Office hours today: after class in Remo

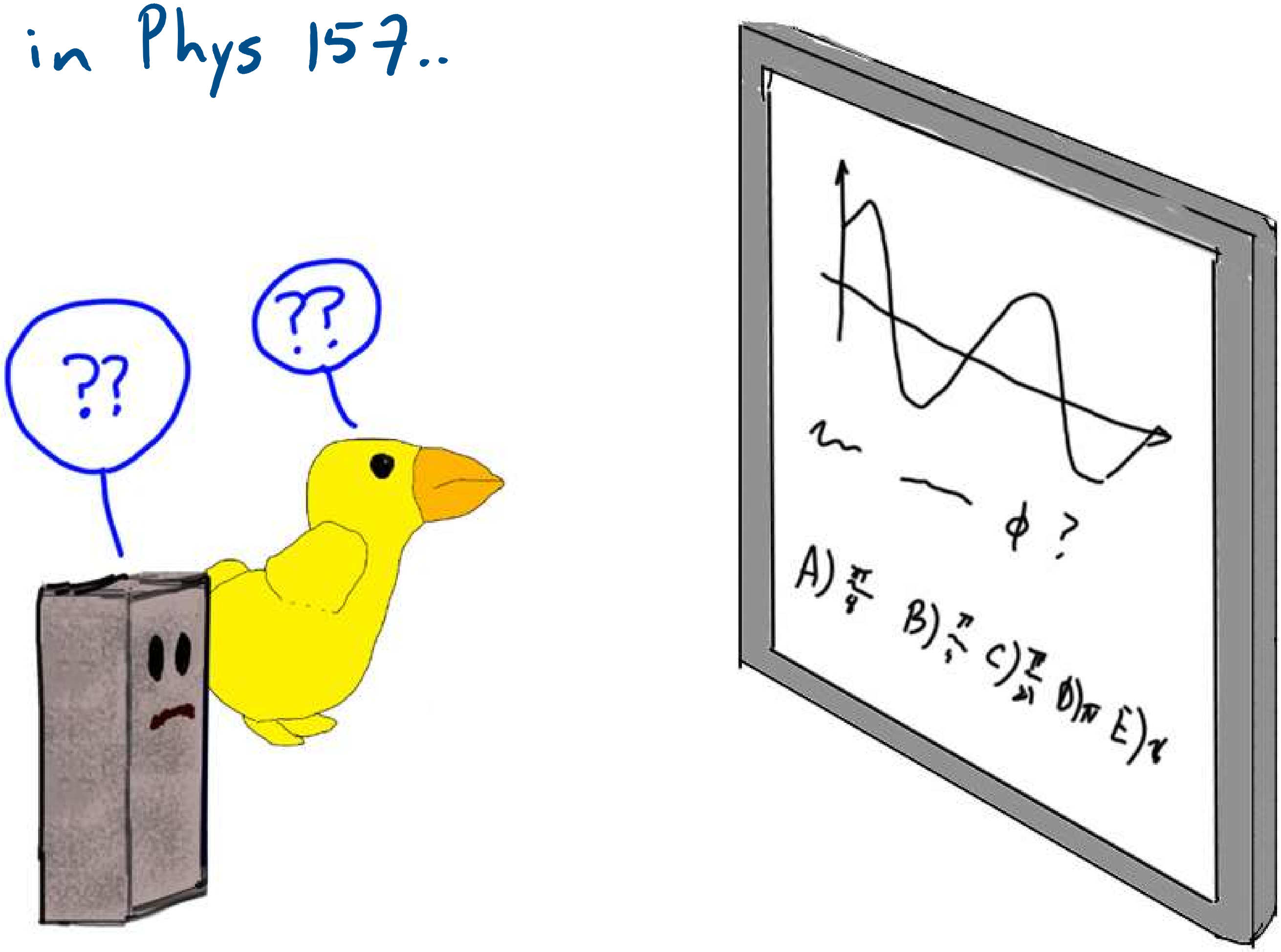
Reminder: quiz Thursday (entropy and oscillations)

Learning goals for today:

To predict the equilibrium position of a system by calculating the various contributions to net force and requiring that the net for vanishes.

