Physics 5B - Winter 2022 - Quiz 3

Name (please print): Hermione Granger

UID: 27183

Lecture Section, 3 (1PM) or 4 (3PM): 3

Instructions

- You will independently be given points for your reasoning, your mathematical work, and for correctness of answers, so make sure to **show your reasoning and work** even if you're not certain you can compute the correct answer. Try to **convey your solution strategy even if you can't execute it in time**.
- If on a given problem you need some space to do scratch work, do that scratch work elsewhere. **Only the work that is included on this test packet in the space provided will be graded.**
- Place final numerical answers, if any, in the box at the end of the space provided for the problem.
- Don't worry about significant figures or precision of final numerical answers. Don't worry about roundoff errors. As long as numerical answers are reasonable close to the correct answer and your process is correct, you will get full credit for numerical answers.

Academic Conduct Acknowledgement

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Please sign here: HG

Faaizah is a medical researcher who needs to measure the speed v of the blood flow in a certain section of a horizontally-oriented blood vessel of length $L = 10\,\text{cm}$ and cross-sectional radius $R = 2\,\text{mm}$. Having taken Physics 5B, she realizes that there's a way to determine the desired blood flow speed in terms of the pressure difference Δp between the two ends of the blood vessel. By treating the flow as viscous but incompressible, she is able to derive the following relationship between v and Δp (recall that $\eta = 2.5 \times 10^{-3}\,\text{Pa}\cdot\text{s}$ is the viscosity of blood):

$$v = \alpha \Delta p, \qquad \text{were} \quad \alpha = \frac{R^2}{8\eta L} \tag{1}$$

$L = 10\text{ cm} = 0.1\text{ m}$
$R = 2\text{ mm} = 0.002\text{ m}$
$\eta = 2.5\times10^{-3}\text{ Pa}$

1. Derive Faaizah's equation (1) using (i) Poiseuille's equation for viscous flow, (ii) an appropriate expression for volume flow rate, and (iii) a fact about circles. After deriving equation (1), use it to compute the numerical value of α (in SI units) for the blood vessel Faaizah is measuring.

Poiseuille's i)

$Q = \frac{\pi R^4}{8\eta L}\cdot\Delta P \Rightarrow \Delta P = \frac{Q\cdot 8\eta L}{\pi R^4}$

$\frac{Q\cdot 8\eta L}{\pi R^4}$

OR $Q = V_{av}\cdot A \Rightarrow Q = (\alpha\Delta P)\cdot(\pi(R)^2)$

$Q = \left(\frac{R^2}{8\eta L}\right)(\Delta P)\cdot\pi R^2 \Rightarrow \frac{8\eta L\cdot Q}{R^4\pi} = \Delta P$

