Lecture 40:

Review Final Exam, part 1

Warming you up with some nice and warm thermodynamics:

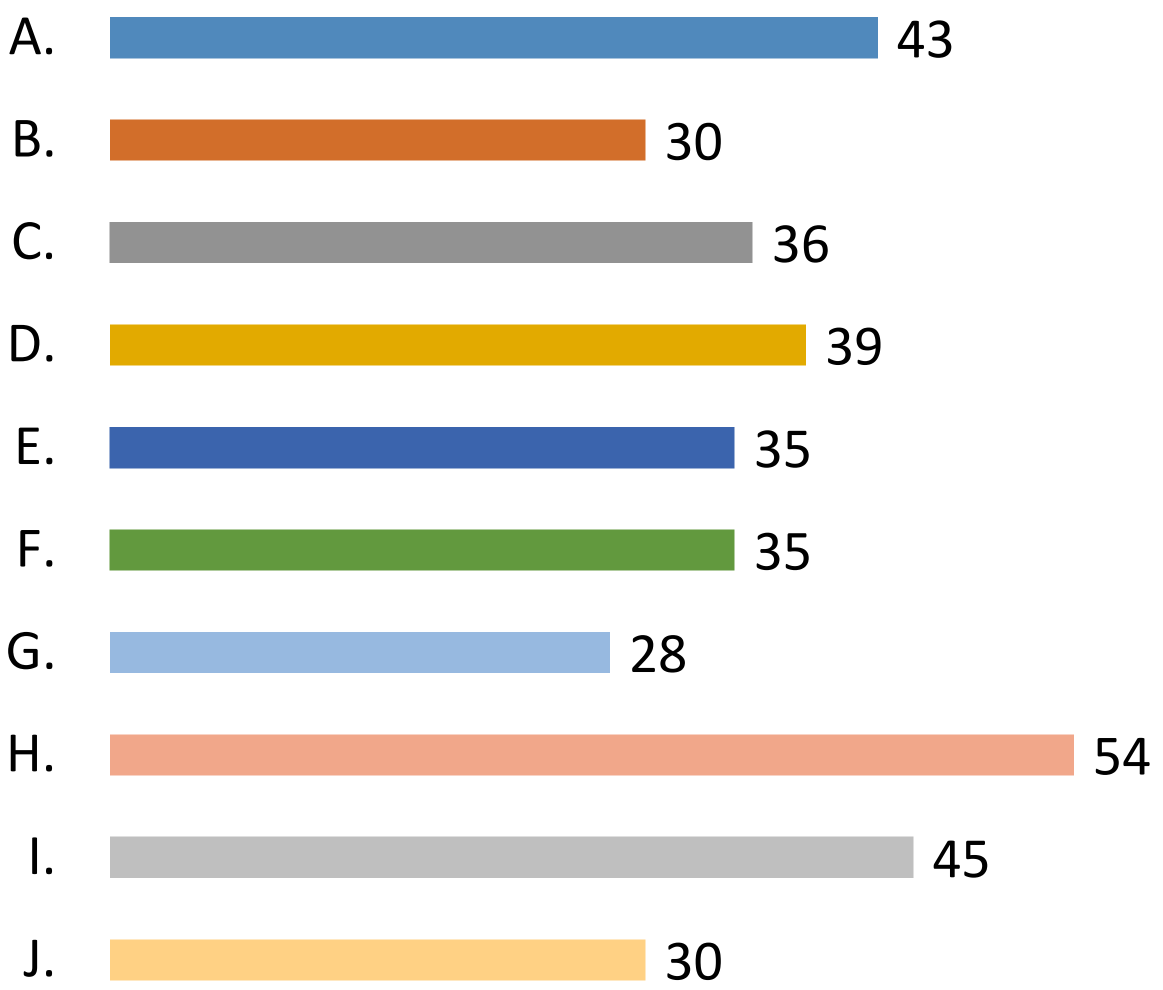
Erik Lascaris

Announcements

- Last two lectures: today + Wednesday!
  - Both will be reviews
- Homework #14 is due tomorrow (Tuesday) midnight!
  - WARNING: no extensions of HW beyond Friday midnight!
- Please check your grades on WebAssign
  - Excused labs show a zero, but don't actually count towards your average
- Office hours!
  - Usual ones at Monday 4-6pm and Tuesday 3-6pm
  - Extra office hours – will decide later when exactly

What is a good moment for extra office hours?

A. Wednesday after last lecture
B. Thursday morning
C. Thursday afternoon
D. Thursday evening, after 5pm
E. Friday morning
F. Friday afternoon
G. Friday evening, after 5pm
H. Sunday afternoon
I. Sunday evening
J. Monday morning



Please check your WebAssign grades!

- Do you have all your discussion & lecture participation points you deserve?
- Do you have all your lab grades?

GradeBook

www.webassign.net

GradeBook

PY 105, section A1

Lab Average for

Assignment	Weight	Score	Total		Factor	%	Weighted
Lab 1: x,v,a	1.00	24.00	25.00		1.00 / 6.00 = 0.16	24.00 / 25.00 = 0.96 x 100 = 96.00	0.16 x 96.00 = 15.99
Lab 2: const acc x	-	0	25.00		-	0 / 25.00 = 0 x 100 = 0	-
Lab 3: projectile motion	1.00	22.00	25.00		1.00 / 6.00 = 0.16	22.00 / 25.00 = 0.88 x 100 = 88.00	0.16 x 88.00 = 14.66
Lab 4: energy and work	1.00	23.00	25.00		1.00 / 6.00 = 0.16	23.00 / 25.00 = 0.92 x 100 = 92.00	0.16 x 92.00 = 15.33
Lab 5: collisions	1.00	25.00	25.00		1.00 / 6.00 = 0.16	25.00 / 25.00 = 1.00 x 100 = 100.00	0.16 x 100.00 = 16.66
Lab 6: torque	1.00	24.00	25.00		1.00 / 6.00 = 0.16	24.00 / 25.00 = 0.96 x 100 = 96.00	0.16 x 96.00 = 15.99
Lab 7: fluids *	-	0	25.00		-	0 / 25.00 = 0 x 100 = 0	-
	6.00					**Average**	**78.66**

* Score Dropped for this Assignment

x This Assignment Excused

WebAssign still makes a mess of calculating your lab grade when you've got an excused lab.

Don't worry, my numbers are correct

New equation sheet

NEW!

- No more Pythagoras and cos/sin/tan -- replaced by areas and volumes

- New Equation Sheet includes a mega super awesome PV-diagram table:

Process	Work done by gas (>0 if expands)	Change of internal energy	Heat added to system	Change in entropy	Ideal gas law
Any process	$W = \int P\,dV$	$\Delta E = nC_V\Delta T$	$Q = \Delta E + W$	$\Delta S \geq 0$	$PV = nRT$
Isobaric	$W = P\Delta V$		$Q = nC_P\Delta T$		$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Isochoric	$W = 0$		$Q = nC_V\Delta T$		$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
Isothermal	$W = nRT\ln(V_f/V_i)$	$\Delta E = 0$	$Q = W$		$P_1V_1 = P_2V_2$
Adiabatic			$Q = 0$	$\Delta S = 0$	$P_1V_1^\gamma = P_2V_2^\gamma$ $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ $\gamma = C_P/C_V$
Complete cycle	$W =$ area enclosed	$\Delta E = 0$		$\Delta S = 0$	-

Monatomic gas: $C_V = \frac{3}{2}R$ Diatomic gas: $C_V = \frac{5}{2}R$ All cases: $C_P = C_V + R$

Final exam

- Monday May 8th at 3pm
- In room COM-101
- Looks like fun
- Are there any tables??

General structure of the PY105 Final Exam

- 7 problems in total

- Problem 1, worth 10 points:
    - Multiple Choice questions about concepts and some stuff you should memorize

- Problems 2, 3, 4, 5, 6, 7, each worth 15 points:
    - Similar problems as on quizzes and homework
        - Fluids: buoyant force (Ch. 9)
        - Fluids: Bernoulli's equation (Ch. 9)
        - Simple Harmonic Motion (Ch. 12)
        - Thermal physics (Ch. 13)
        - Specific heat and latent heat (Ch. 14)
        - PV-diagrams and heat engines (Ch. 15)

- Sums up to 100 points in total

How to prepare for the final

Final Exam: Monday May 8th at 3pm in COM-101

- Try to do the quizzes again, and understand the solutions *solutions = on Piazza*
  - Quiz 9: fluids: Bernoulli's equation
  - Quiz 10: specific heat and latent heat

- Practice the homework problems – worked-out solutions are on Piazza! *solutions soon on Piazza*
  - HW-11, problems 1, 2, 5, 7, 9
  - HW-12, problems 2, 3, 5
  - HW-13, problems 1, 2, 5, 8
  - HW-14, problems 3, 4, 5, 6

- Go to Piazza, and make sure you understand slides
- Do the practice exams
  - Sorry, none of them are "complete"...
- Check out the list on Piazza: Things_you_should_know_for_Final_Exam.pdf (soon on Piazza)
- Memorize the "List of things to memorize"

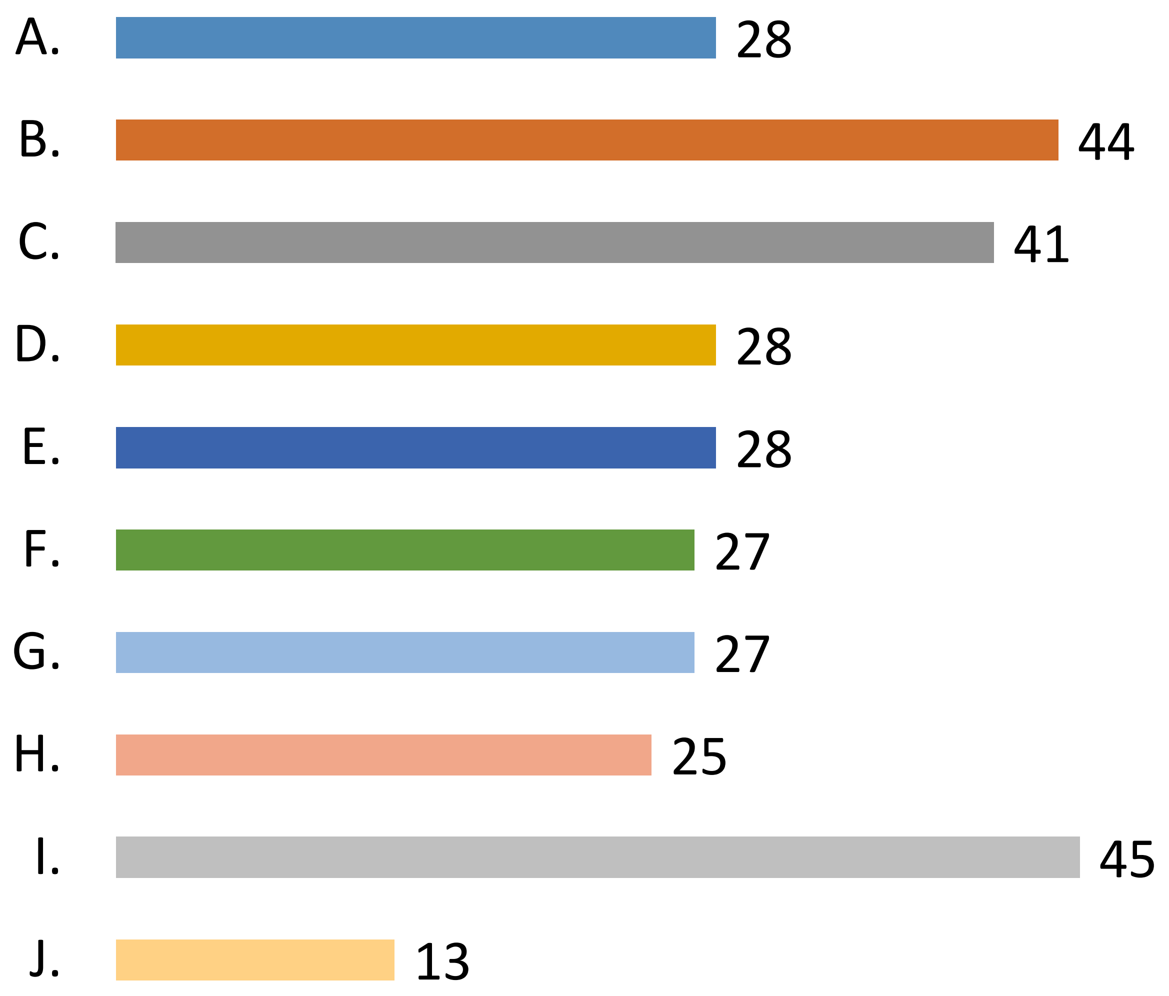
Things you need to memorize!

some of **These things are literally Problem 1 on midterm!**

- Know the definition of a fluid: a state of matter than can flow (in other words: a gas or a liquid)
- Know that when an object is submerged in water, it still feels the buoyant force.
- Know the difference between laminar flow and turbulent flow, and be able to recognize the flow from a picture with streamlines.
- Know how Q, ΔP, and R are related in the Hagen-Poiseuille equation: $Q = \pi R^4 \Delta P / 8\eta L$ which implies that if R becomes 2x larger, Q increases by 16x!
- Remember that these are units of pressure: pascal (Pa), N/m^2, atm, bar, millibar, "mm of mercury" (mmHg), pounds-per-square-inch (psi)
- Know the difference between gauge pressure and absolute pressure
- Remember power = watts (W) = energy per time = joules/second (1 W = 1 J/s)
- Know the 3 types of heat transfer: conduction, convection, and thermal radiation (and know what they are / how they look like)
- Understand why you cannot cool below "absolute zero" (0 K): because at 0 K atoms have no motion and do you cannot move less than that
- Understand how sweating helps you cool down (liquid sweat evaporates in the sun, and evaporation removes heat from a system)
- Know what a thermal equilibrium is (there's no net heat flow)
- Know that if you have a mixture of a liquid and its vapor (in thermal equilibrium) then the temperature of the mixture is at the boiling temperature
- Know that if you have a mixture of a liquid and its solid (in thermal equilibrium) then the temperature of the mixture is at the melting temperature
- Know definitions of 4 thermodynamics processes: isothermal (= constant T), isobaric (= constant P), isochoric (= constant V), adiabatic (no heat in or out).
- Know that temperature is a macroscopic quantity that is a measure of the average kinetic energy of the atoms in the material
- Know that the emissivity ε of an object is a number between 0 and 1, where 1 indicates that the object emits a lot of heat.
- And things listed in Things_you_should_know_for_Final_Exam.pdf --- soon on Piazza!