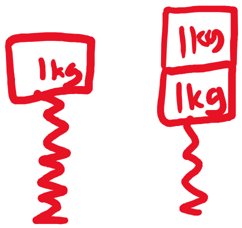
To predict the oscillation frequency of a system given the net force as a function of position or given physical information that permits the calculation of net force as a function of position.

Last time in Phys 157..



A 1 kg mass sits on a spring with k=1000N/m. If we add another 1kg mass on top, the amount by which the equilibrium position changes is:

A) 1cm
B) 2cm
C) 10cm
D) 1m
E) It can’t be determined without knowing the unstretched length of the spring.



A 1 kg mass sits on a spring with k=1000N/m. If we add another 1kg mass on top, the amount by which the equilibrium position changes is about:

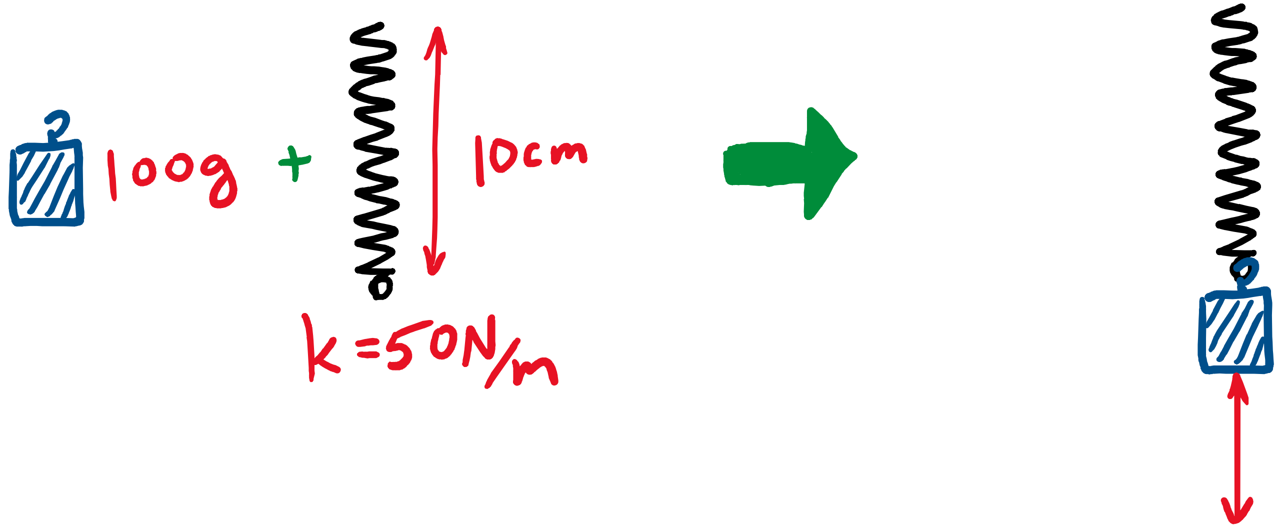
A) 1cm
B) 2cm
C) 10cm
D) 1m
E) It can't be determined without knowing the unstretched length of the spring.