ii) $Q = v\cdot A \Rightarrow Q = v\cdot\pi R^2$

$\frac{\pi R^4}{8\eta L} = v\cdot\pi R^2$

$\frac{\pi(0.002)^4}{8(2.5\times10^{-3})(.1)} = v\cdot\pi(0.002)^2$

$2.5\times10^{-8} = v\cdot 1.3\times10^{-5}$

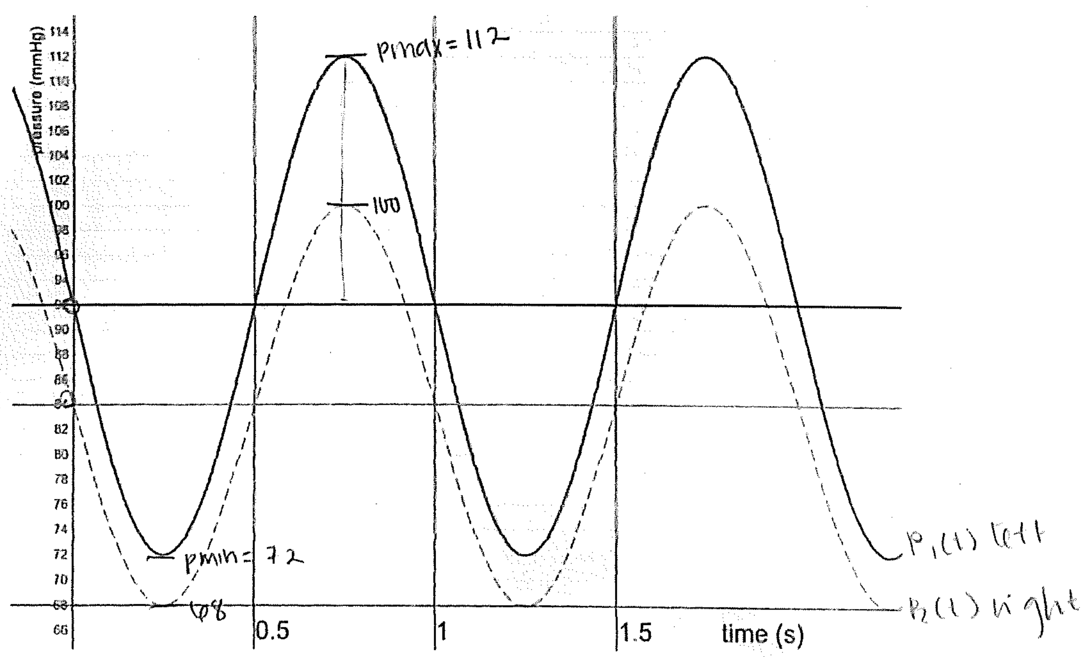
$v = 0.002\text{ m/s}$

iii) Utilize circular cross sections to apply Poiseuille's

$\alpha = \frac{R^2}{8\eta L} = \frac{(0.002\text{ m})^2}{8(2.5\times10^{-3}\text{ N/m}^2)(.1)\text{ m}} = 2\times10^{-3}\text{ N/m}$

$\boxed{2\times10^{-3}\text{ J}}$

2. Suppose that the blood is flowing from the left end of the blood vessel to its right end and that $p_1(t)$ and $p_2(t)$ are the pressures at the left and right ends respectively. The following plot shows the graphs of these pressures as functions of time. The black solid line is $p_1(t)$ and the red dotted line is $p_2(t)$. Carefully note the values of the tick marks and labels on the vertical and horizontal axes.



The plotted pressures $p_1(t)$ and $p_2(t)$ can be written in variables in the following form:

$$p_1(t) = P_1 + A_1 \cos(\omega t + \phi_0), \qquad p_2(t) = P_2 + A_2 \cos(\omega t + \phi_0) \tag{2}$$

Based on the graphs above, what are the SI values (with units) of the variables P_1, P_2, A_1, A_2, ω, and what is the value of ϕ_0 in radians? Recall that 1 mmHg ≈ 133 Pa.