Which concepts do you struggle the most with?

A. Buoyant force
B. Drag force / terminal speed
C. Using Bernoulli's equation (like quiz 9)
D. Simple harmonic motion
E. Thermal expansion
F. Heat through conduction
G. Specific heat & Latent heat (like quiz 10)
H. Using the ideal gas law
I. Getting $Q, W, \Delta E$ from PV-diagrams
J. I don't know



- Thank you for your feedback!

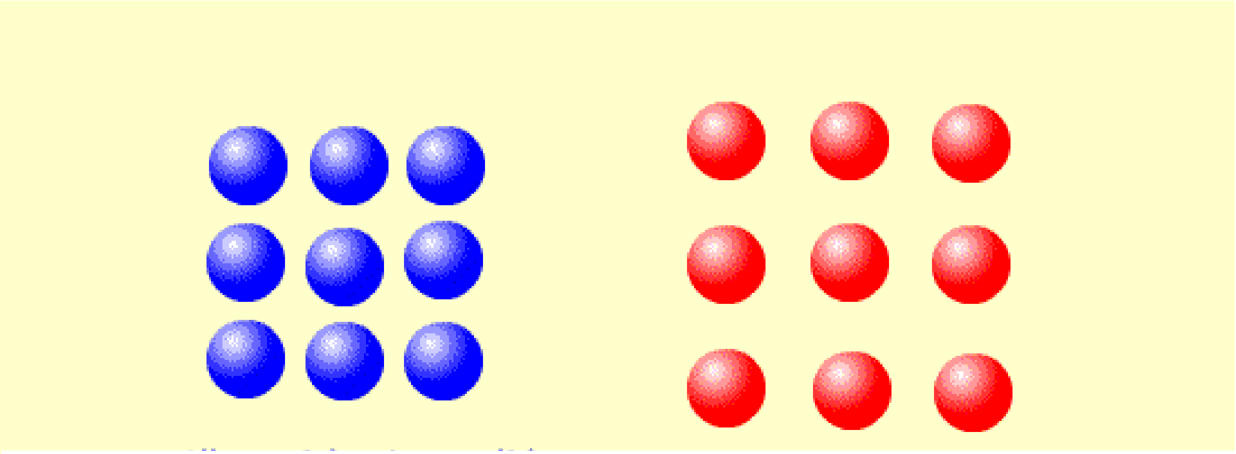
- I'll use this list + my office hours experiences for Wednesday's review lecture!

Review: Thermal physics

Temperature

What is temperature?

It represents the <u>average kinetic energy</u> of the atoms inside the material



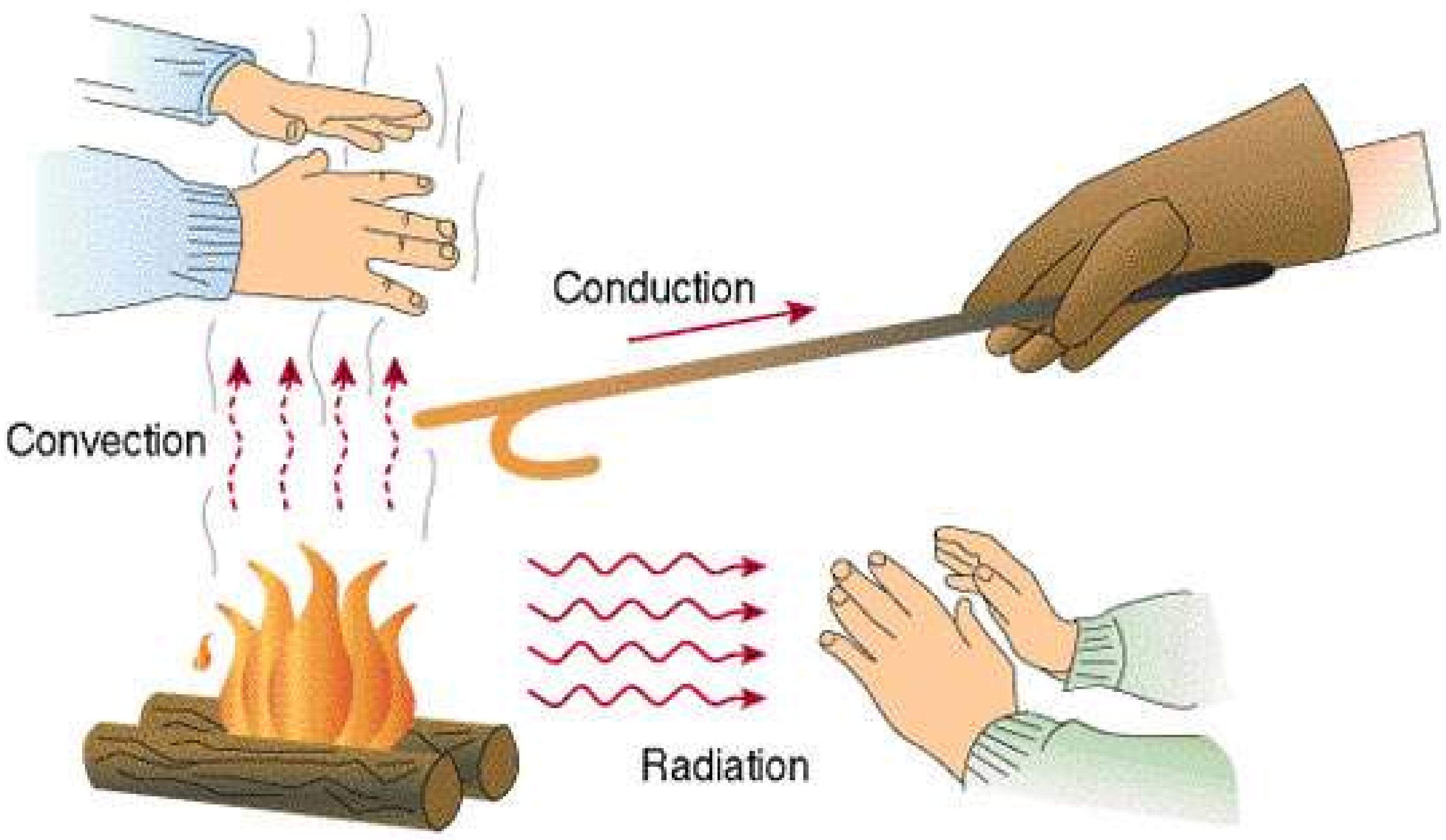
cold solid
little kinetic energy
low temperature

hot solid
lots of kinetic energy
high temperature

Absolute zero

If the material is so cold that none of the atoms move (zero kinetic energy) then the temperature T is at "absolute zero" = 0 Kelvin = −273.15 °C = − 459.67 °F