At equilibrium, compression of the spring is determined by $F_{NET} = 0$

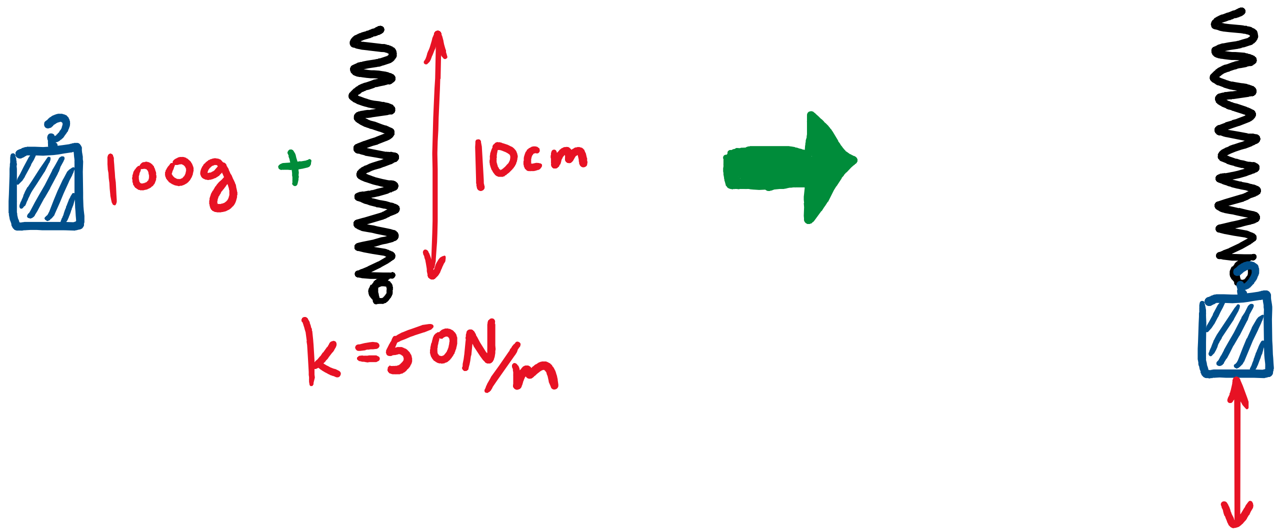
$mg = kx$

With different masses, $\overset{1kg}{m_1} g = k x_1$, and $\overset{2kg}{m_2} g = k x_2$, so when we add the extra mass, $\Delta m \cdot g = k \cdot \Delta x$. Thus: $\Delta x = \frac{\Delta m g}{k}$

