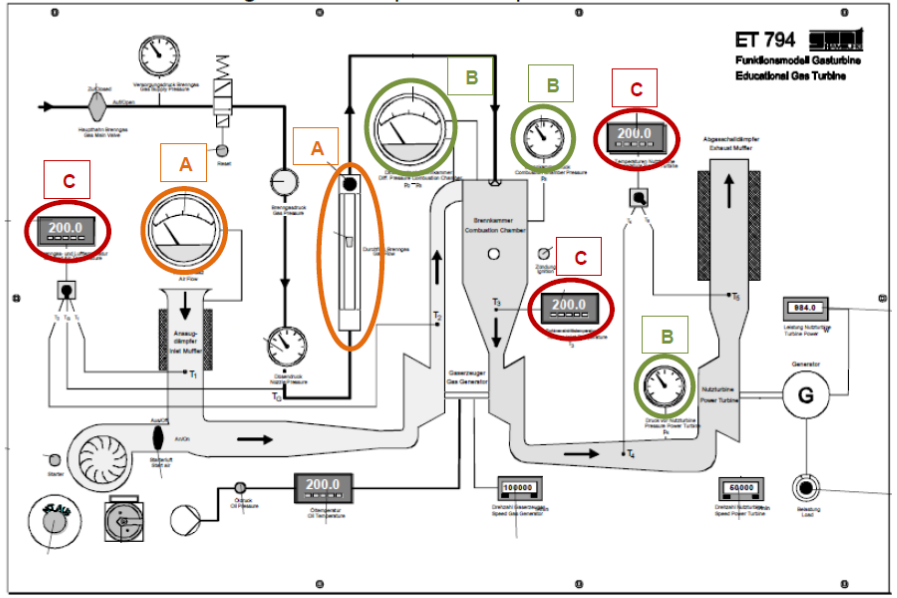
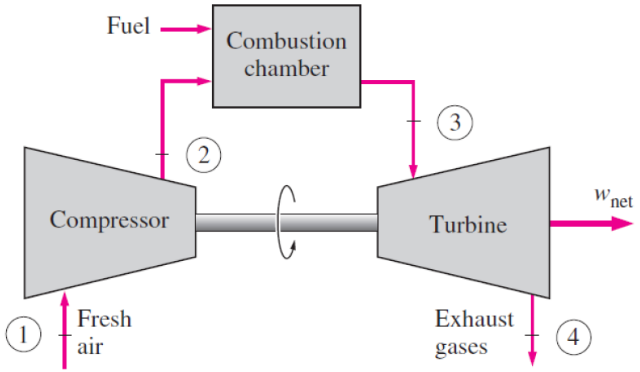


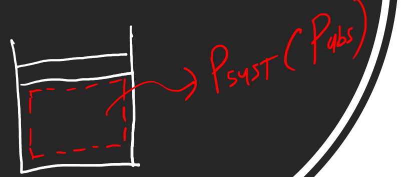
Figura 3. – Esquema del proceso

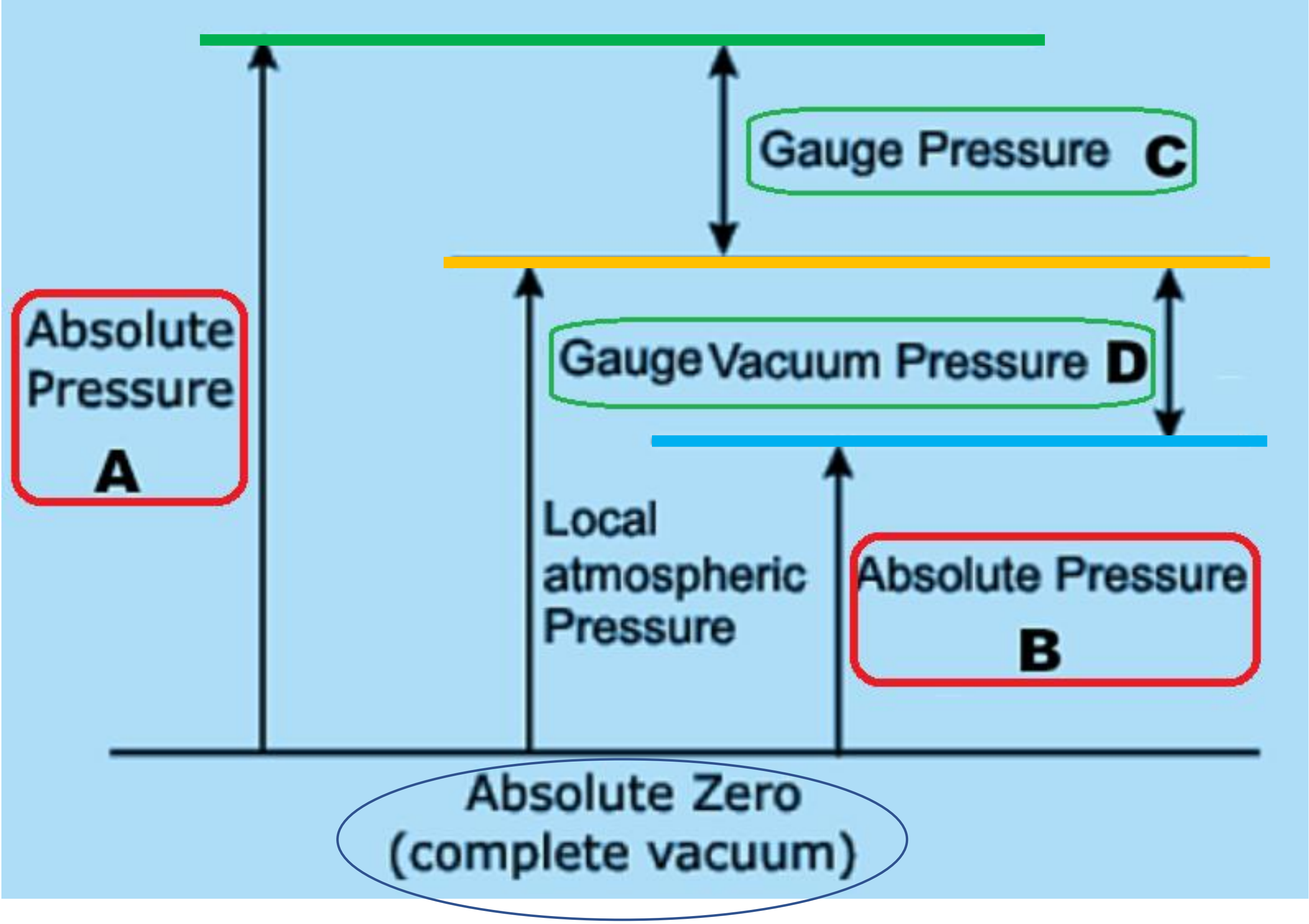


Power cycle_ Brayton cycle (ideal)