Three forms of heat transfer

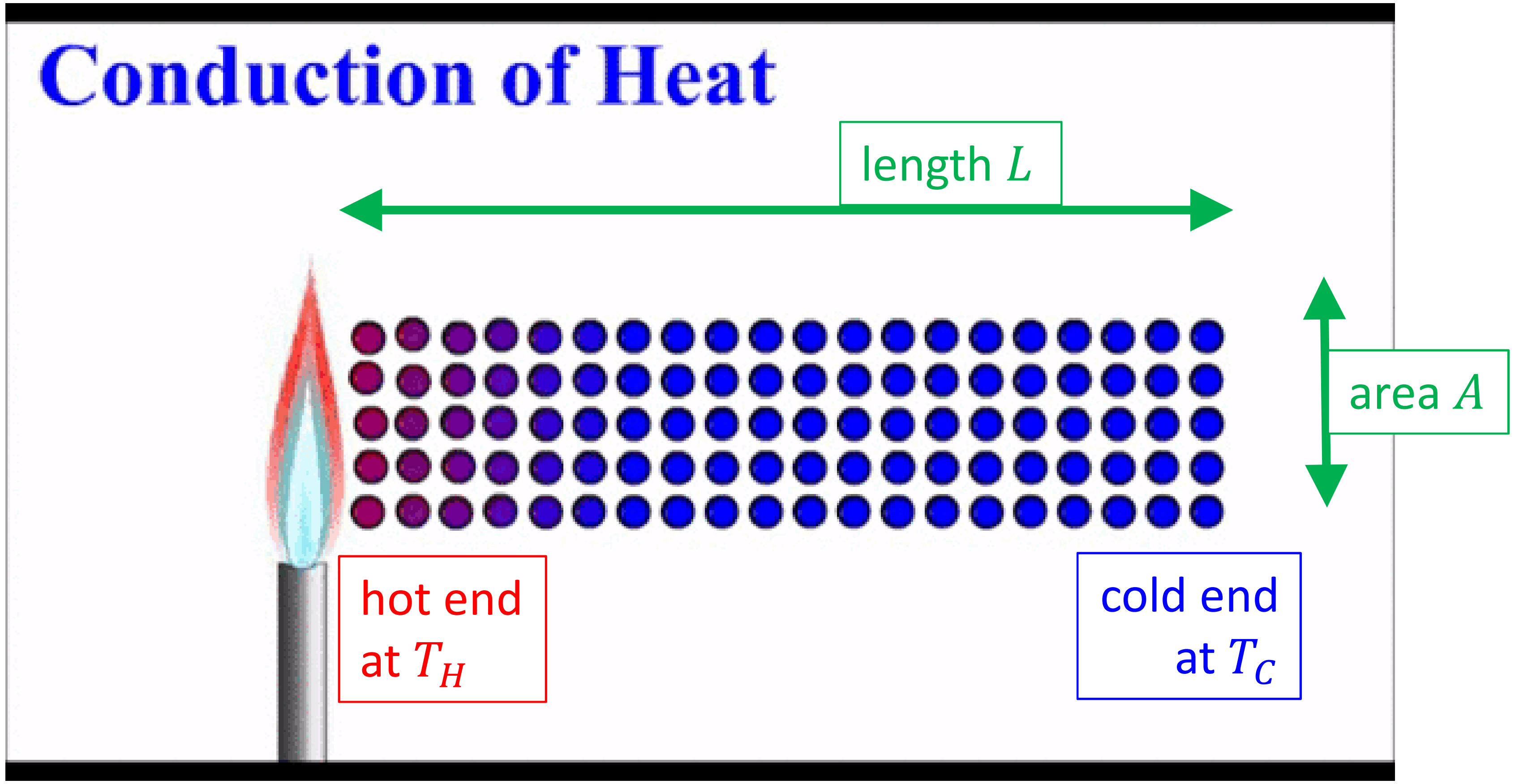


Heat transfer by conduction

- Think of a metal bar,
  one end is hot,
  the other end is cold

- The cold end will slowly warm up

- Heat is transferred from hot end to the cold end

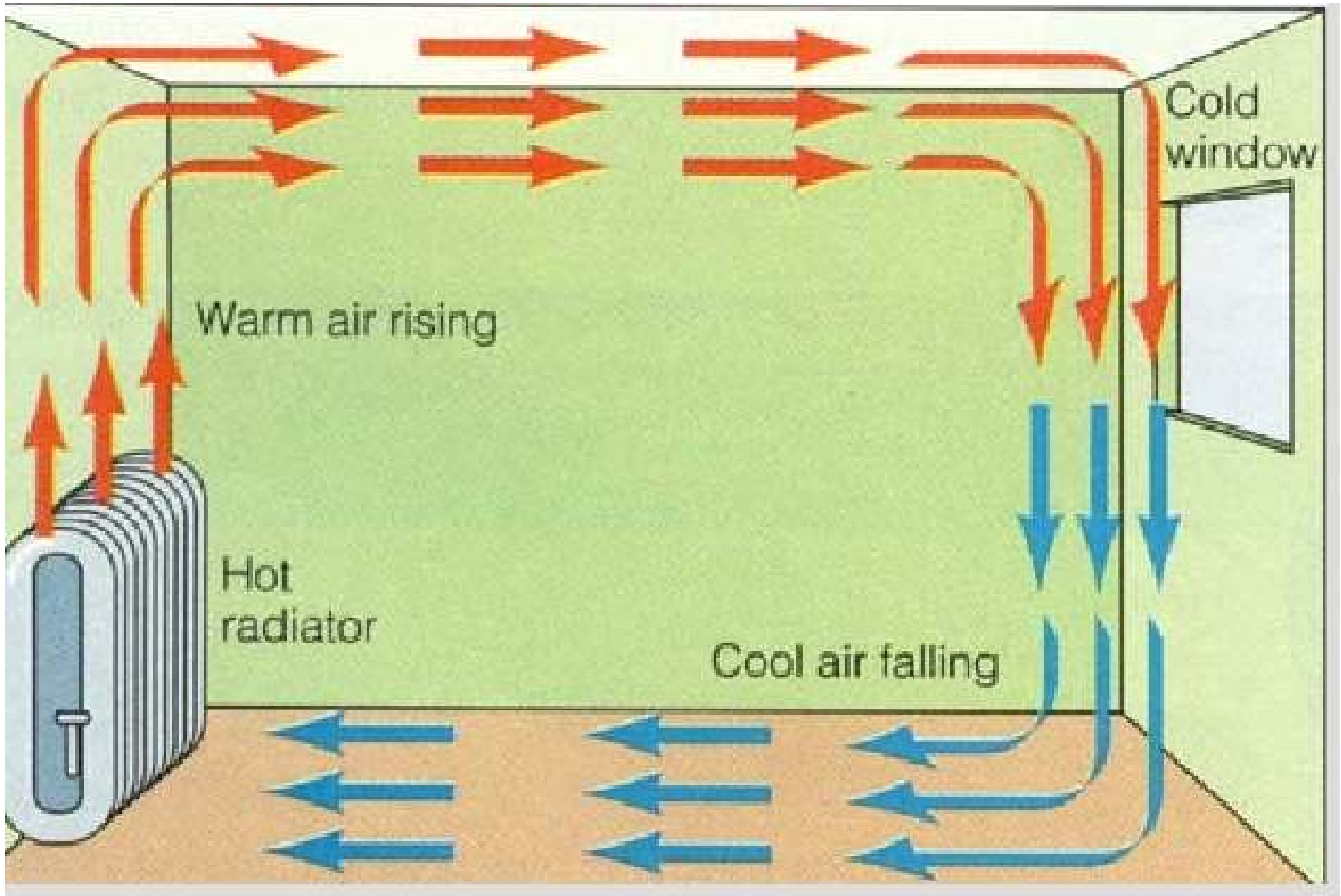


thermal conductivity k

Amount of energy that flows = energy/time = power = $P = \frac{kA}{L}(T_H - T_C)$

Heat transfer by convection

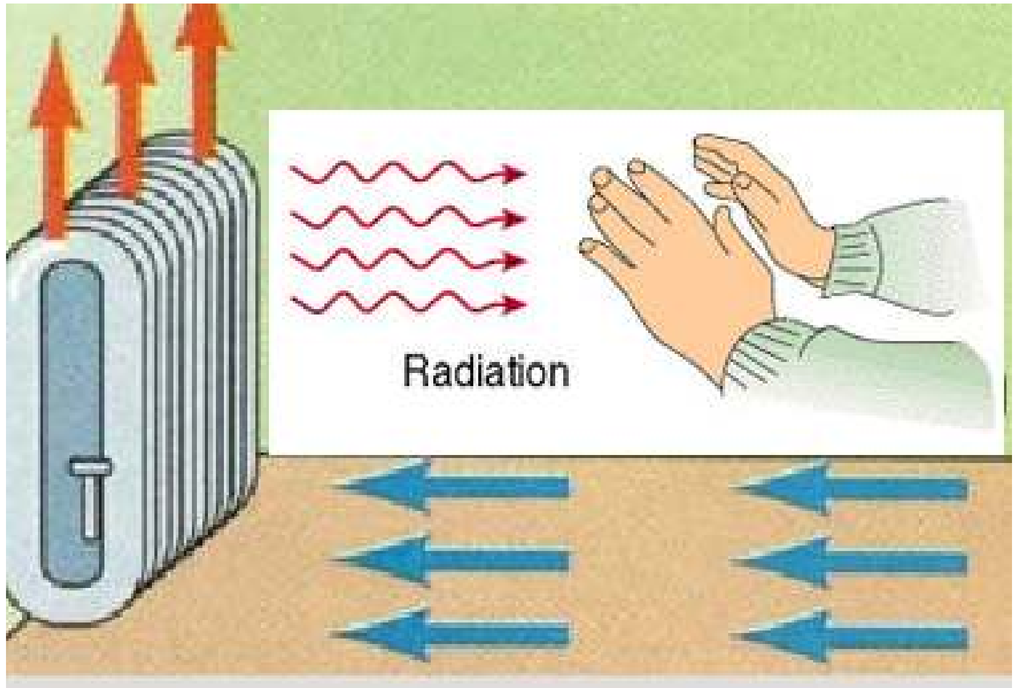
- Think of a radiator (that's on)
- Via conduction, it heats the air
- Hot air moves up because it's less dense
- The hot air touches the ceiling, and via conduction warms it up



No equation??? Nope, it's very complicated to calculate heat transfer by convection..

Heat transfer by thermal radiation

- Think of a radiator (that's on)
- At the top you feel hot air (that's convection!)
- In front of the radiator you feel "heat (thermal) radiation".



Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/m²

emissivity ε (how shiny it is)

Amount of energy that is radiated
from an object at temperature T = energy/time = power = $P = A\varepsilon\sigma T^4$

Emissivity, ε

- The rate at which heat is radiated from an object depends on its emissivity.

- Black objects both absorb and emit heat at a higher rate than shiny objects.

Very, very black object: $\varepsilon \approx 1$ (absorbs AND emits as much as possible)
Very, very shiny object: $\varepsilon \approx 0$ (absorbs AND emits almost nothing)

Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/m²

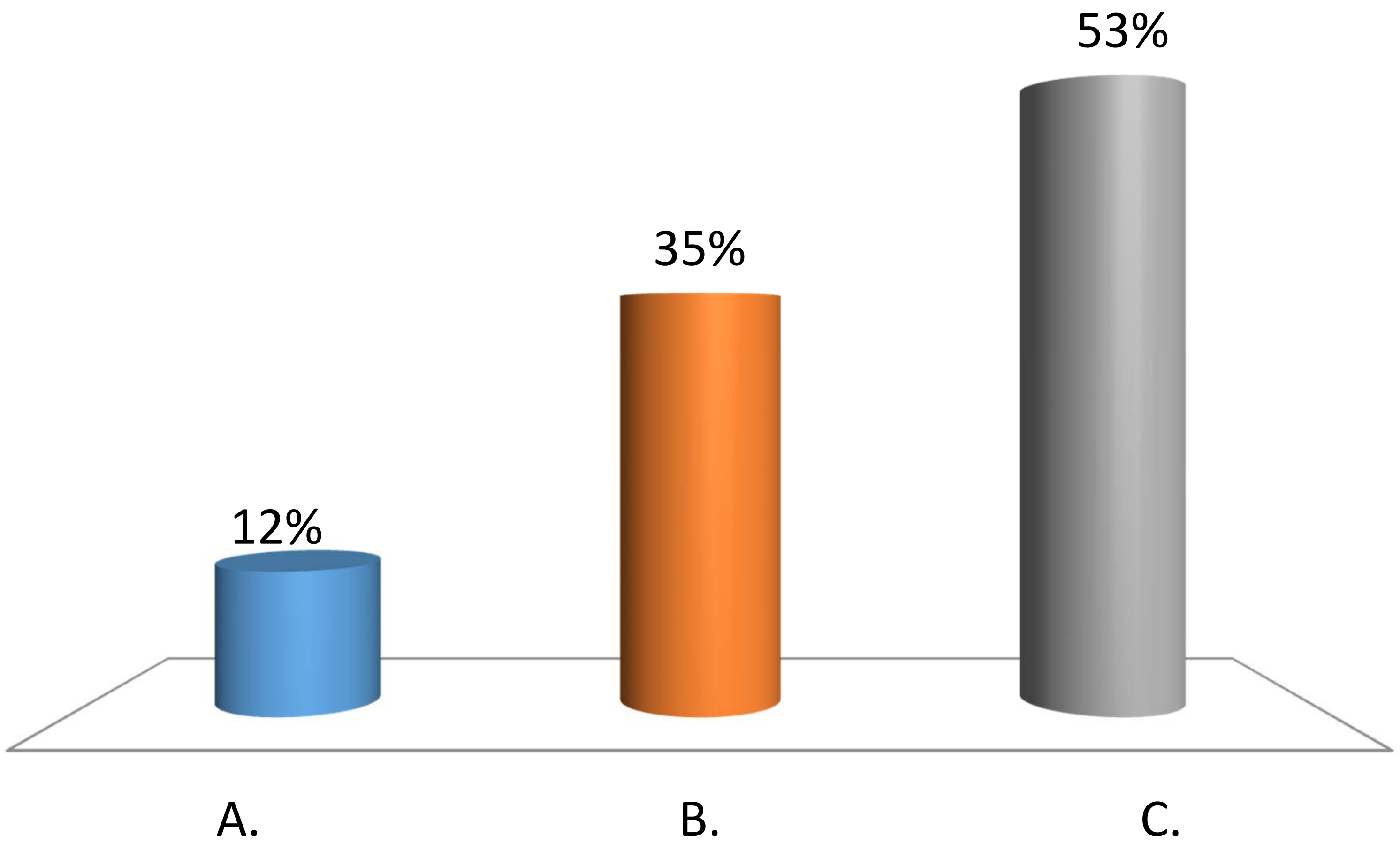
emissivity ε (how shiny it is)

Amount of energy that is radiated
from an object at temperature T = energy/time = power = $P = A\varepsilon\sigma T^4$

Which one cools faster?

If we add boiling water to both a black and a silver bottle, which bottle cools down faster?

A. Both cool down at the same rate
B. Black one cools down faster
C. Silver one cools down faster



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Very, very black object: $\varepsilon \approx 1$ (absorbs AND emits as much as possible)
Very, very shiny object: $\varepsilon \approx 0$ (absorbs AND emits almost nothing)