$= 1cm$

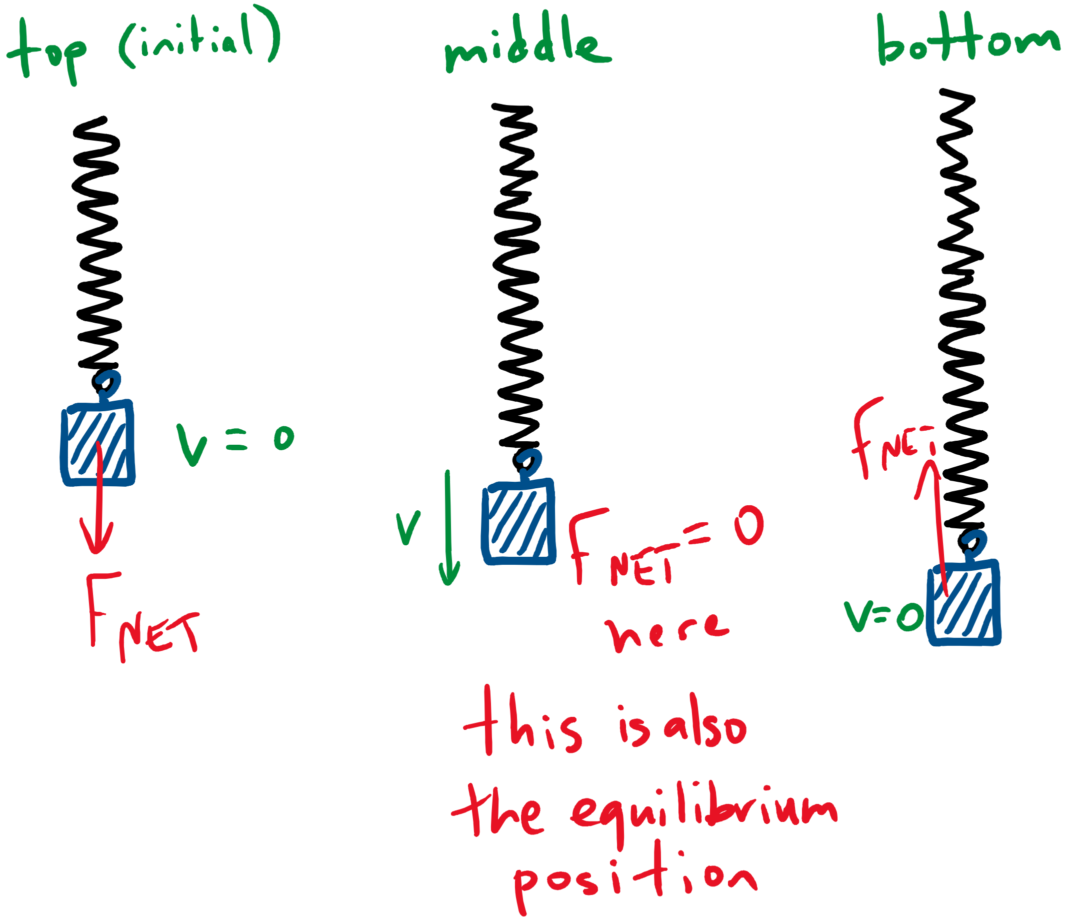


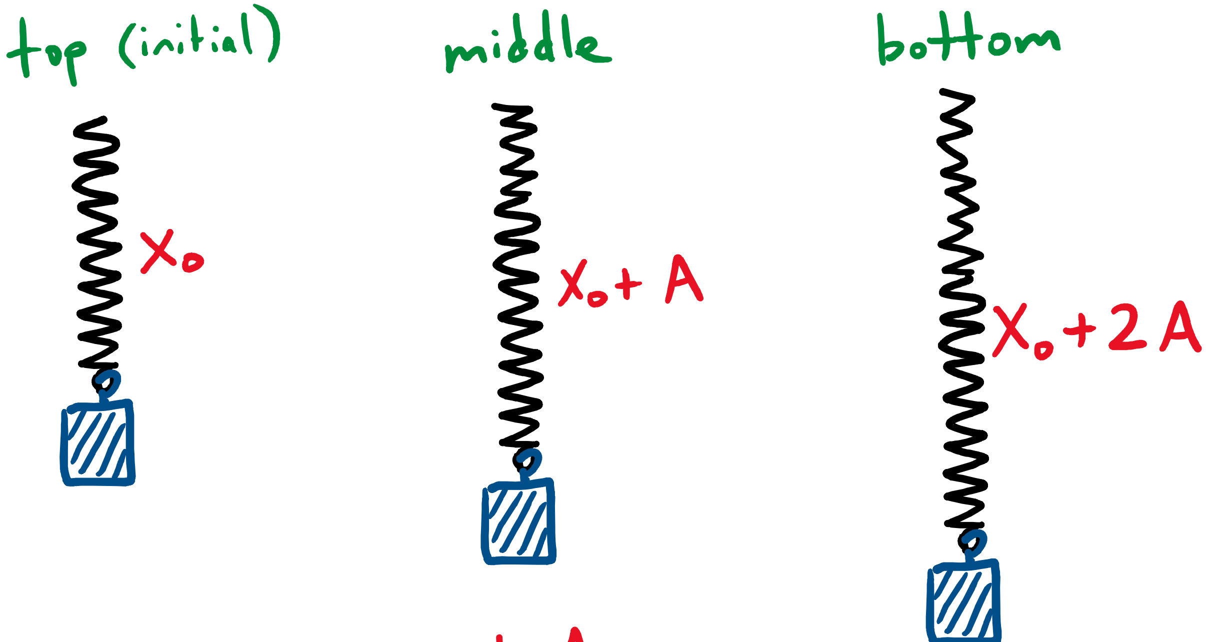
Discussion question: A 10cm long spring has a spring constant of 20 N/m. If we attach a 100g weight to the spring and release it, what will be the amplitude of the resulting oscillation?



Discussion question: A 10cm long spring has a spring constant of 20 N/m. If we attach a 100g weight to the spring and release it, what will be the amplitude of the resulting oscillation?