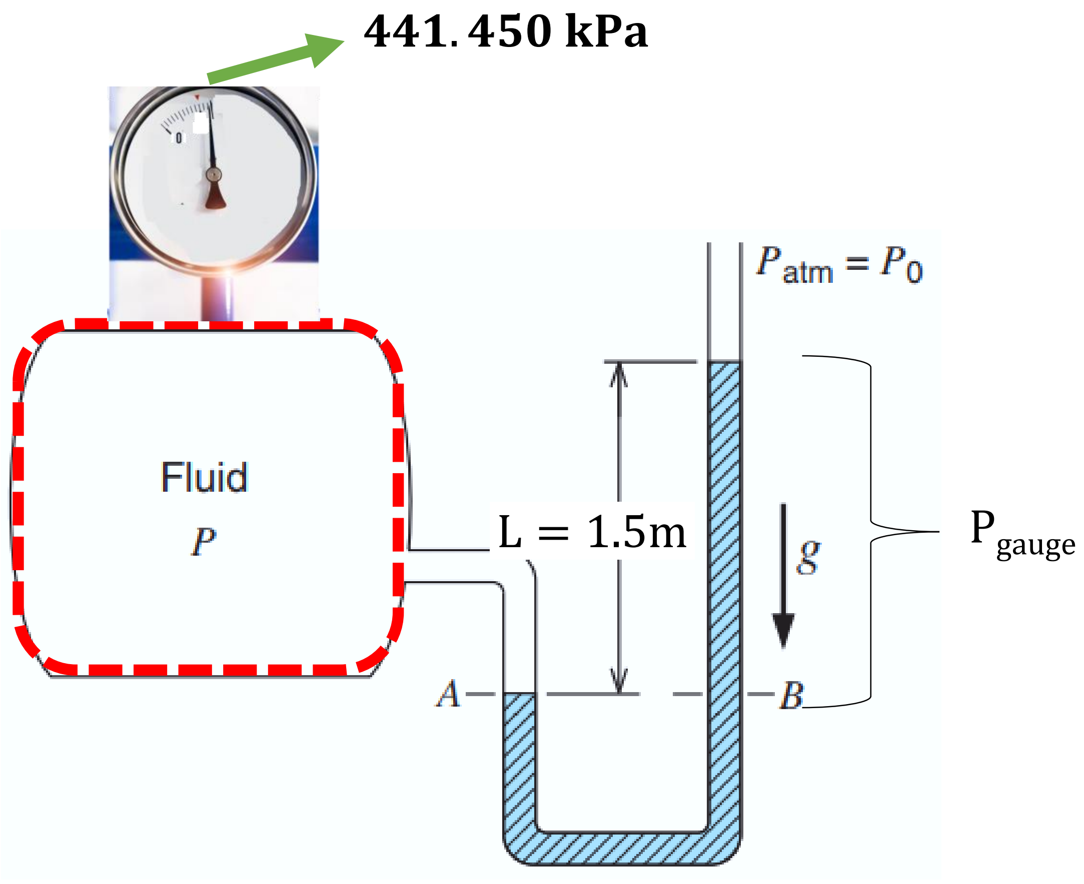
SUMMARY


P_{syst} (P_{abs})


Gauge Pressure C
Absolute Pressure A
Gauge Vacuum Pressure D
Local atmospheric Pressure
Absolute Pressure B
Absolute Zero (complete vacuum)

Example 1.3

A manometer shows a pressure difference of 1.50 m of a special polymer of density equal to 30000 kg/m^3. Find P_{gage} and the fluid pressure (P or P_{abs}) in kPa. $P_0 = 101.325\text{ kPa}$



The P_{gage} is:

$$P_{gage} = \rho g L$$

$$P_{gage} = 30000\,\frac{\text{kg}}{\text{m}^3} \times 9.81\,\frac{\text{m}}{\text{s}^2} \times 1.5\text{m}$$

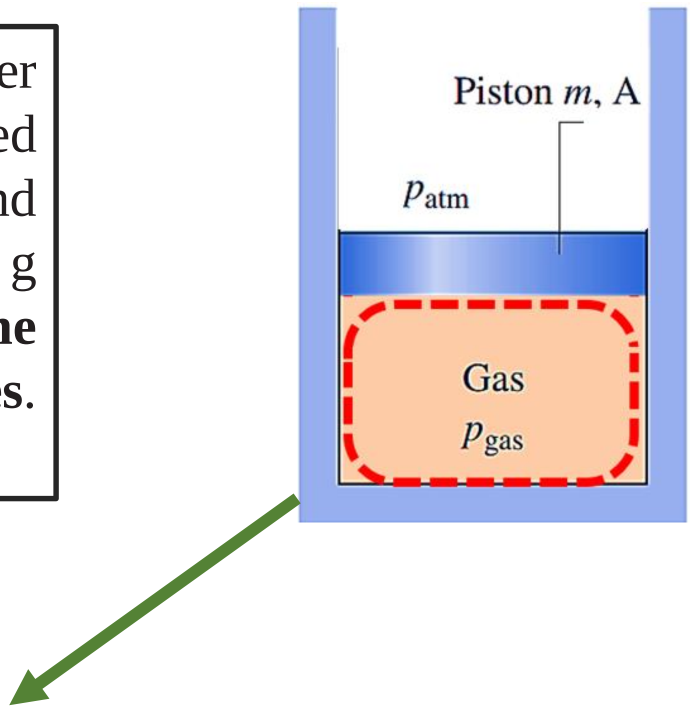
$$P_{gage} = \mathbf{441450\ Pa = 441.450\ kPa}$$