Black bottle emits more heat radiation: $P = A\varepsilon\sigma T^4$

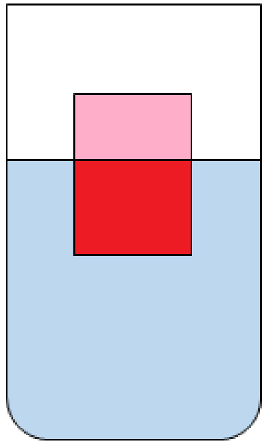
Review: Fluids

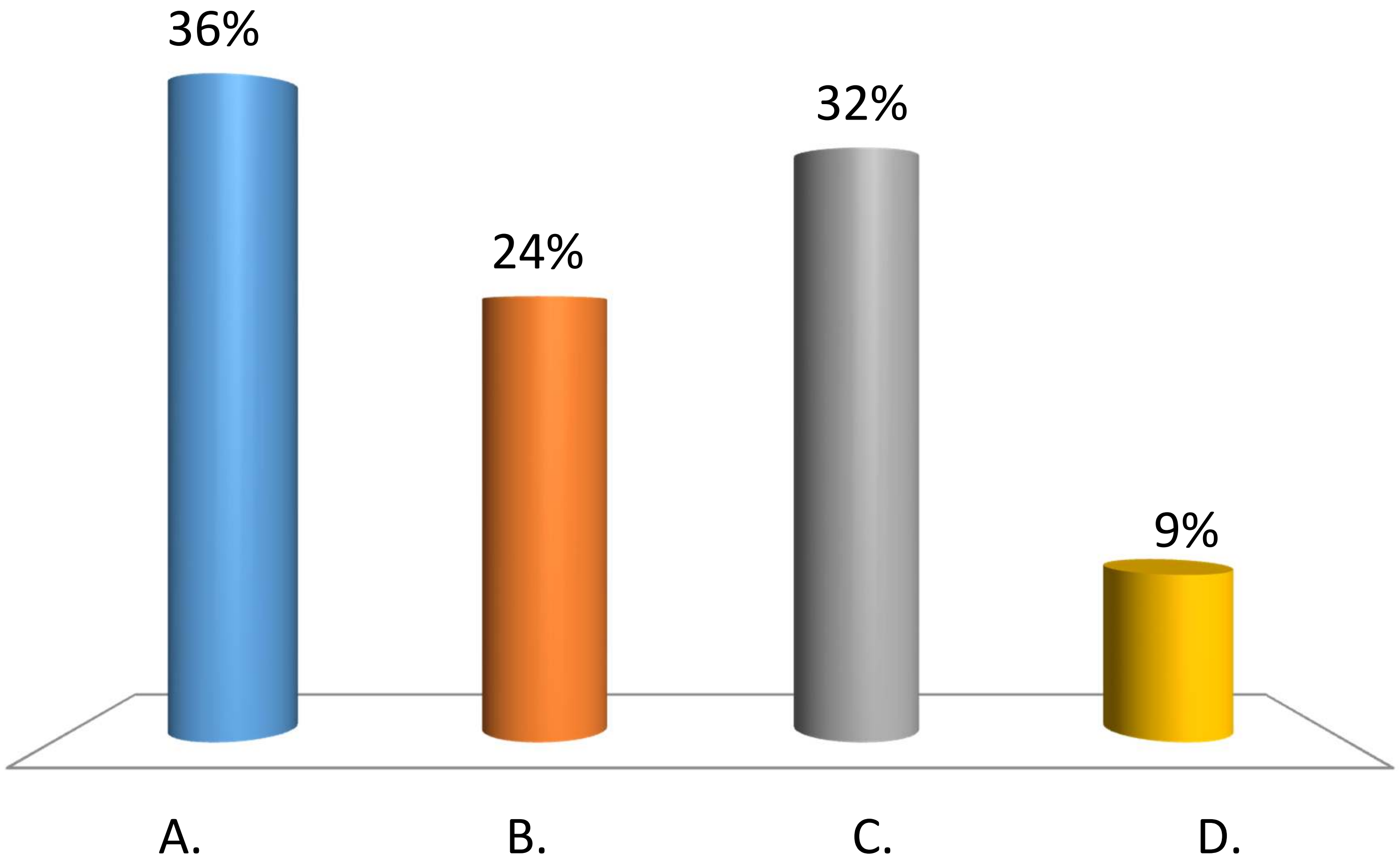
How large is the buoyant force here?

A. About 3500 N
B. About 5000 N
C. About 7000 N
D. About 10000 N

Block made of plastic (density 700 kg/m3)
Block has mass 700 kg
Block has volume of 1 m^3
Block has 50% under water
Water has density 1000 kg/m^3
$g = 10\ m/s^2$

$$F_B = \rho_f g V_{sub}$$





How large is the buoyant force here?

A. About 3500 N

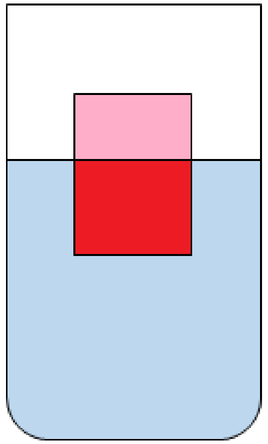
B. About 5000 N

C. About 7000 N

D. About 10000 N

- Take the density of the fluid (the water):
  - $\rho_f = 1000$ kg/m3
- We got $g = 10$ m/s^2
- Take the volume that is "submerged" (under water):
  - $V_{sub} = 50\%\text{ of }1\text{ m}^3 = 0.5\text{ m}^3$
- Buoyant force is: 1000 × 10 × 0.5 = 5000 N

Block made of plastic (density 700 kg/m3)
Block has mass 700 kg
Block has volume of 1 m^3
Block has 50% under water
Water has density 1000 kg/m^3
g = 10 m/s^2



$$F_B = \rho_f g V_{sub}$$

- If you have any fluid questions – feel free to interrupt and ask!

How large is the absolute pressure at this depth?

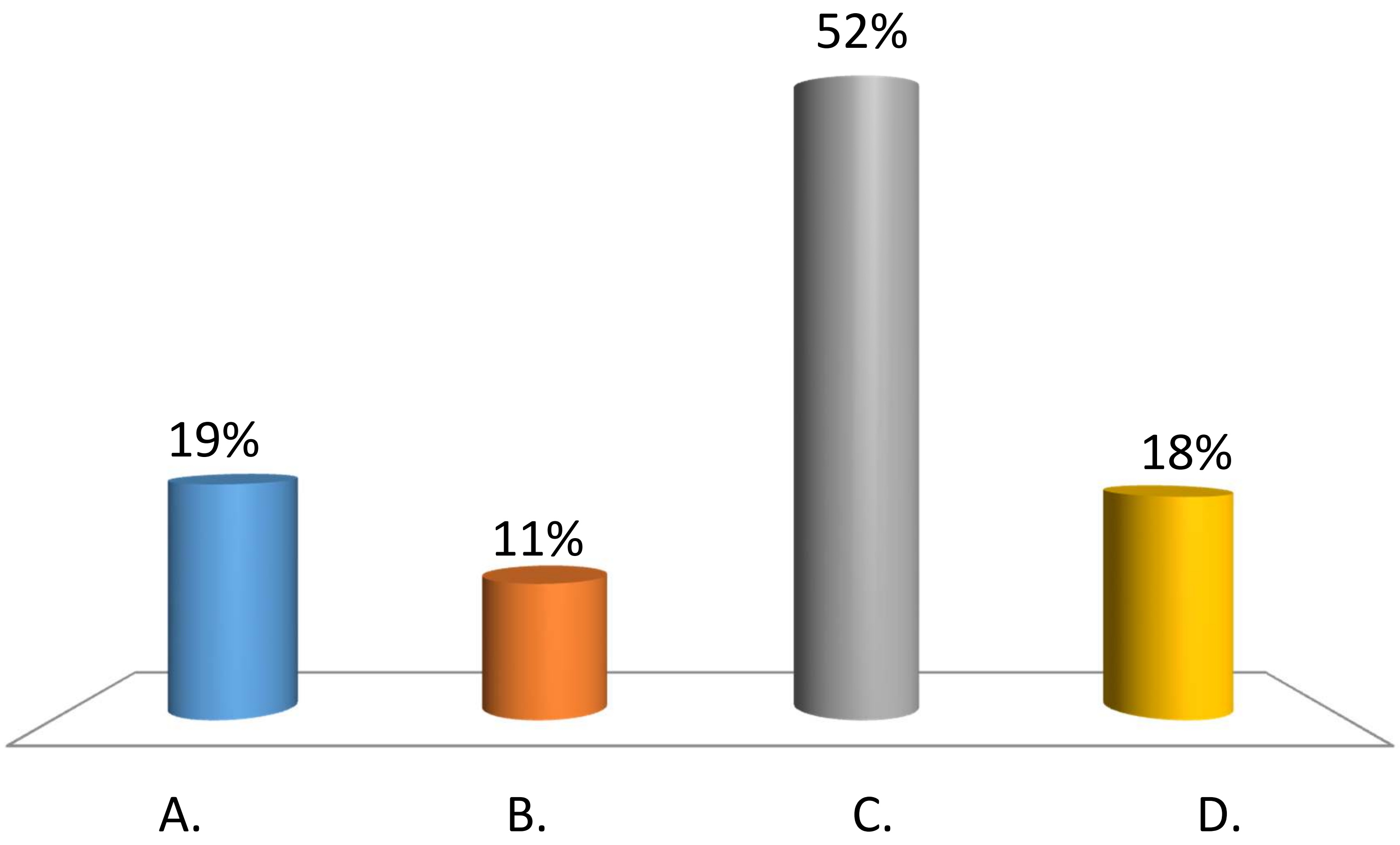
Consider a diver 3 meter below water surface.

Atmospheric pressure is 100 kPa.

Density of water is 1000 kg/m3

$g = 10\ m/s^2$

A. About 30,000 Pa
B. About 100,000 Pa
C. About 130,000 Pa
D. About 300,000 Pa



$P = \rho g \Delta h$

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Consider a diver 3 meter below water surface.

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Density of water is 1000 kg/m3

g = 10 m/s^2

A. About 30,000 Pa
B. About 100,000 Pa
C. About 130,000 Pa
D. About 300,000 Pa

Absolute pressure = weight of water + atmosphere

$P = \rho g \Delta h$

How large is the gauge pressure at this depth?

Consider a diver 3 meter below water surface.

Atmospheric pressure is 100 kPa.

Density of water is 1000 kg/m3

$g = 10\ m/s^2$

A. About 30,000 Pa
B. About 100,000 Pa
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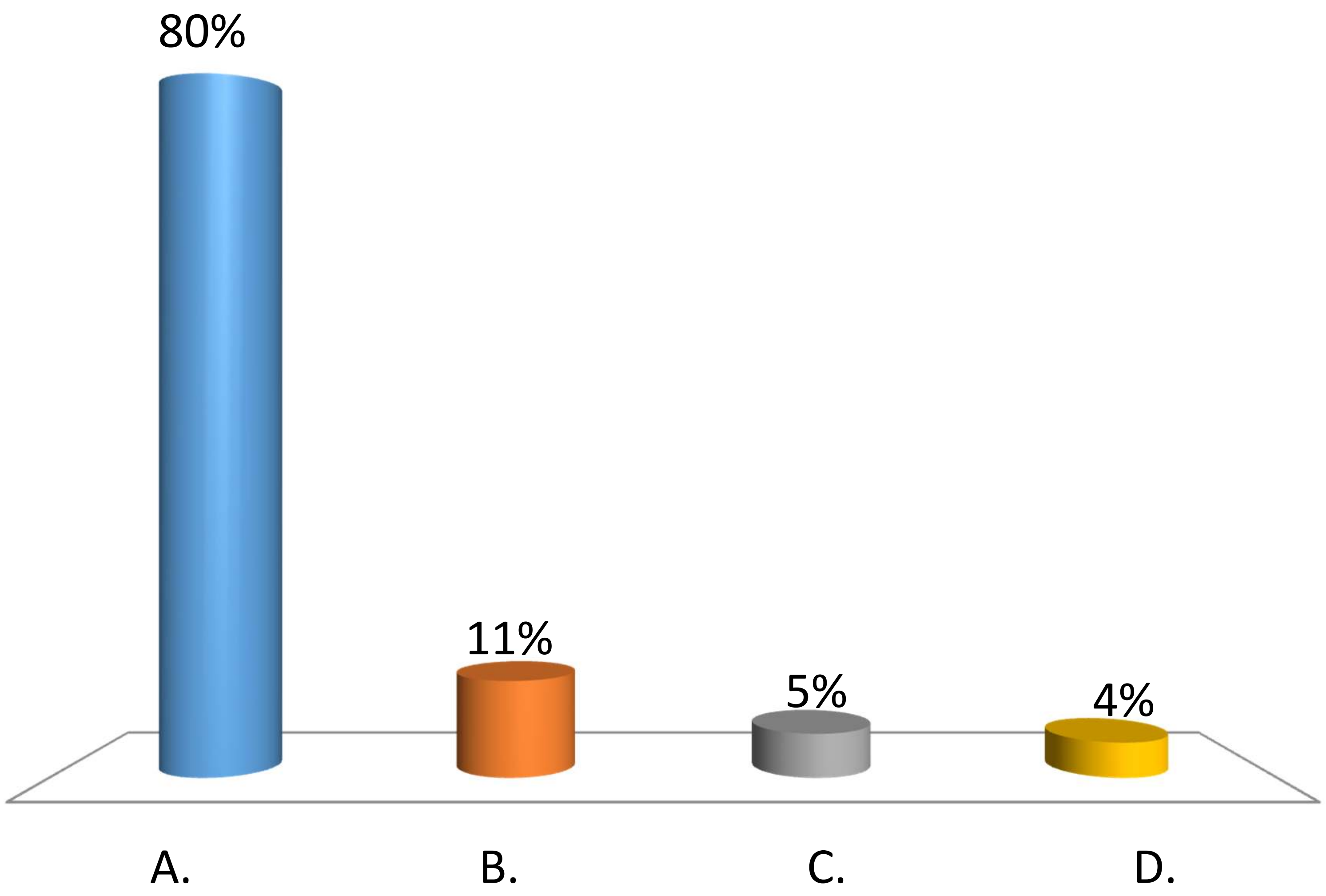

$P = \rho g \Delta h$

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Atmospheric pressure is 100 kPa.