A) 1cm B) 2cm C) 3cm D) 4cm E) 5cm


top (initial)
v = 0
F_{NET}
middle
v
$F_{NET} = 0$ here
this is also the equilibrium position
bottom
F_{NET}
v=0



Middle position is equilibrium position, so $F_{NET} = mg - kA = 0$ here.

$$A = \frac{mg}{k} = \frac{1\,N}{50\,N/m} = 2\,cm$$

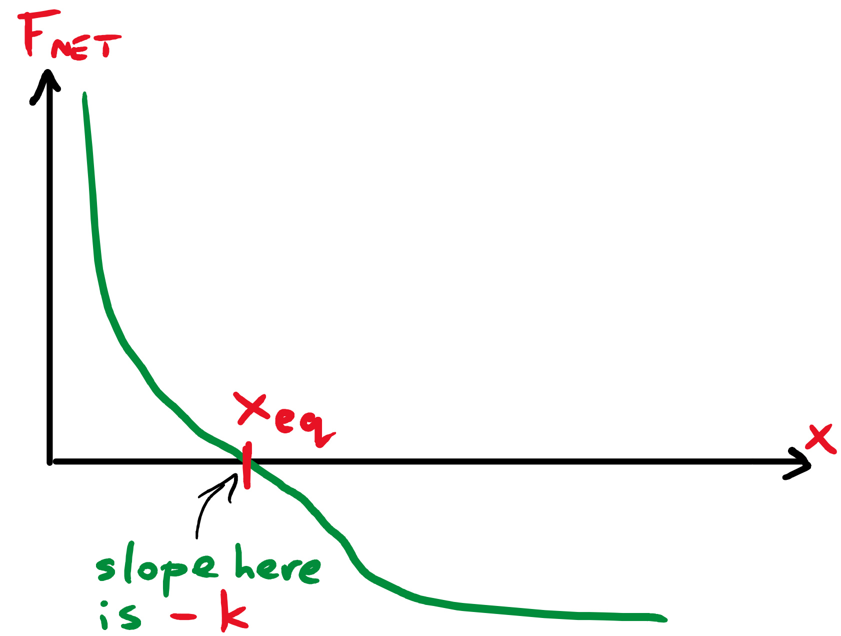
How to find ω in examples:

① Find F_{NET} as a function of position x

② Find equilibrium value x_{eq} by solving $F_{NET}(x_{eq}) = 0$.

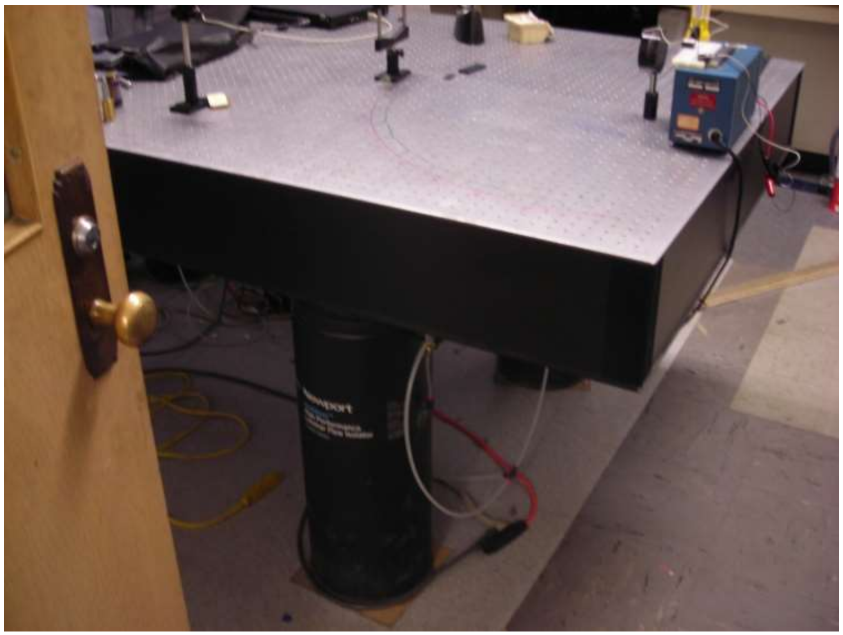
③ $-k$ is $F'_{NET}(x_{eq})$, the slope at x_{eq}.