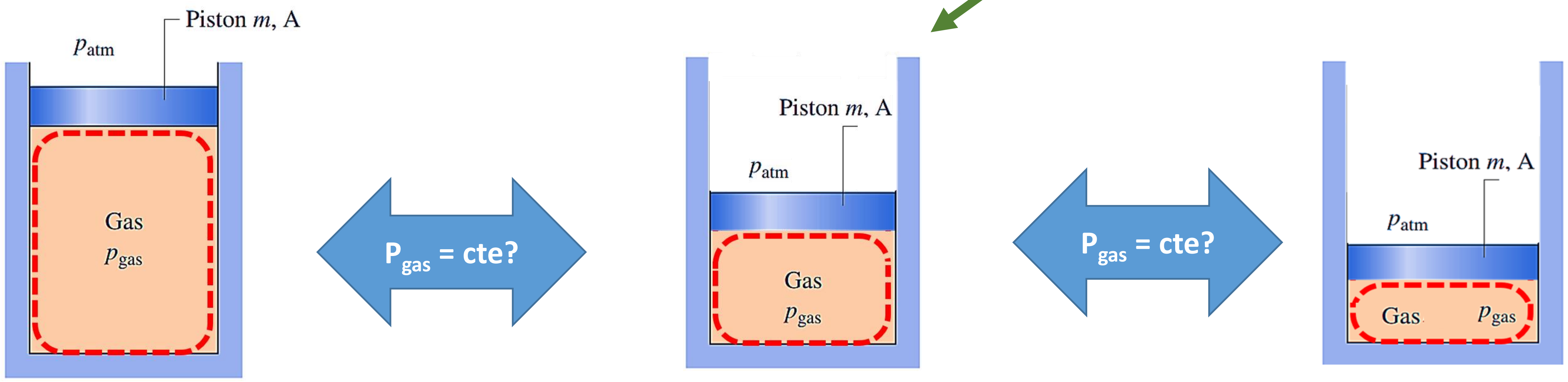
$$P_{abs} = \mathbf{441.450 + 101.325 = 542.775\ kPa}$$

P_{sys}

Example 4.1

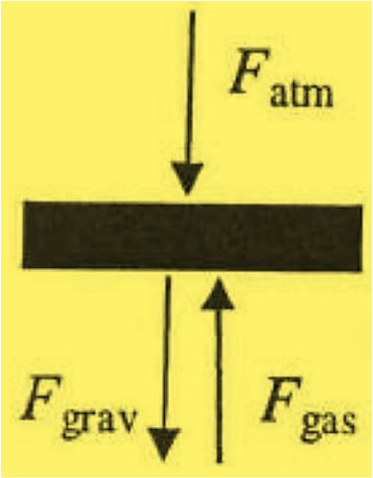
As shown in Figure, a gas is contained in a piston–cylinder assembly. The piston mass and cross-sectional area are denoted m and A, respectively. Assuming the piston moves smoothly and quasistatic in the cylinder and the local acceleration of gravity g is constant, **show that the pressure of the gas acting on the bottom of the piston remains constant as gas volume varies**. What would cause the gas volume to vary?





Example 4.1

The body free diagram for the piston is:



Since the piston should move in equilibrium, all forces going upwards should cancel with those going downwards, in other words:

$$F_{atm} + F_{grav} = F_{gas}$$

Atmospheric and gas pressures can be expressed in terms of pressure and cross-sectional area and gravity force depends on piston mass, therefore:

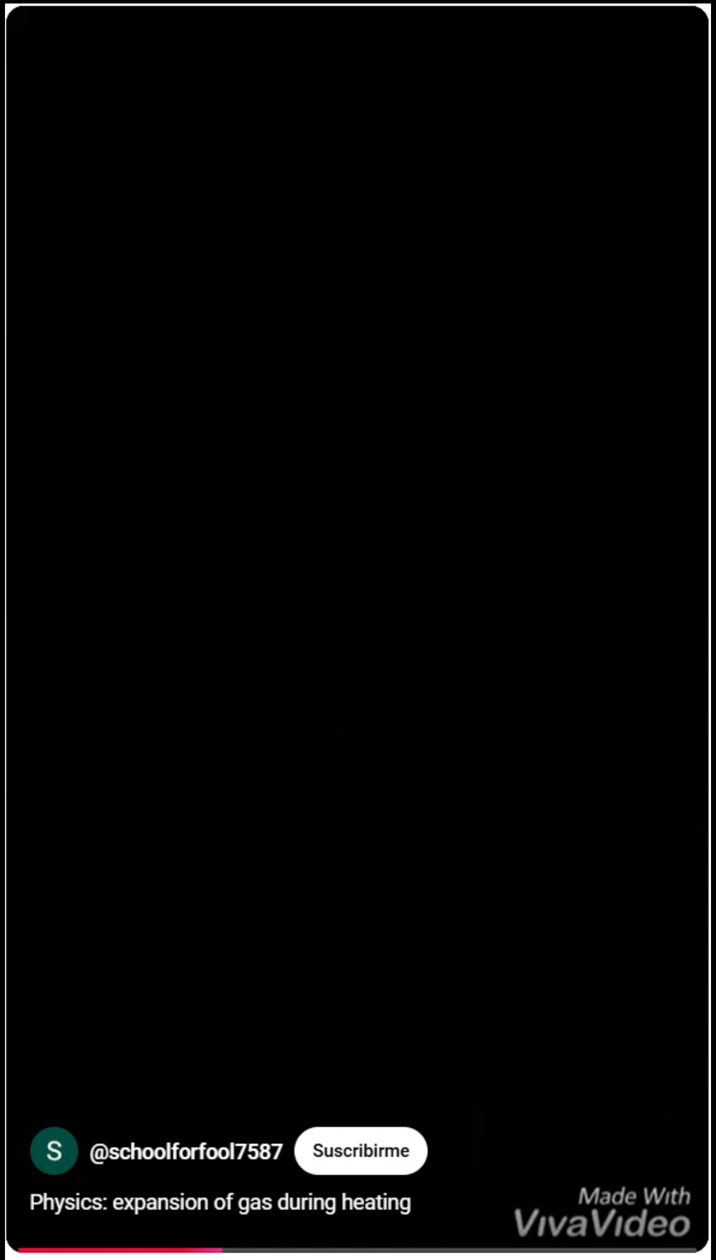
$$P_{atm}A + m_{piston}g = P_{gas}A$$

$$P_{gas} = P_{atm} + \frac{m_{piston}g}{A}$$

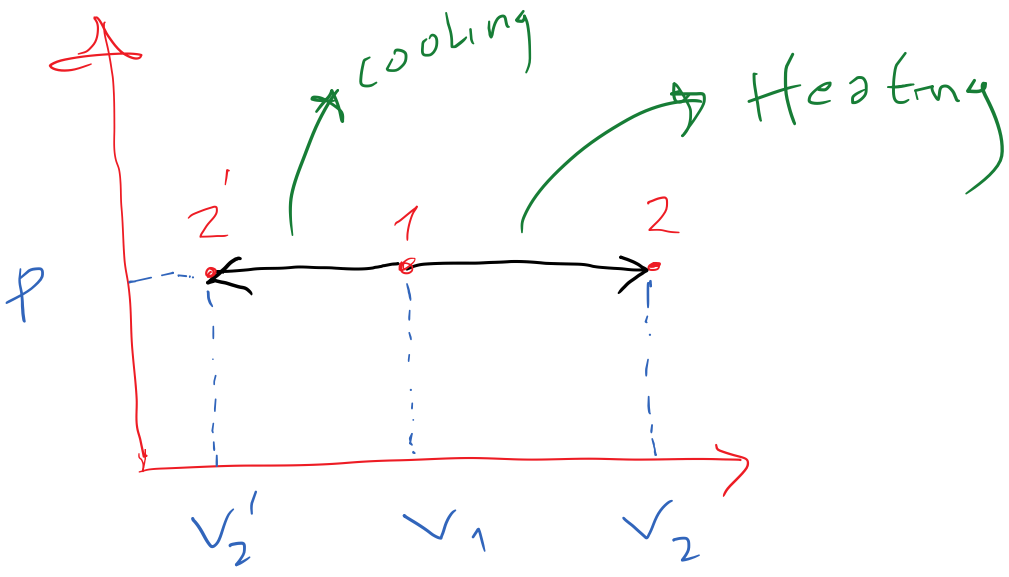
Gas pressure depends on atmospheric pressure, the piston mass, gravity acceleration and cross-sectional area which remain constant during the piston movement. Therefore, the gas pressure remains constant.

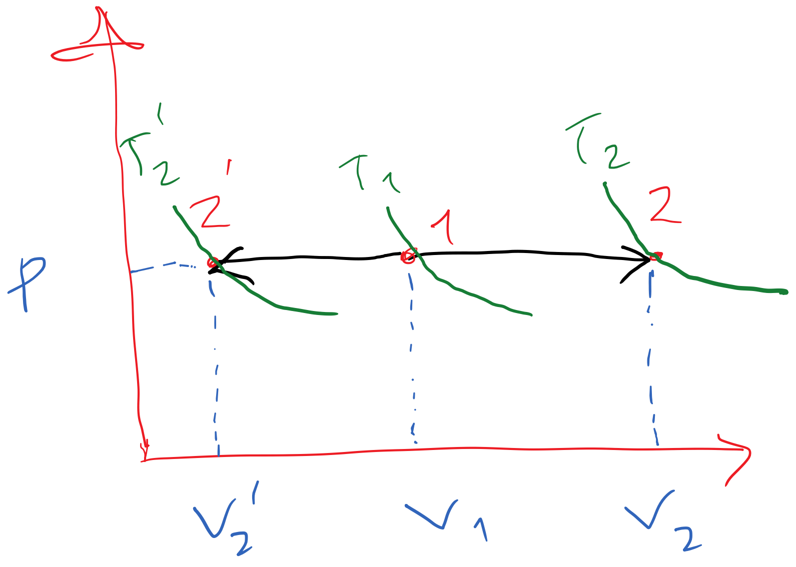
Volume change occurs as the gas is heated or cooled.

Heating a gas



PV – Diagram ?

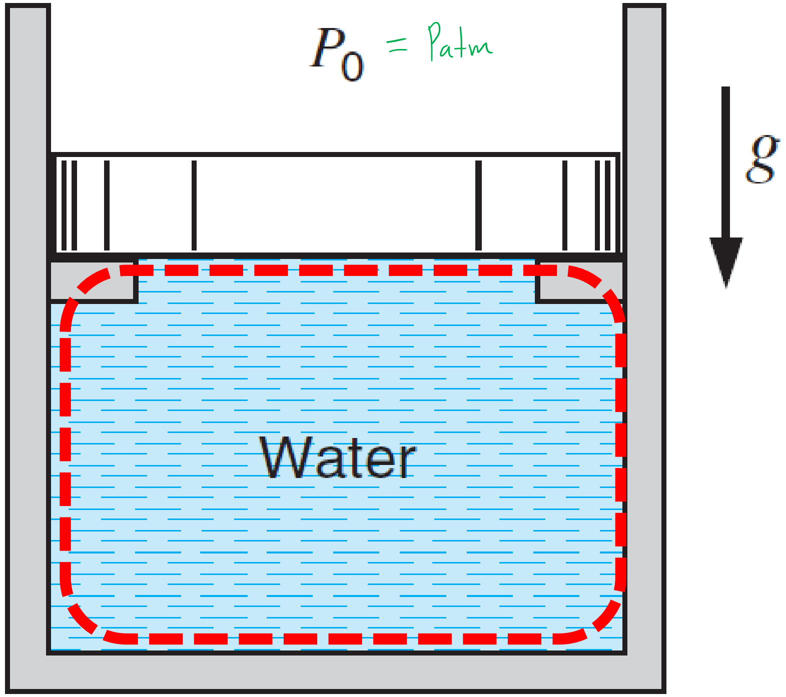




constant pressure !!

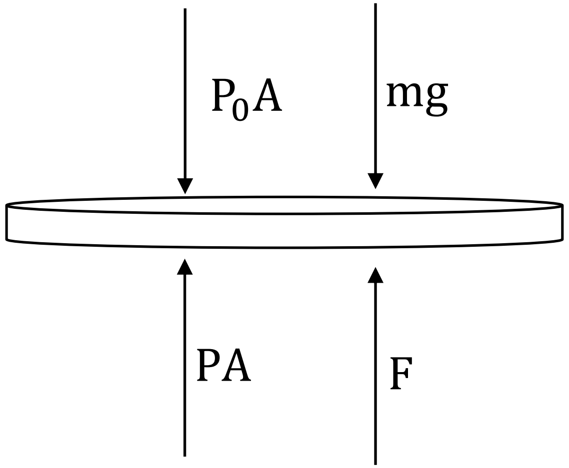
Example 5.4

A piston/cylinder with a cross-sectional area of 0.01 m^2 has a piston mass of 100 kg resting on the stops [state 1], as shown in the figure. With an outside atmospheric pressure of 100 kPa, what should the water pressure be to just lift the piston [**kPa**]? [state 2]. $g = 9.81\ \text{m/s}^2$. Assume the piston moves smoothly and quasistatic. Ignore the area occupied by the stops.