Density of water is 1000 kg/m3

g = 10 m/s^2

A. About 30,000 Pa
B. About 100,000 Pa
C. About 130,000 Pa
D. About 300,000 Pa

Absolute pressure = weight of water + atmosphere

Gauge pressure = only the weight of water
= absolute pressure – atmospheric pressure

$P = \rho g \Delta h$

Gauge pressure vs. atmospheric pressure

$P = \rho g \Delta h = (1000)(10)(3)$

- The atmospheric pressure is approx. $P_{\mathrm{atm}} = 101{,}325$ Pa.
- The absolute pressure (or total pressure) on the diver is: weight of atmosphere + weight of water:

$$P_{\mathrm{abs}} = 100{,}000 \text{ Pa} + 30{,}000 \text{ Pa} = 130{,}000 \text{ Pa}$$

- The gauge pressure = total pressure – atmospheric pressure = 30,000 Pa
-

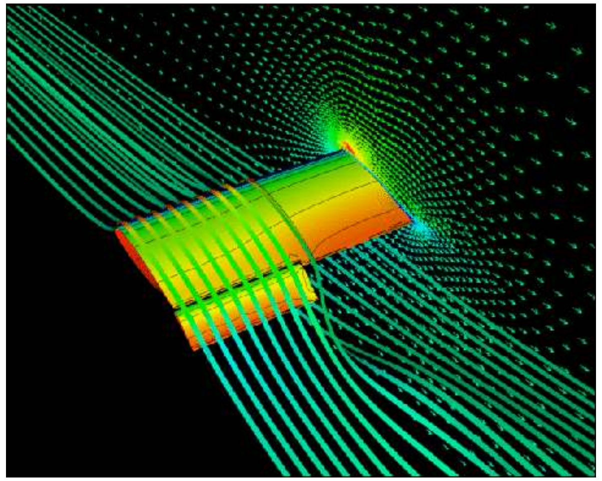
a gauge

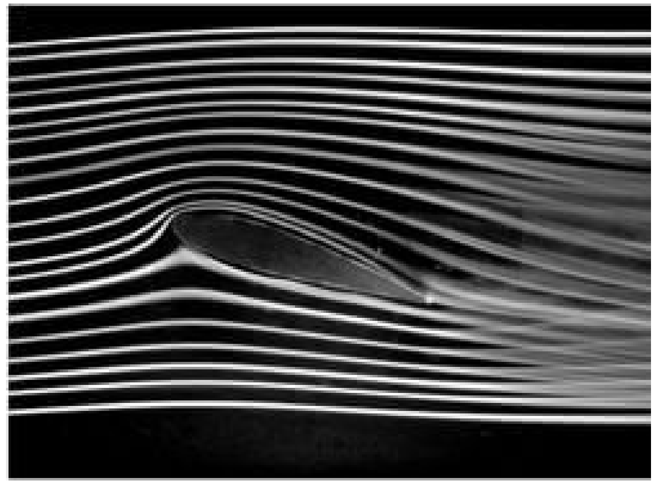
Streamlines

- How should you visualize a moving fluid?

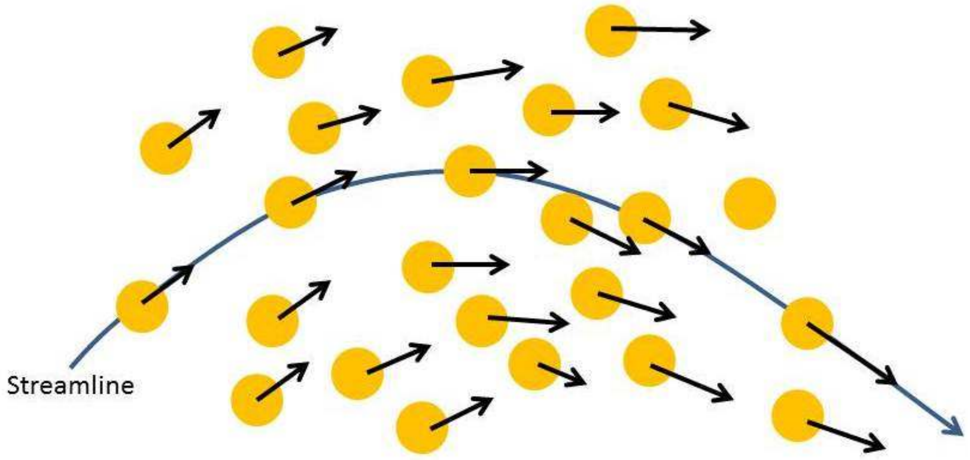
- When I say "imagine a fluid flowing through a pipe" what should you think of?

streamline = path taken by particles in the fluid





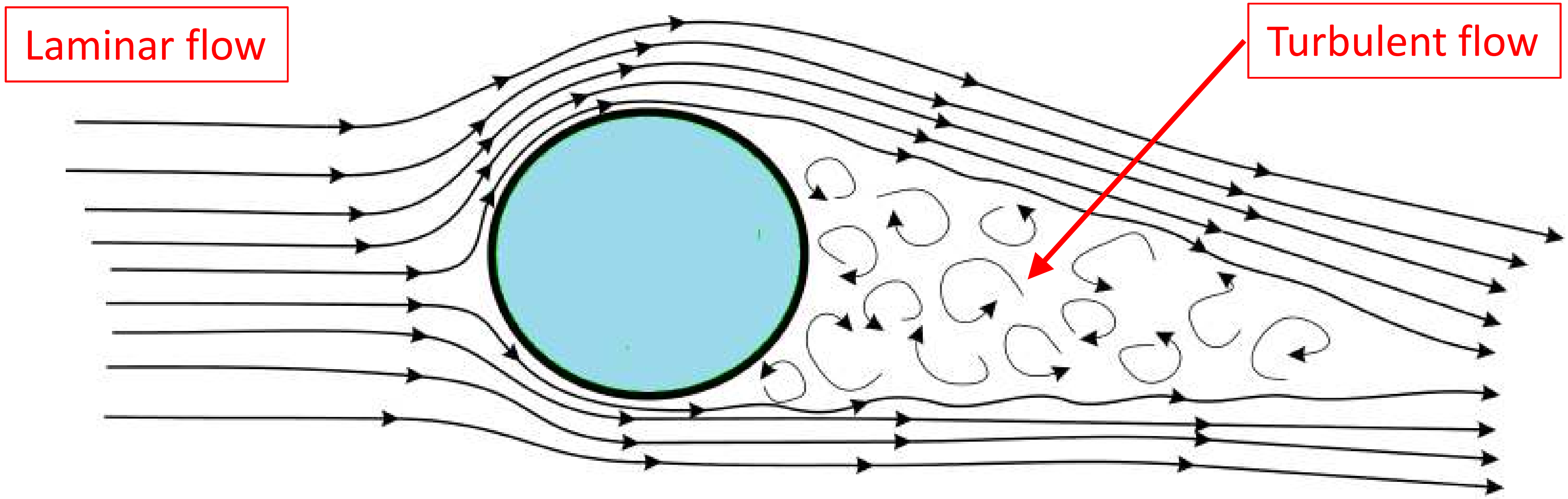
streamlines around airplane wing



Laminar flow vs. turbulent flow

Fluids typically flow in two distinct ways:

- Laminar flow (in nice, steady layers)
- Turbulent flow (crazy weird and unpredictable)



Bernoulli's equation

- Consider two points in the fluid: point 1 and point 2.

- Assume that:
  - Laminar flow (flow is steady and without any rotation – no swirls or eddies)
  - Flow is incompressible (density of fluid is constant) [uhum, sometimes we'll ignore this a little...]
  - Fluid is non-viscous – more like water and not like honey (no energy lost via friction)

- In that case:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Don't be scared! Often most terms are zero! :-)

What is the first step when using Bernoulli's Equation?

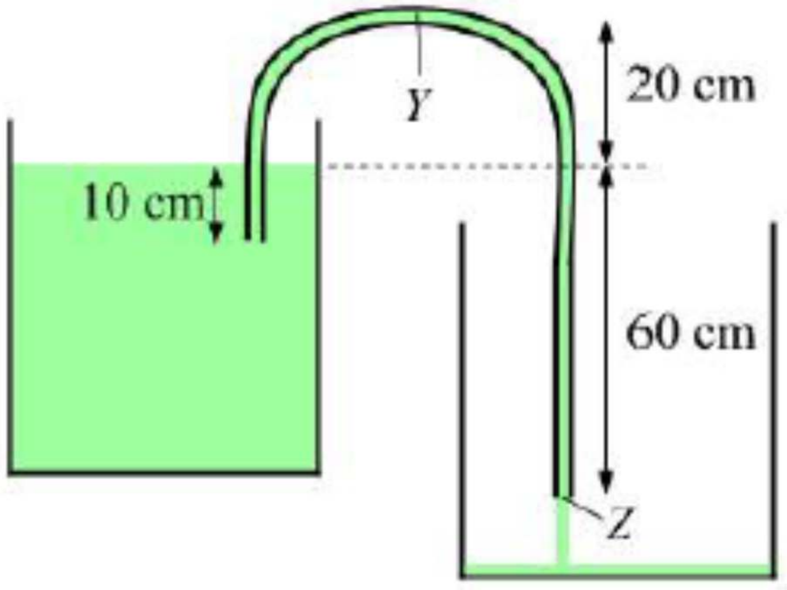
A. Plug in all the values!

B. Identify two points that are relevant to the problem.

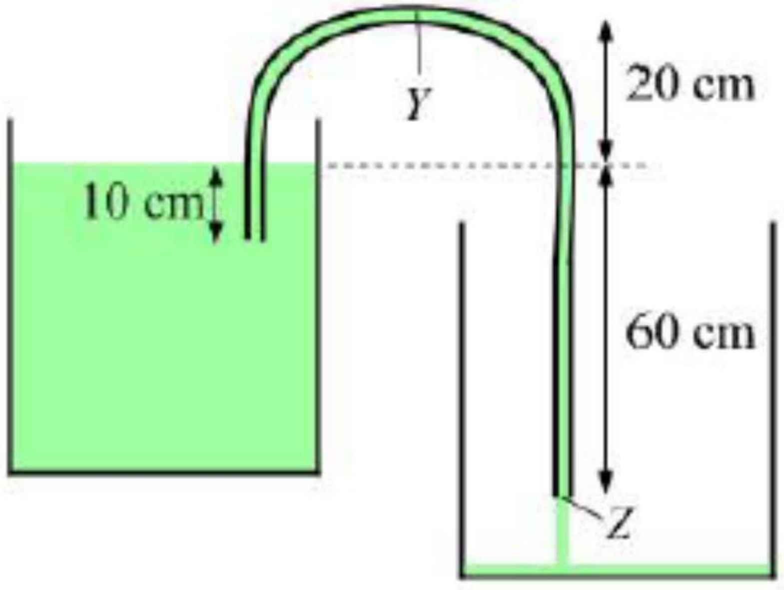
C. Determine which terms in the equation are zero.

Homework 11, problem 5

A flexible tube can be used as a simple siphon to transfer fluid from one container to a lower container. The fluid has a density of 800 kg/m3. See the dimensions given in the figure, and take atmospheric pressure to be 101.3 kPa. (If you need it, use g = 9.8 m/s2.)



Homework 11, problem 5



A flexible tube can be used as a simple siphon to transfer fluid from one container to a lower container. The fluid has a density of 800 kg/m3. See the dimensions given in the figure, and take atmospheric pressure to be 101.3 kPa. (If you need it, use g = 9.8 m/s2.)

(a) If the tube has a cross-sectional area that is much smaller than the cross-sectional area of the higher container, what is the speed of the fluid at point *Z*?

Answer: use Bernoulli's Eq.

$$\boxed{P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2}$$

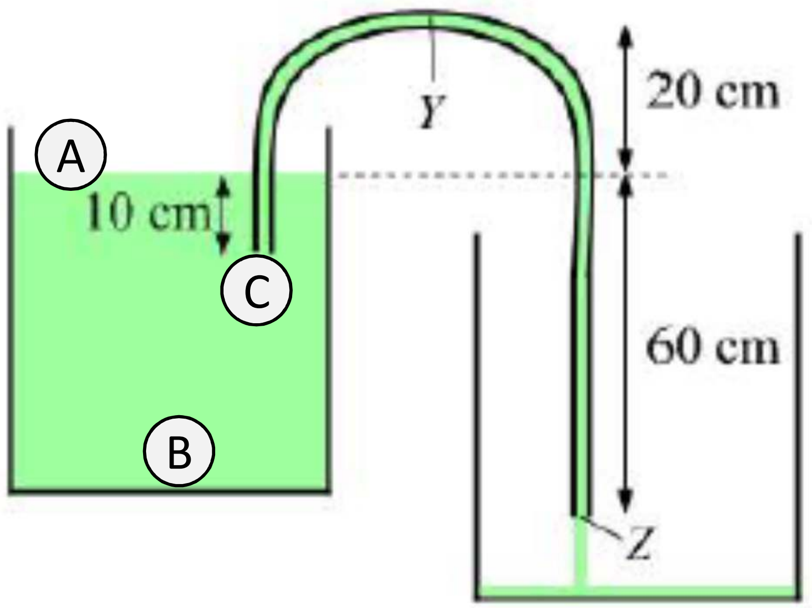
But how do you choose your two points???