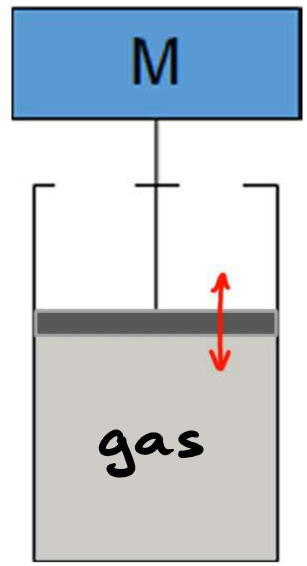
④ Then $\omega = \sqrt{\frac{k}{m}}$



Example: air leg

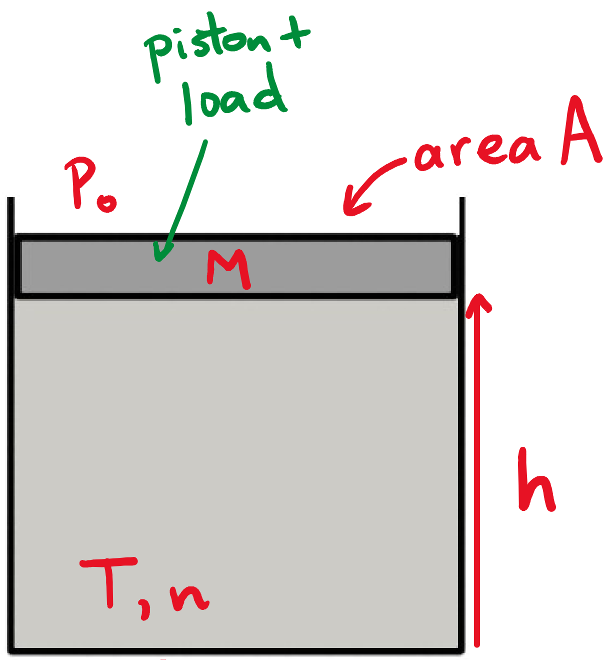
- used to isolate sensitive equipment from vibration.





assume: any motion of piston is slow
so compression/expansion is isothermal

Example: air leg



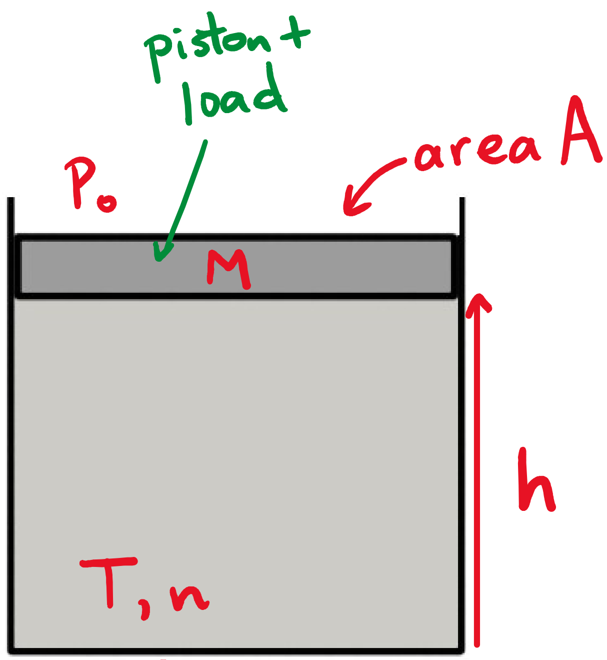
$P_0 = 100\,kPa$
$M = 200\,kg$
$g \approx 10\,m/s^2$
$A = 0.03\,m^2$
$T = 300\,K$
$n \cdot R = 5\,J/K$

a) Draw a free body diagram for the object of mass M showing the vertical forces.

b) Calculate the magnitude of the net upwards force on the object as a function of the height h of the piston.

Your answer should be a function of h

Example: air leg



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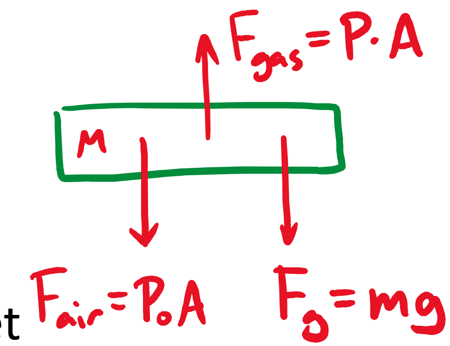