Example 5.4

The body free diagram for the piston is:



At the state 1 shown in picture, the equilibrium for the piston shows:

Resorte

$K.x \Rightarrow \frac{N}{m} \cdot m = 1N$

$$\overset{Pa}{P_0}\overset{m^2}{A} + \overset{kg}{m}\overset{m/s^2}{g} = \overset{Pa}{Psys_1}\overset{m^2}{A} + \overset{N}{F} \qquad [N]$$

To lift the piston smoothly within the cylinder (state 2), <u>the force on the stops must be zero</u>. That is:

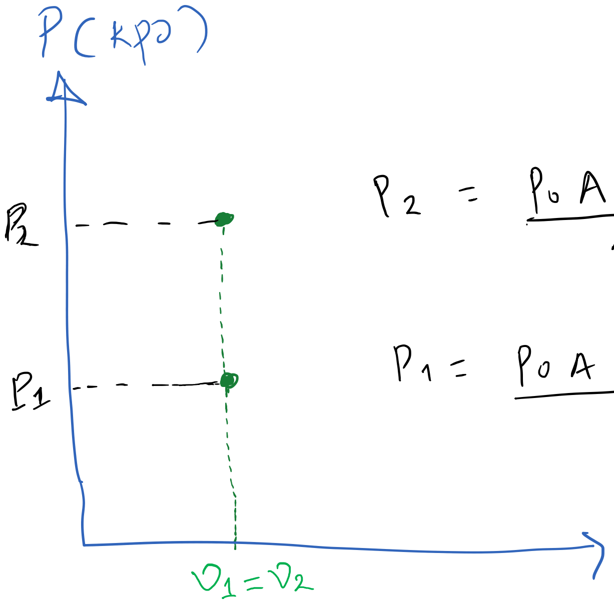
$$P_0A + mg = Psys_2A + 0$$

$$100000 \times 0.01 + 100 \times 9.81 = P_{sys} \times 0.01$$

$$1981 = P_{sys} \times 0.01$$

$$\mathbf{P_{sys} = P_2 = 198100\ Pa = 198.1\ kPa}$$

PV – Diagram?



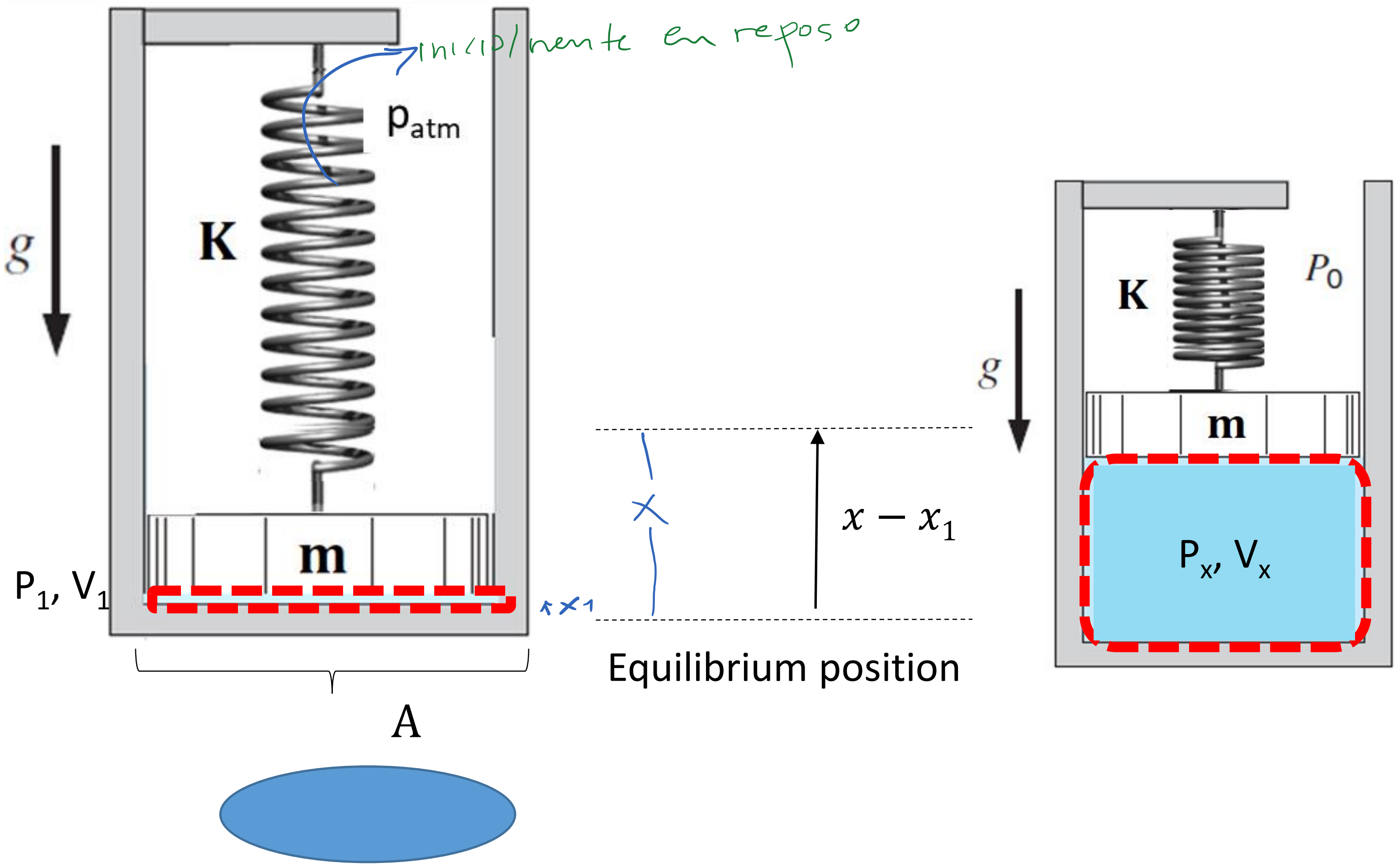
$$P_2 = \frac{P_0 A + mg}{A} = 198.1 \text{ kPa}$$

$$P_1 = \frac{P_0 A + mg - F}{A} \rightarrow \text{no lo conocemos}$$

Que tipo de proceso obtengo si sigo calentando??

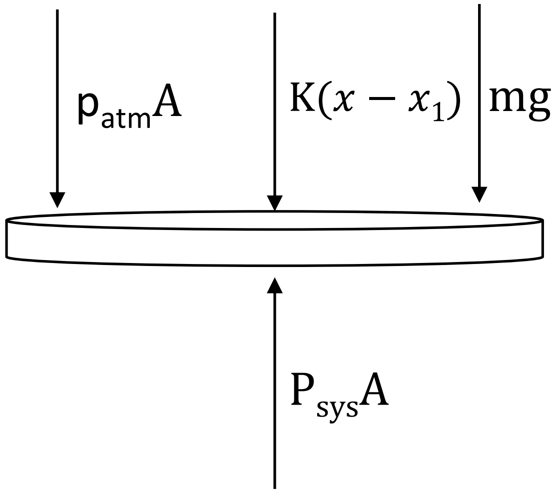
Example 7.1:

For the device in the figure, deduce an expression for the pressure inside (P) as a function of the volume (V). Notice that this linear spring exerts no force on the piston when it is at the bottom of the cylinder (equilibrium position). In a distance “x” from the bottom the system is also in equilibrium. Assume that the piston moves smoothly (quasistatic) in the cylinder.