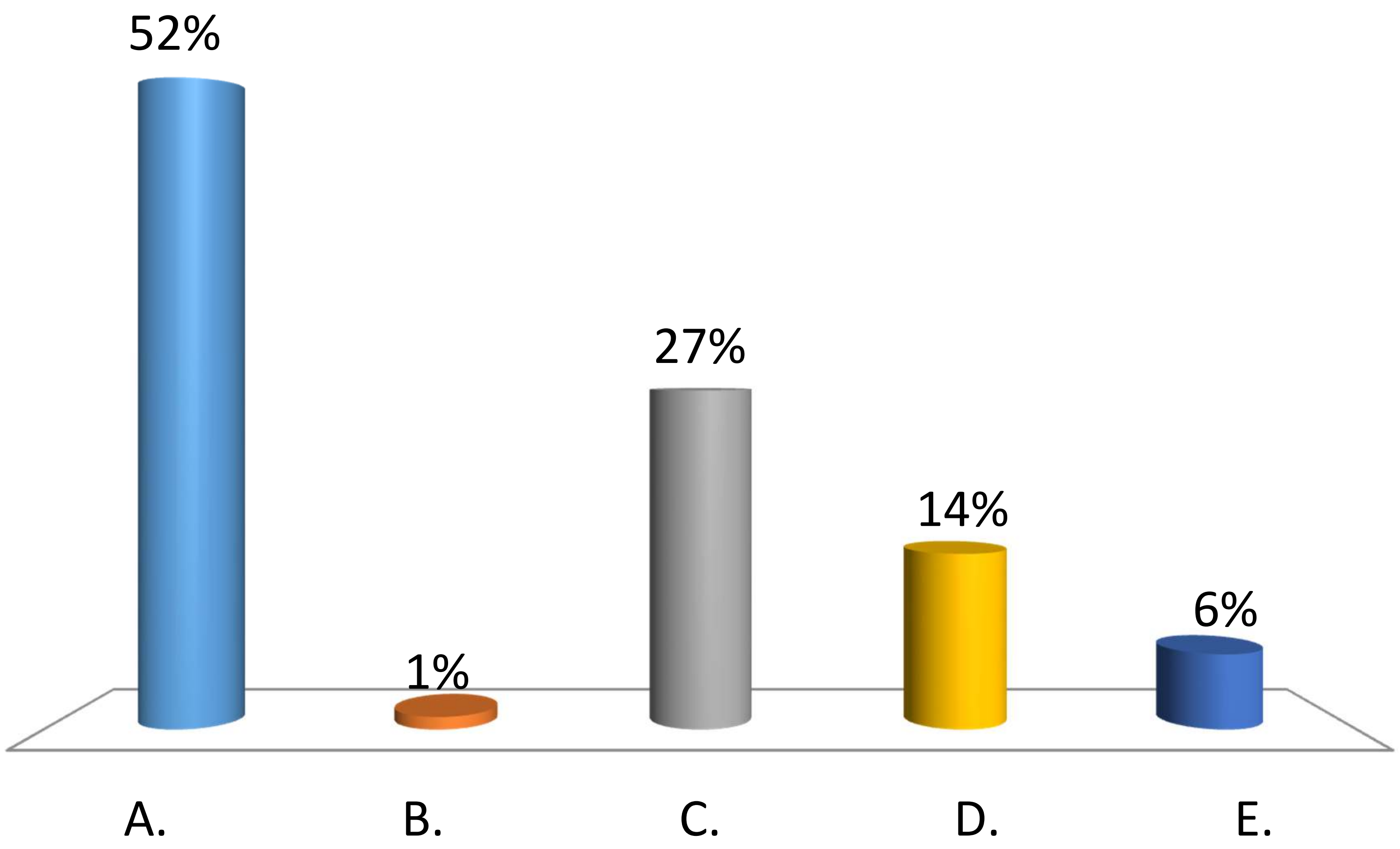
Point 1 is a often your "reference point" and point 2 is where you want to know P, v, or h.

Good reference points are those where you already know P, v, or h (or where they're approximately zero).

Which point would be a good "reference point"?

A. Point A
B. Point B
C. Point C
D. Point Y
E. Point Z





$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Which point would be a good "reference point"?

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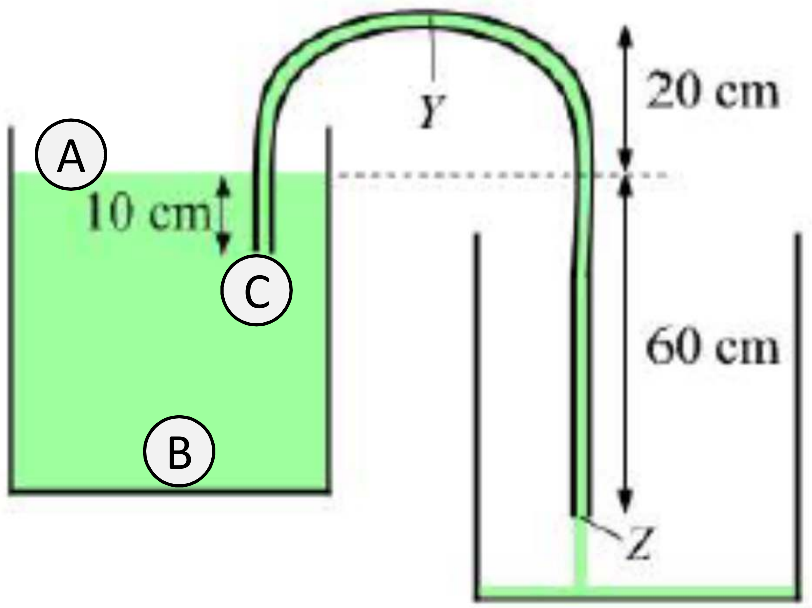


Make point A your "point 1"

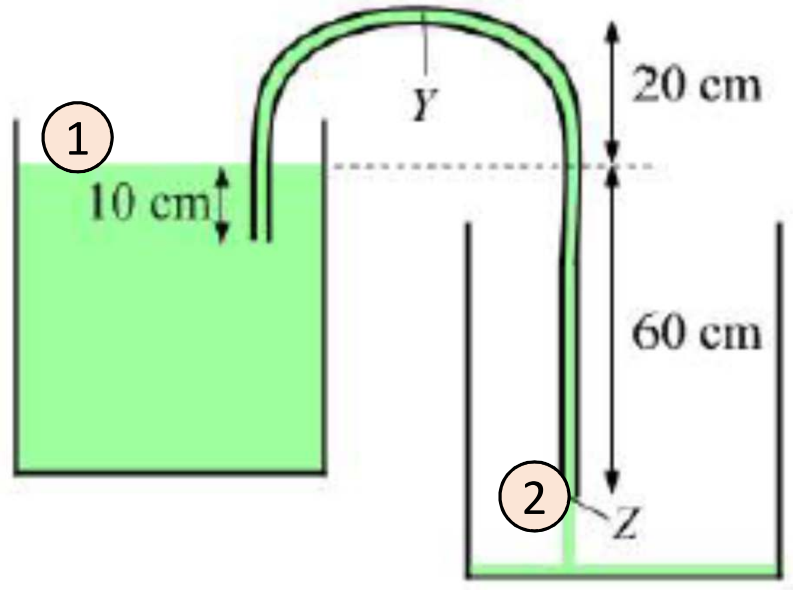
Because at that point you know everything:
$P_1 = P_{atm}$
$v_1 \approx 0$ (if cross section tank >> tube size)
$h_1 = h_Z + 60\text{ cm}$

Point 2 = point Z, because they want to know
the speed of the fluid at point *Z*

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Homework 11, problem 5

A flexible tube can be used as a simple siphon to transfer fluid from one container to a lower container. The fluid has a density of 800 kg/m3. See the dimensions given in the figure, and take atmospheric pressure to be 101.3 kPa. (If you need it, use g = 9.8 m/s2.)



(a) If the tube has a cross-sectional area that is much smaller than the cross-sectional area of the higher container, what is the speed of the fluid at point *Z*?

Answer: use Bernoulli's Eq.

$$\boxed{P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2}$$

$$P_{atm} + \frac{1}{2}\rho(0)^2 + \rho g(0.60) = P_{atm} + \frac{1}{2}\rho v_2^2 + \rho g(0)$$

Remember: if the fluid touches the air, it's at P_{atm}!

Which one cools faster?

If we add boiling water to both a black and a silver bottle, which bottle cools down faster?

A. Both cool down at the same rate
B. Black one cools down faster
C. Silver one cools down faster

Very, very black object: $\varepsilon \approx 1$ (absorbs AND emits as much as possible)
Very, very shiny object: $\varepsilon \approx 0$ (absorbs AND emits almost nothing)

Black bottle emits more heat radiation: $P = A\varepsilon\sigma T^4$

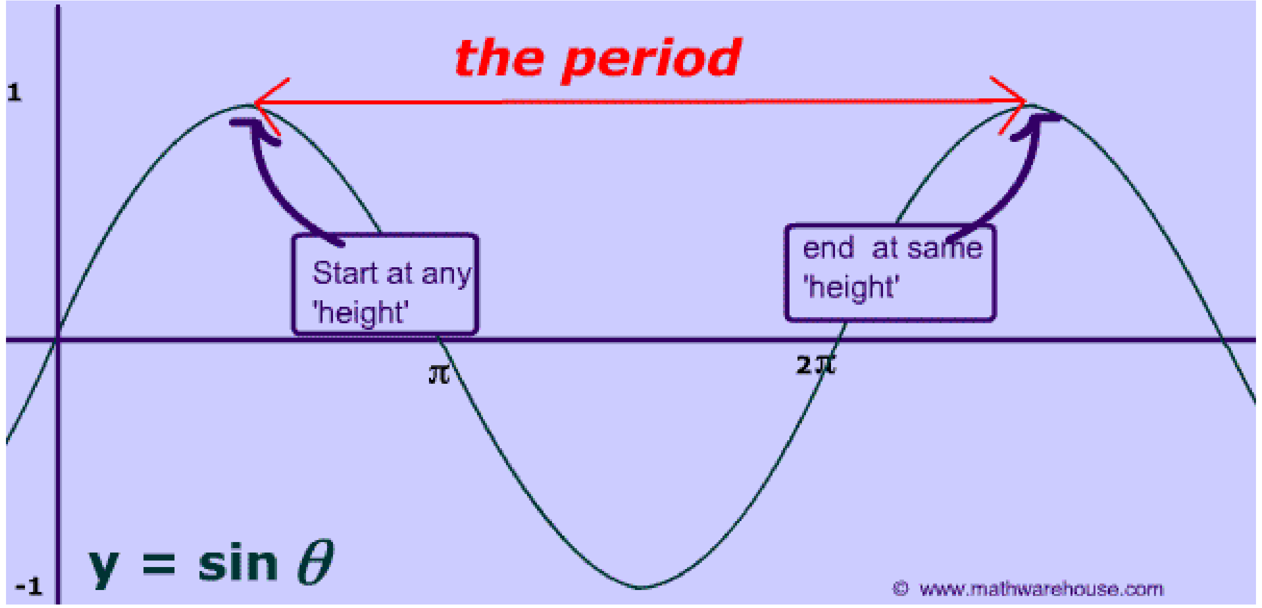
Review: Simple Harmonic Motion

Angular frequency ω, frequency f, period T

These all represent the same thing!!
(number of oscillations within a certain time)

- If you find one, you got the others! $\omega = 2\pi f$ $\omega = \frac{2\pi}{T}$ $f = \frac{1}{T}$

- Hint: often you can get the period T by
  - Read it off a graph
  - Figure it out from the text – for example:
    "a mass on spring bounces 4 times per minute"
    => 60 sec / 4 oscillations => period T = 15 sec

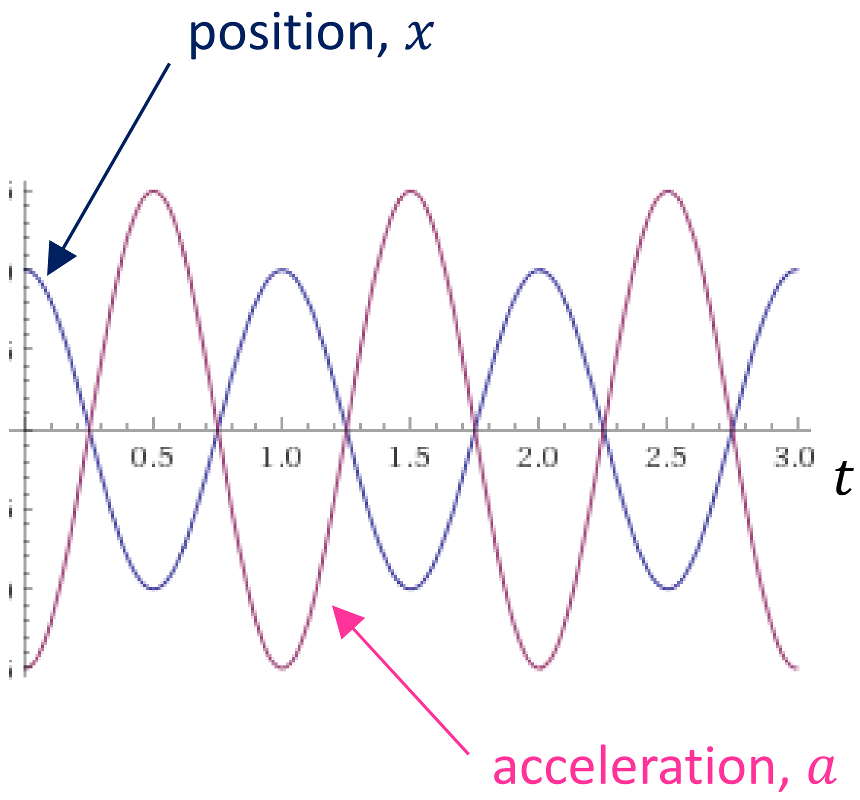


Simple Harmonic Motion

- Often when an object oscillates without friction, you find a special relationship between acceleration and position:

$$\vec{a}(t) = -\omega^2 \vec{x}(t)$$

  with ω a constant (the angular frequency).