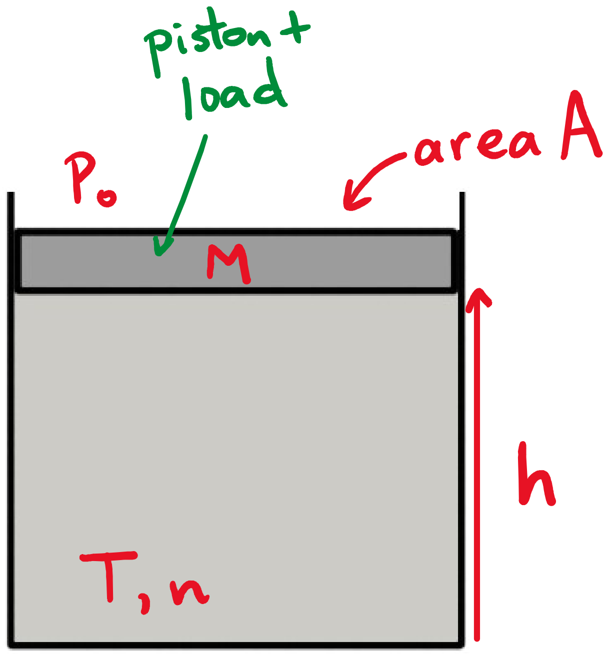
b) Calculate the magnitude of the net upwards force on the object as a function of the height h of the piston.

Have: $P = \dfrac{nRT}{V} = \dfrac{nRT}{A \cdot h}$

so $F_{gas} = PA = \dfrac{nRT}{h}$

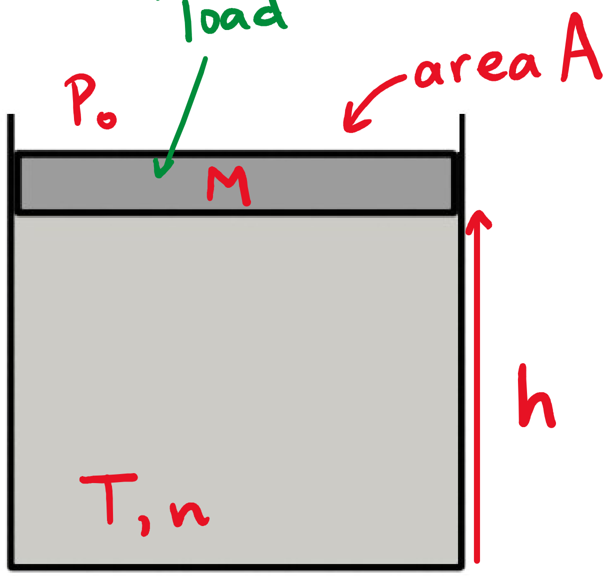
$$F^{up}_{NET} = \frac{nRT}{h} - P_0 A - mg = \frac{1500\,\text{J}}{h} - 5000\,\text{N}$$

Example: air leg



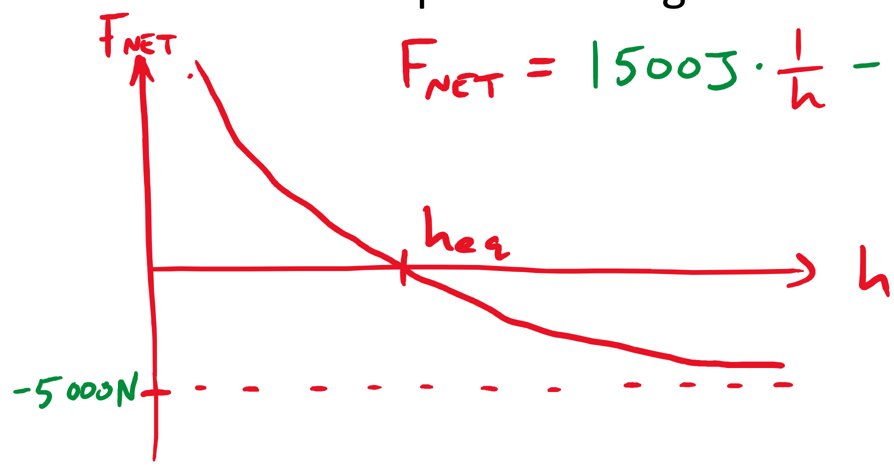
c) Graph this upward force as a function of h, for positive values of h up to the height of the object.