Example 7.1:

The body free diagram for the piston is:



For the equilibrium: (Analizando el piston en un X cualquiera)

$$P_{sys}A = P_{atm}A + K(x - x_1) + mg$$

$$P_{sys} = P_{atm} + \frac{K(x - x_1)}{A} + \frac{mg}{A}$$

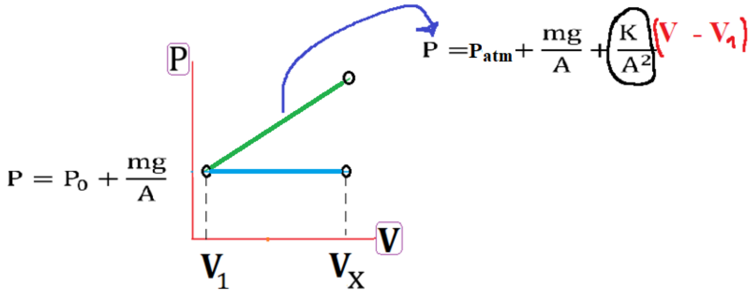
$$P_{sys} = P_{atm} + \frac{mg}{A} + \frac{K(x - x_1)}{A} \times \frac{A}{A}$$

$$P_{sys} = P_{atm} + \frac{mg}{A} + \frac{K(\mathbf{V} - \mathbf{V1})}{A^2}$$

Vx

$$P_{sys} = \overbrace{P_{atm} + \frac{mg}{A} - \frac{K(\mathbf{V1})}{A^2}}^{C1} + \overbrace{\frac{K(\mathbf{V})}{A^2}}^{C_2}$$

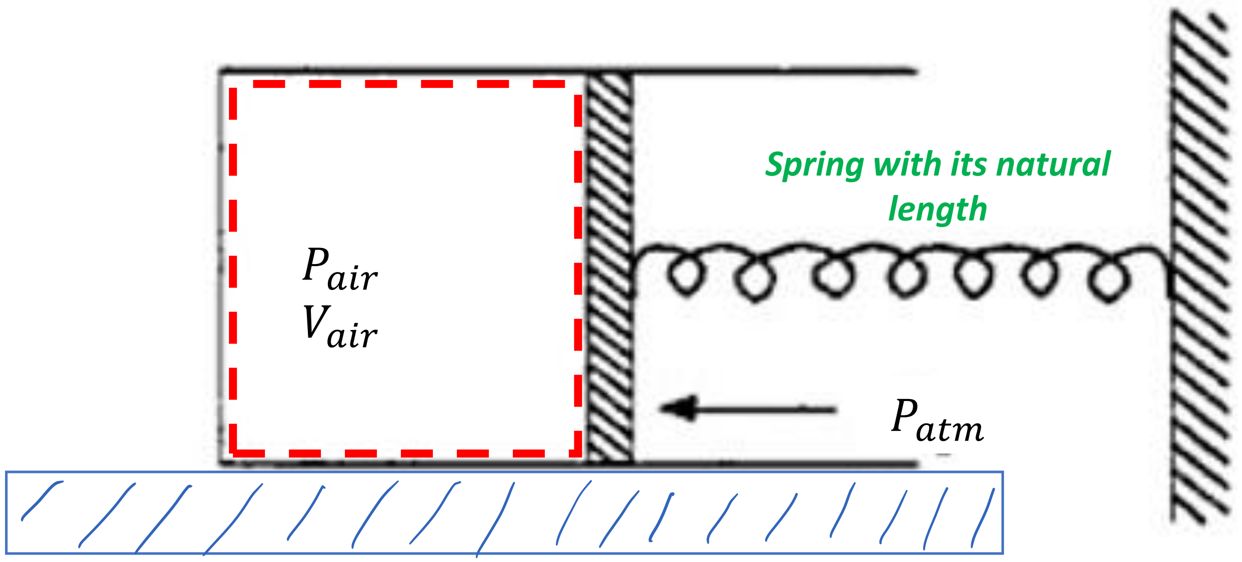
$$\mathbf{P_{sys}} = C_1 + C_2\mathbf{V}$$