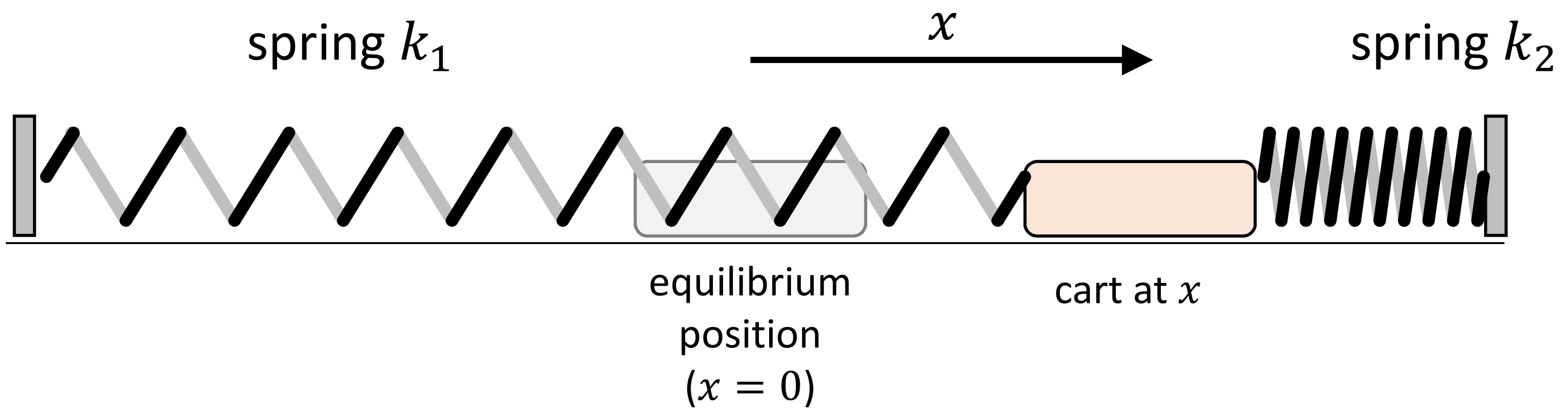
- Period is then given by: $T = 2\pi/\omega$

- For spring on a mass: $ma = -kx \quad \Rightarrow \quad \omega = \sqrt{k/m}$

- For simple pendulum: $ma \approx -mg\, x/L \quad \Rightarrow \quad \omega = \sqrt{g/L}$

Example of SHM: cart on two springs

A cart with mass M is connected to two springs, one with spring constant k_1, the other with constant k_2. When at rest, springs are not stretched. Ignore any friction. **Find the period T of the oscillation.**



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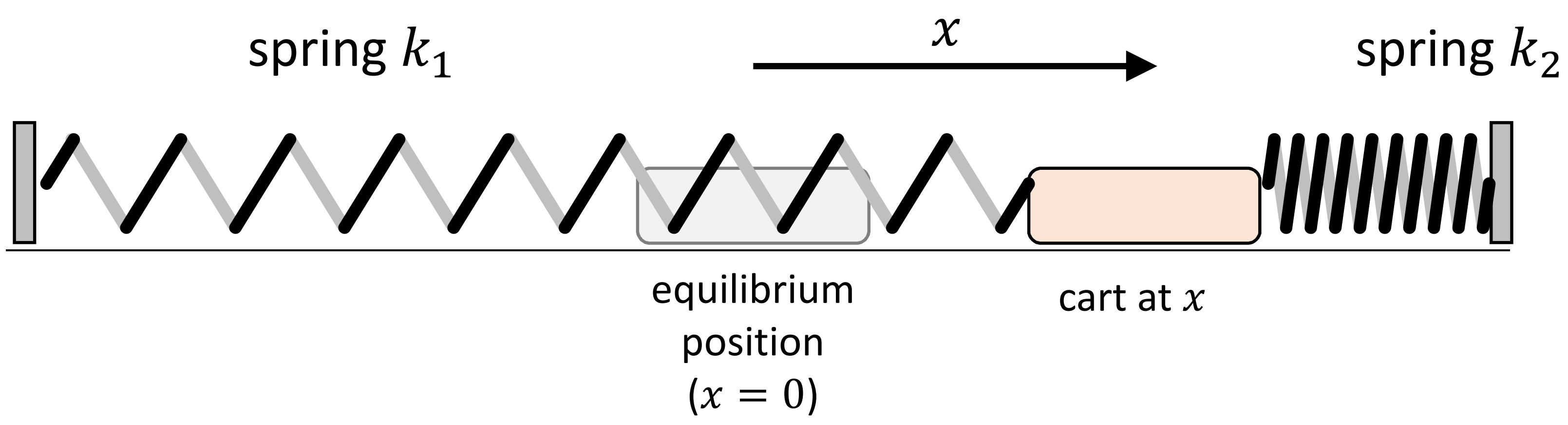
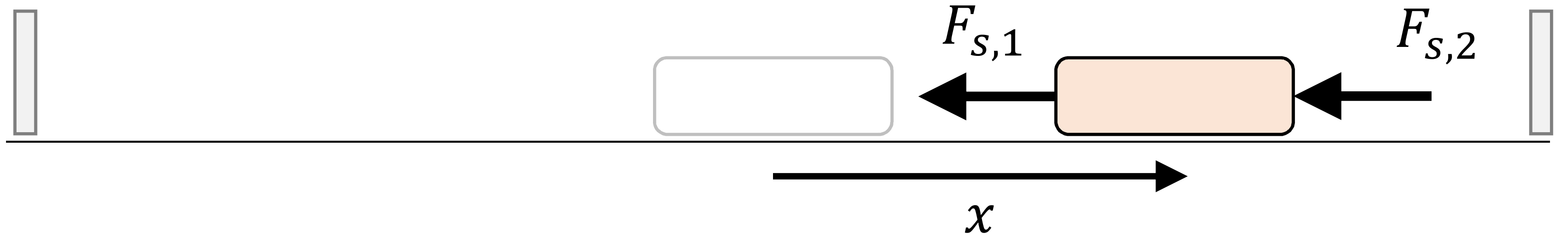
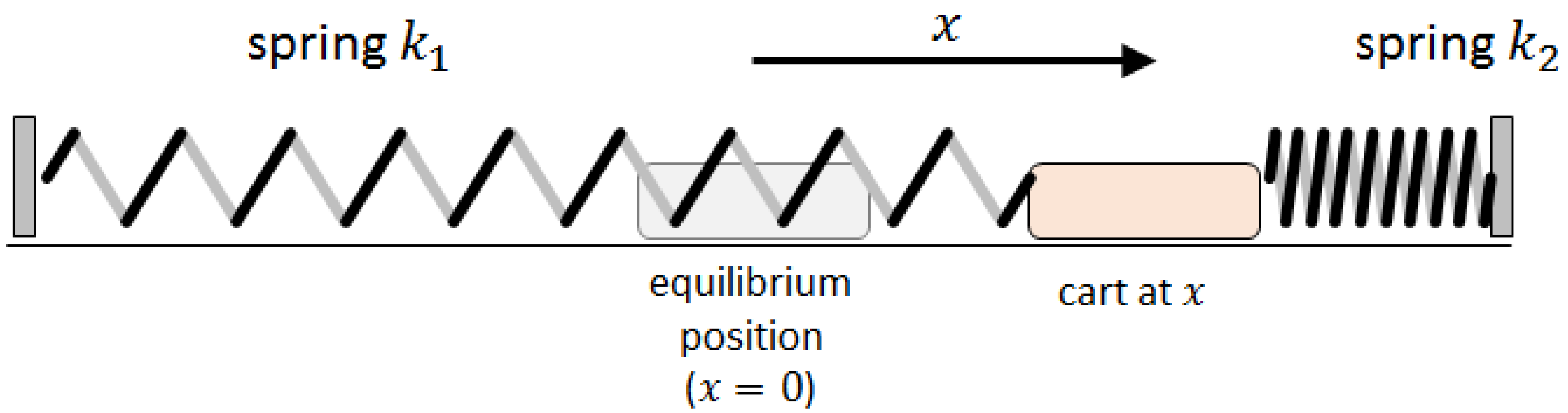
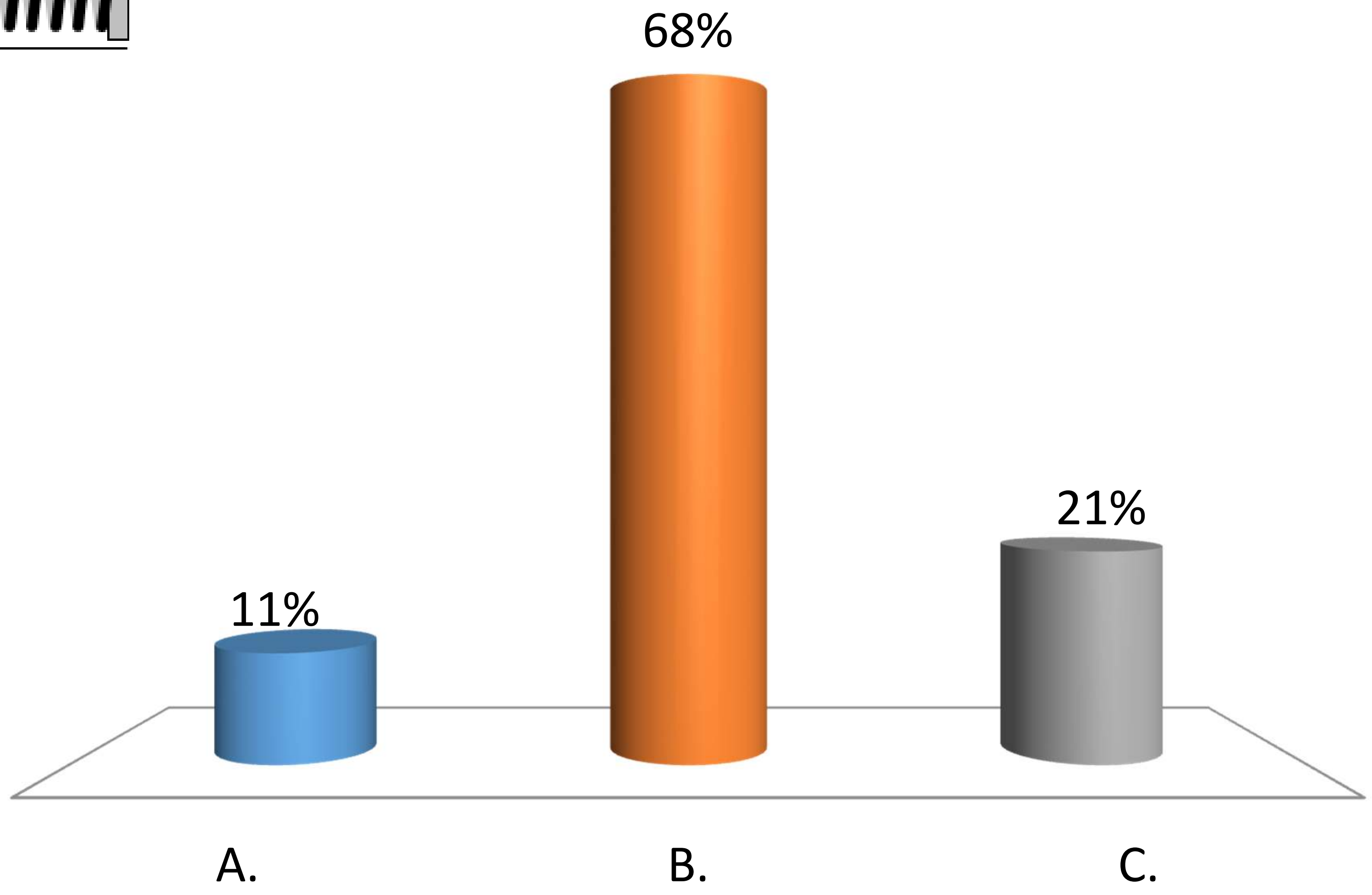


As always, start with a free-body diagram!