Example: air leg

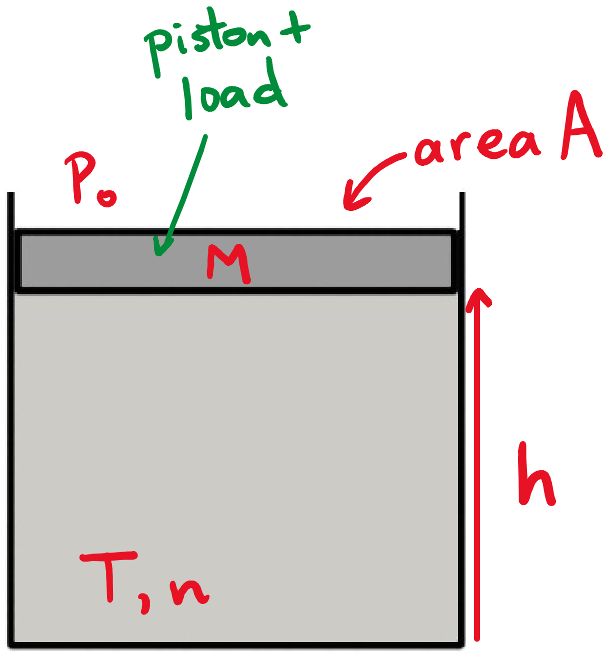


c) Graph this upward force as a function of h, for positive values of h up to the height of the object.

$$F_{NET} = 1500\,J \cdot \frac{1}{h} - 5000\,N$$



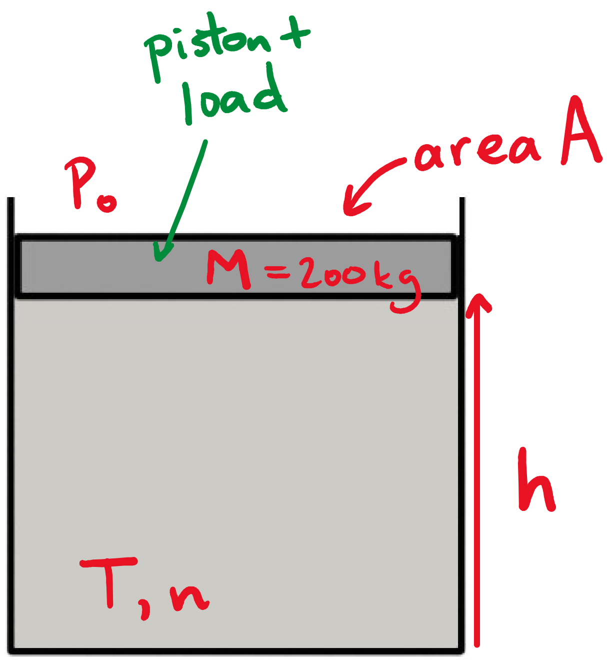
Example: air leg



d) What is the equilibrium height of the piston?

e) What is the oscillation frequency f?

Example: air leg



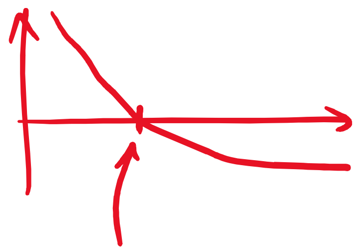
$$F_{NET} = \frac{1500\,J}{h} - 5000\,N$$

d) What is the equilibrium height of the piston?

equilibrium height: $F_{NET} = 0$

$$h_{eq} = 0.3\,m$$

e) What is the oscillation frequency f?



$$k = -\frac{dF}{dh} \text{ at } h_{eq} = \frac{1500\,J}{h_{eq}^2} = 1.67 \times 10^4\,N/m$$

$$\longrightarrow \quad \omega = \sqrt{\frac{k}{m}} = 9.1\,s^{-1}$$

$$f = \frac{\omega}{2\pi} = 1.45\,s^{-1}$$