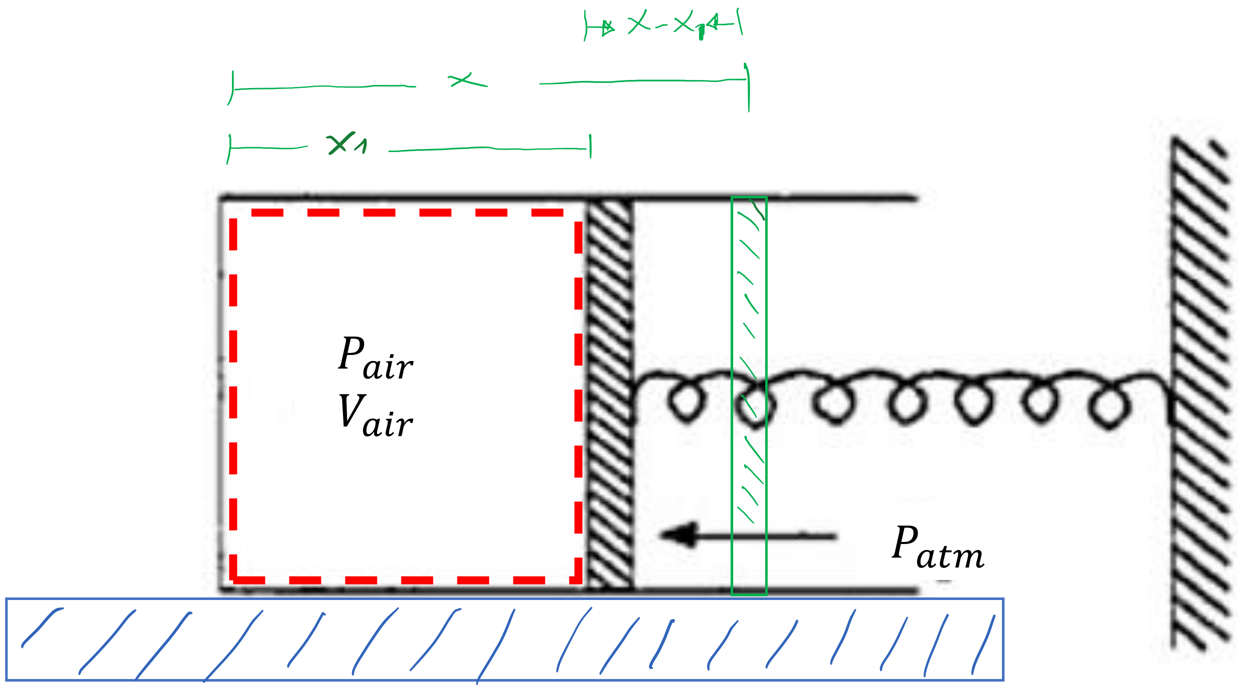


Pressure is a linear function of volume

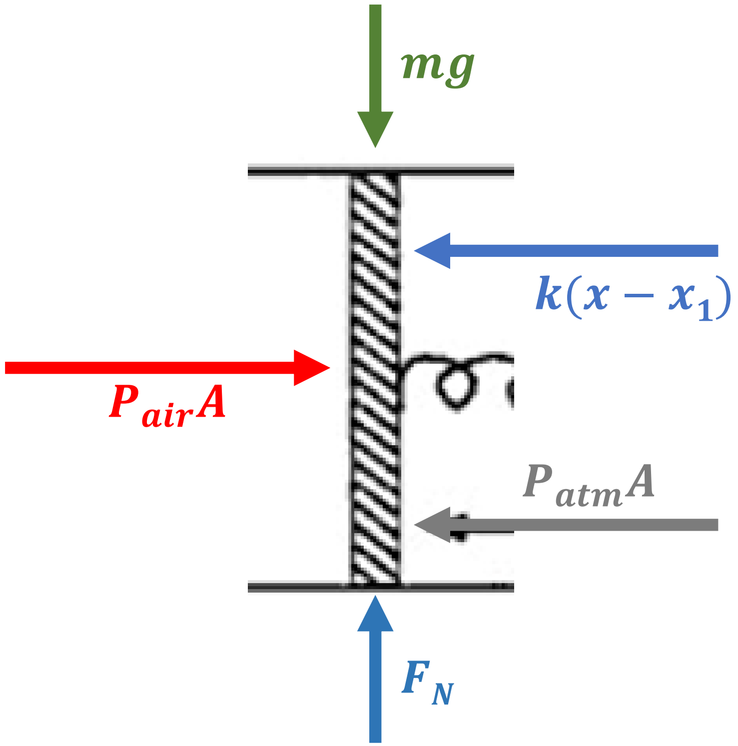
EXAMPLE 9.1a:

A piston-cylinder assembly contains air at 100kPa and occupies a volume of $0.01m^3$. The piston is attached to one end of a spring and the other end of the spring is fixed to a wall. The force exerted by the spring on the piston is proportional to the decrease in the length of the spring from its natural length. The ambient atmospheric pressure is 100kPa. Now, the air in the cylinder is heated until the volume is doubled and at this instant it is found that the pressure of the air in the cylinder is 500kPa. Calculate the spring constant if the area of the piston is $100mm^2$. Assume the piston moves smoothly and quasistatic.




x - x1
x
x1
P_air
V_air
P_atm

A force balance on the piston (“x” position) :



$$mg = F_N$$

$$\left(P_{air}A = k(x - x_1) + P_{atm}A\right) * A$$

$$\left(P_{air}\,A^2 = k(x - x_1) * A + P_{atm}A^2\right) \div A^2$$

$$P_{air} = k\frac{V_{air} - V_1}{A^2} + P_{atm}$$

This equation shows a linear relationship between P and V

$$P_1 = k\frac{\cancel{V_1 - V_1}}{A^2} + P_{atm} \quad (1)$$

$$P_2 = k\frac{V_2 - V_1}{A^2} + P_{atm} \quad (2)$$

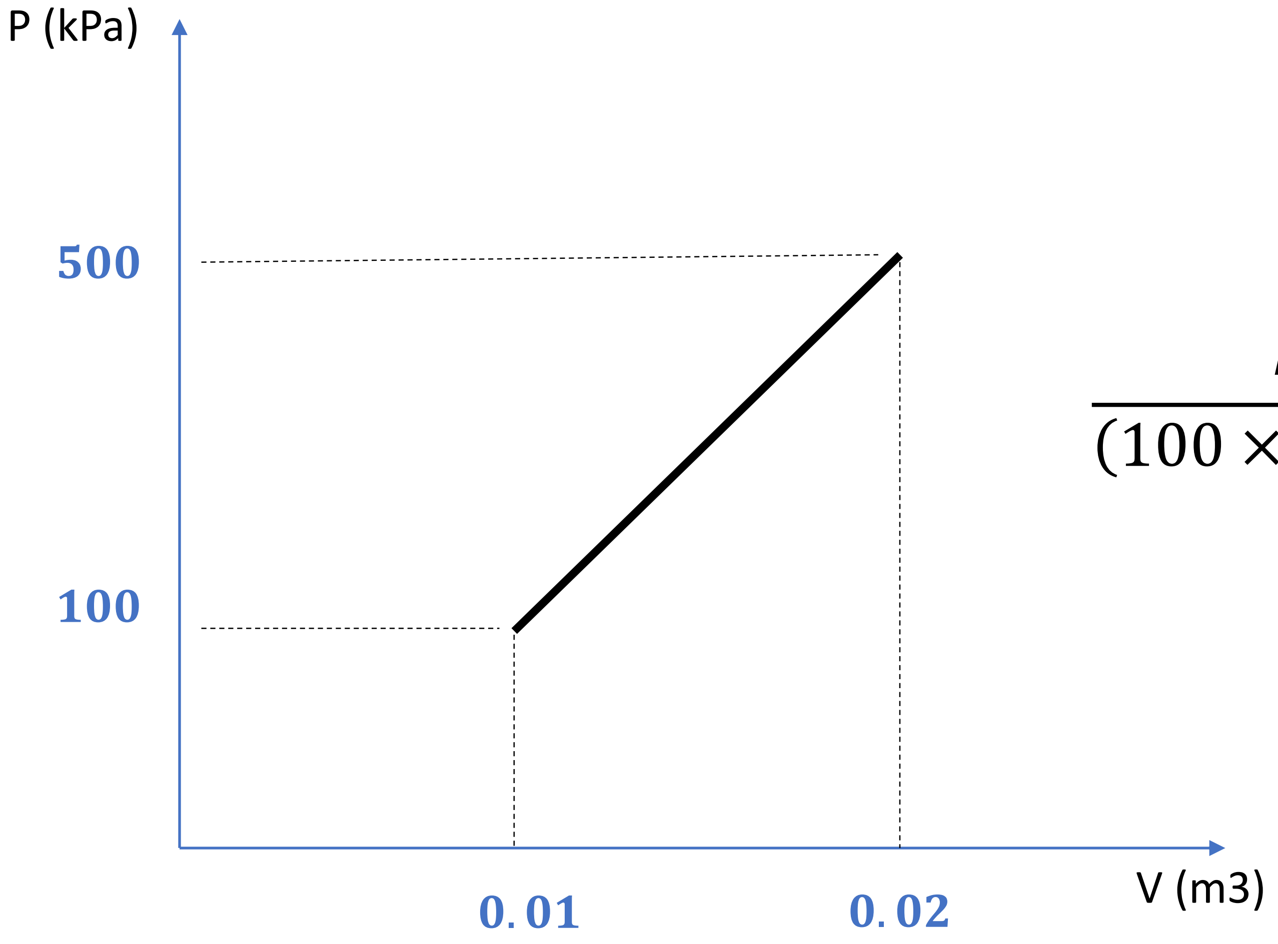
$$P_1 = k\frac{V_1 - V_1}{A^2} + P_{atm} \quad (1) \longrightarrow \quad P_1 = P_{atm}$$