When the cart is at x, how much is spring 1 stretched?





A. Spring 1 is not stretched
B. Spring 1 is stretched by x
C. Spring 1 is stretched by $2x$

Remember: we assume that when $x = 0$ it's not stretched.

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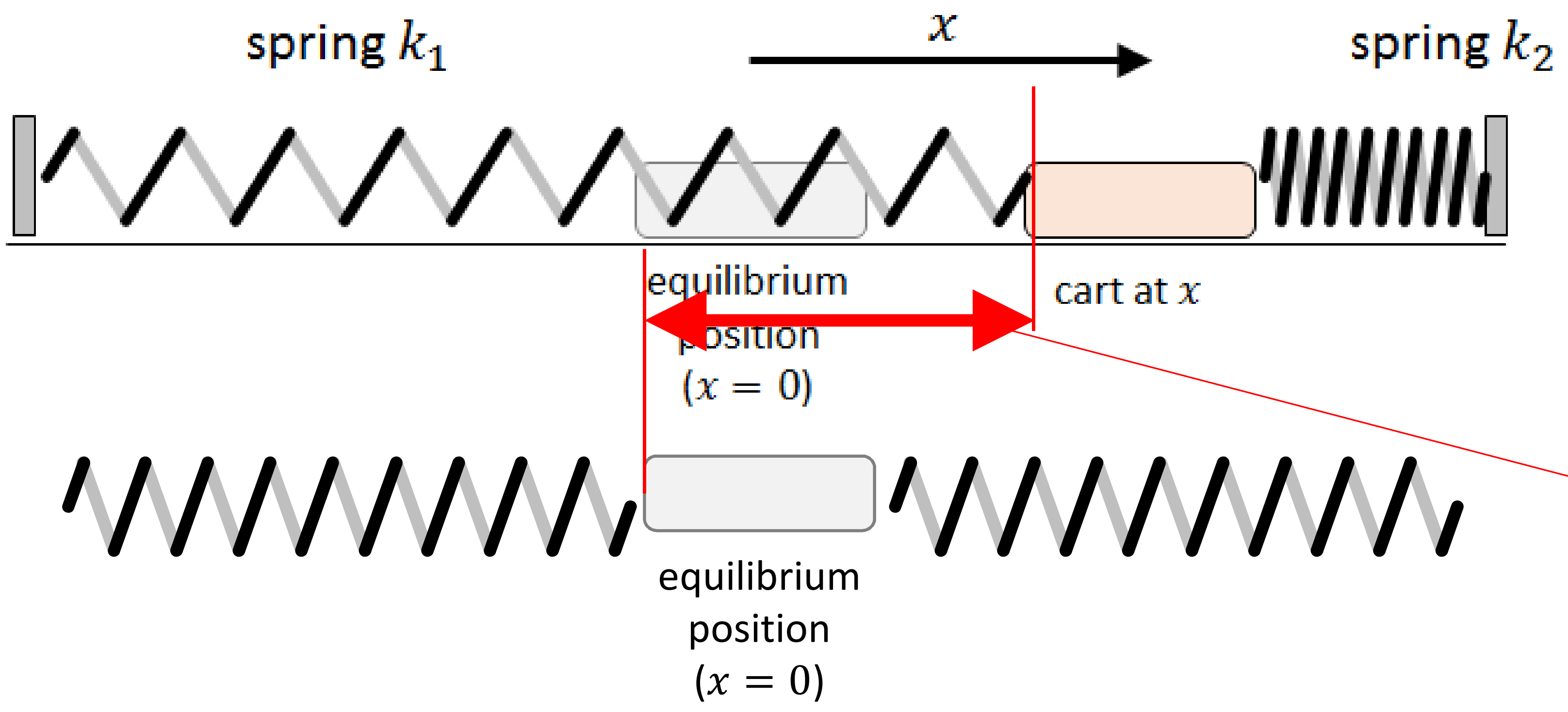

The amount spring 1 is stretched by, is exactly length x.

Therefore the force produced by this spring is $F_{s,1} = k_1 x$ with x the position of the cart.

A. Spring 1 is not stretched

B. Spring 1 is stretched by x

C. Spring 1 is stretched by $2x$

Same for spring 2: $F_{s,2} = k_2 x$

Remember: we assume that when $x = 0$ it's not stretched.

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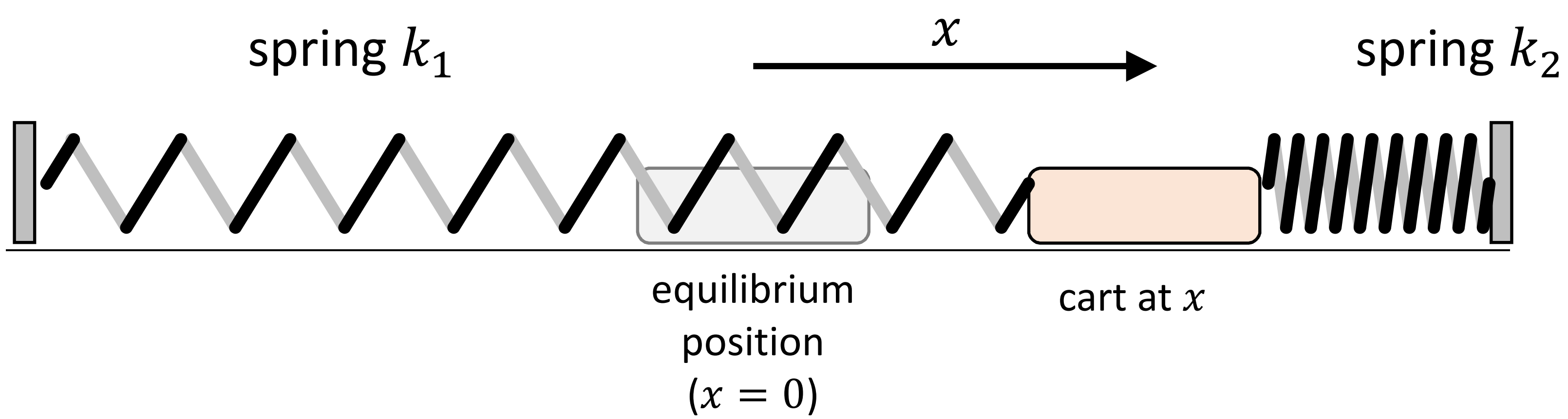

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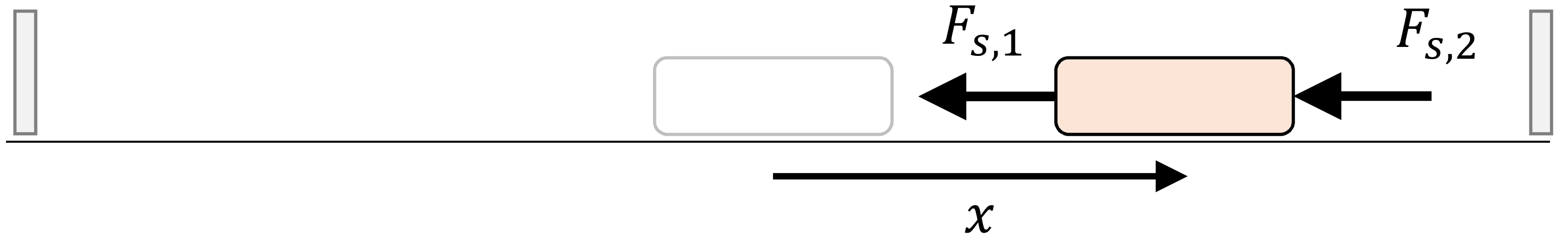

$$\Sigma F_x = -k_1\vec{x} - k_2\vec{x} = m\vec{a}$$

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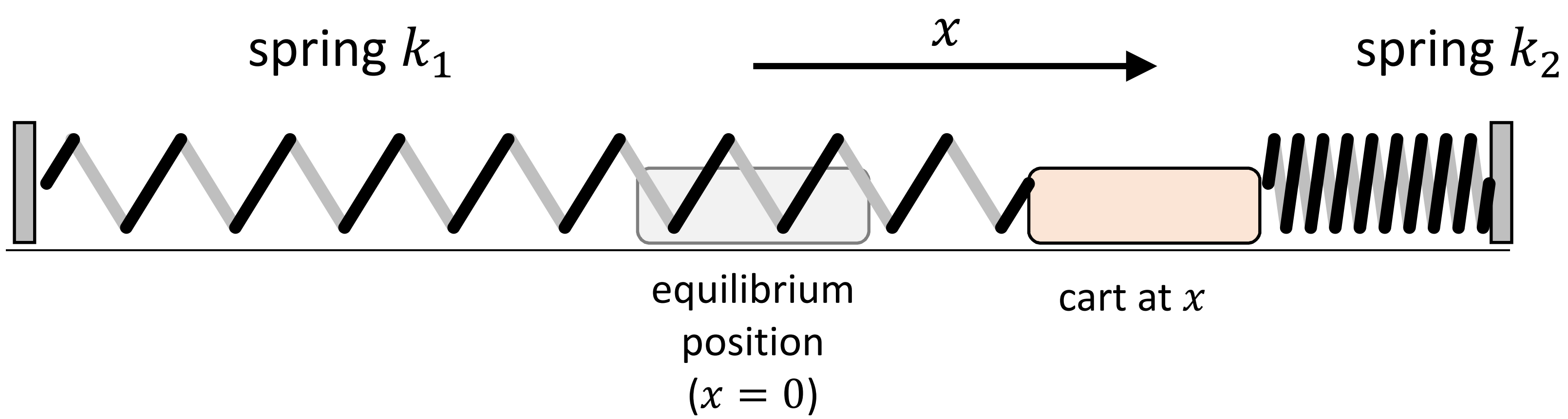

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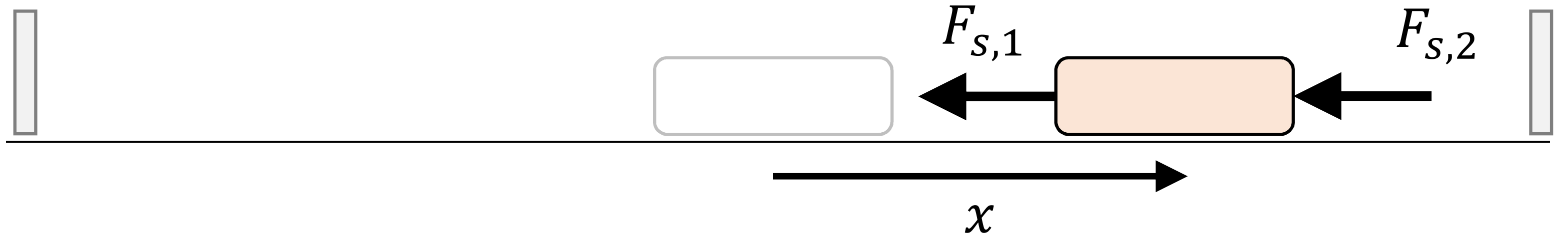

$$\Sigma F_x = -k_1\vec{x} - k_2\vec{x} = m\vec{a}$$

$$\vec{a} = -\left(\frac{k_1 + k_2}{m}\right)\vec{x} \quad \Rightarrow \quad \vec{a} = -\omega^2\vec{x} \quad with \quad \omega = \sqrt{\frac{k_1 + k_2}{m}}$$

Period $T = 2\pi/\omega$

Which one cools faster?

If we add boiling water to both a black and a silver bottle, which bottle cools down faster?

A. Both cool down at the same rate

B. Black one cools down faster

C. Silver one cools down faster

Very, very black object: $\varepsilon \approx 1$ (absorbs AND emits as much as possible)
Very, very shiny object: $\varepsilon \approx 0$ (absorbs AND emits almost nothing)

Black bottle emits more heat radiation: $P = A\varepsilon\sigma T^4$

- Let me know if you have any questions

- See you in office hours!
  - Mon 4-6pm
  - Tue 3-6pm

Thank you!

See you next time: Wednesday May 3rd at 2:30pm