$$P_2 = k\frac{V_2 - V_1}{A^2} + P_{atm} \quad (2)$$

$(2) - (1)$

$$P_2 - P_1 = \frac{k}{A^2}(V_2 - V_1)$$

Plotting P vs V:



Slope of the line:

$$\frac{k}{A^2} = \frac{P_2 - P_1}{V_2 - V_1}$$

$\rightarrow \frac{N}{m^2}$

$\rightarrow m^3$

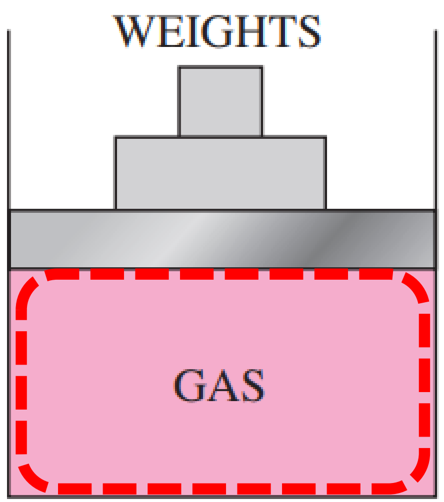
m^4

$$\frac{k}{(100 \times 10^{-6})^2} = \frac{(500 - 100) \times 10^3}{0.02 - 0.01}$$

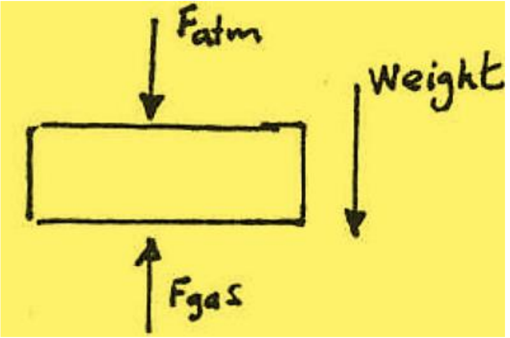
$$\boldsymbol{k = 0.4\ N/m}$$

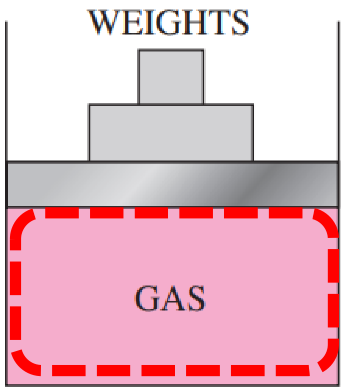
Example 6.1

A vertical piston–cylinder device contains a gas at a pressure of 100 kPa. The piston has a mass of 10 kg and a diameter of 10 cm. Pressure of the gas is to be increased by placing some weights on the piston. Determine the local atmospheric pressure (kPa) and the mass of the weights (kg) that will double the pressure of the gas inside the cylinder. Assume the piston moves smoothly (without friction and quasistatic).



Example 6.1





Assuming no friction between the piston and the cylinder, in the beginning the gas pressure force should be equal piston weight plus the force exerted by the atmosphere:

$$\mathrm{F_{gas}} = \mathrm{F_{atm}} + \mathrm{F_{grav}} \rightarrow \mathrm{P_{gas}A} = \mathrm{P_{atm}A} + \mathrm{m_{piston}g}$$

$$\mathrm{P_{atm}} = \mathrm{P_{gas}} - \frac{\mathrm{m_{piston}g}}{\mathrm{A}}$$

The cross-sectional area is:

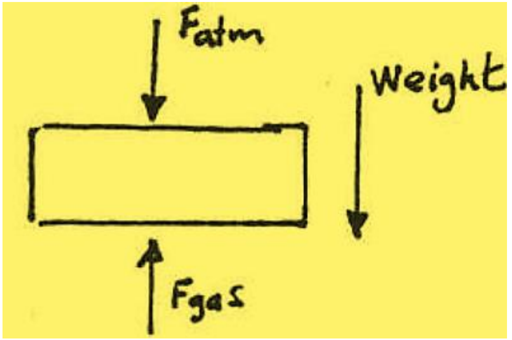
$$\mathrm{A} = \pi(D/2)^2 = \pi \times \frac{0.1^2}{4} = 7.854 \times 10^{-3}\mathrm{m}^2$$

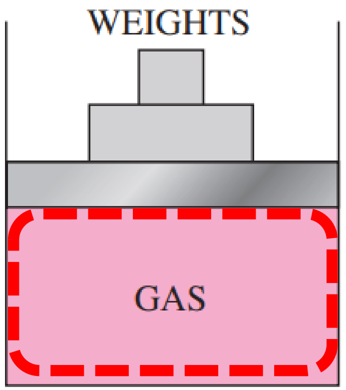
Replacing the values to find the atmospheric pressure:

Pa

$$\mathrm{P_{atm}} = 100\mathrm{kPa} - \frac{10 \times 9.81}{7.854 \times 10^{-3}} \times \frac{1\mathrm{kPa}}{10^3\mathrm{Pa}} = 87.5095\ \mathrm{kPa}$$

Example 6.1





When some weights are place over the piston, the total gravity force increases, and the gas pressure becomes the double:

$$F_{gas} = F_{atm} + F_{grav} \rightarrow P_{gas}A = P_{atm}A + \left(m_{piston} + m_{weights}\right)g$$

$$P_{gas} = P_{atm} + \frac{\left(m_{piston} + m_{weights}\right)g}{A}$$

$$100\text{kPa} \times 2 = 87.51\text{kPa} + \frac{\left(10 + m_{weights}\right) \times 9.81}{7.854 \times 10^{-3}} \times \frac{1\text{kPa}}{10^{3}\text{Pa}}$$

$$\mathbf{m_{weights} = 80.0612\ kg}$$

Thanks!