$P_1(t) = P_1 + A_1 \cos(\omega t + \phi_0)$

$= 92 + A_1 \cdot \cos\left(\sqrt{\frac{k}{m}} \times 0.5 + \phi_0\right)$

$\hookrightarrow A = \sqrt{q(0)^2} + \sqrt{\frac{V_0^2}{\omega^2}}$

$P_2(t) = 84 + A_2 \cos(\omega t + \phi_0)$

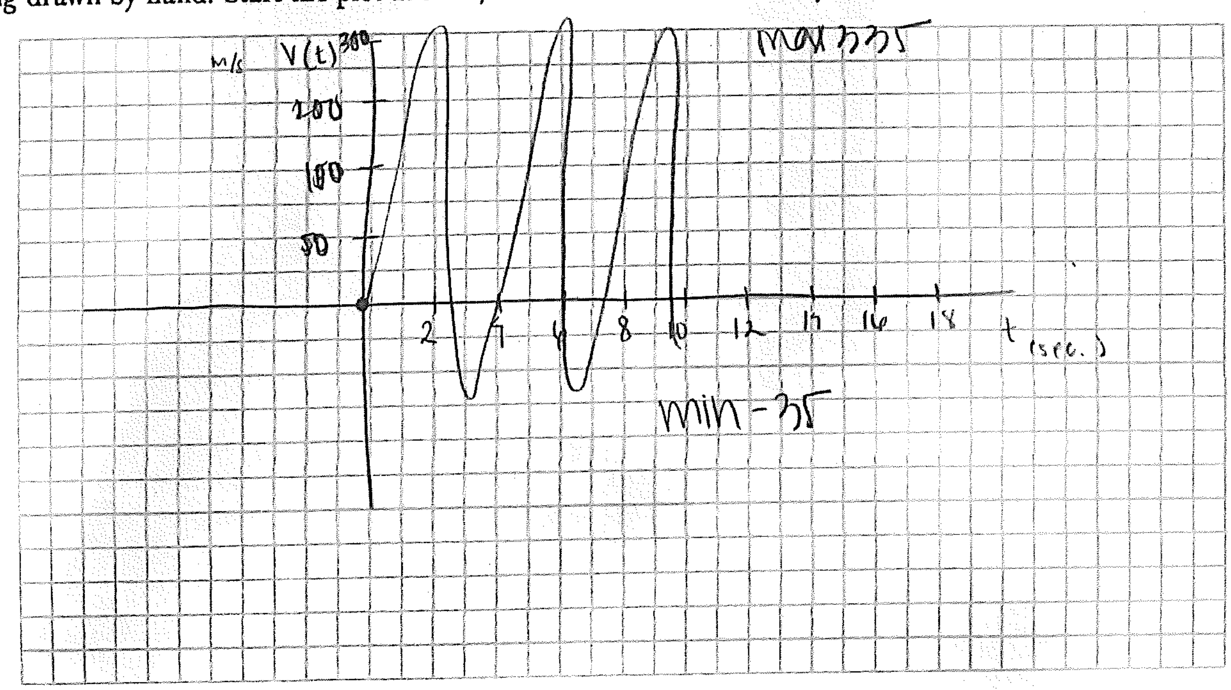
$= 84 + A_2 \cos\left(\sqrt{\frac{k}{m}} \times 0.5 + \phi_0\right)$

$P_1 =$ mmHg, $P_2 =$ mmHg, $A_1 =$ m, $A_2 =$ m, $\omega =$ rad/s, $\phi_0 = \pi$

3. Using equations (1) and (2) it can be shown that the speed as a function of time $v(t)$ of the blood in the vessel can be written as follows:

$$v(t) = \alpha(P_1 - P_2) + \alpha(A_1 - A_2)\cos(\omega t + \phi_0) \tag{3}$$

You can take this expression for granted. Use this expression and some intermediate calculations on scratch paper to plot $v(t)$ in meters per second versus t in seconds on the grid below. Make sure to include tick marks with values and axis labels with units on your plot. Try to make it as numerically accurate as you can given that it's being drawn by hand. Start the plot at $t = 0$, and show at least two full cycles of the oscillation on the plot.



Physics 5B - Winter 2022 - Quiz 3

Name (please print): Harry Potter

UID: 31416

Lecture Section, 3 (1PM) or 4 (3PM): 3

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Please sign here: HP

Faaizah is a medical researcher who needs to measure the speed v of the blood flow in a certain section of a horizontally-oriented blood vessel of length $L = 10$ cm and cross-sectional radius $R = 2$ mm. Having taken Physics 5B, she realizes that there's a way to determine the desired blood flow speed in terms of the pressure difference Δp between the two ends of the blood vessel. By treating the flow as viscous but incompressible, she is able to derive the following relationship between v and Δp (recall that $\eta = 2.5 \times 10^{-3}$ Pa · s is the viscosity of blood):

$$v = \alpha \Delta p, \qquad \text{were} \quad \alpha = \frac{R^2}{8\eta L} \tag{1}$$

1. Derive Faaizah's equation (1) using (i) Poiseuille's equation for viscous flow, (ii) an appropriate expression for volume flow rate, and (iii) a fact about circles. After deriving equation (1), use it to compute the numerical value of α (in SI units) for the blood vessel Faaizah is measuring.

Faaizah's eq: $V = \frac{R^2 \Delta P}{8\eta L}$ Poiseuille's eq. $Q = \frac{\pi R^4 \Delta P}{8\eta L}$

I believe Faaizah used the continuity equation $Q = vA$ and Poiseuille's equation to derive her own:

we have $Q = vA$ and $Q = \frac{\pi R^4 \Delta P}{8\eta L}$.

So, $vA = \frac{\pi R^4 \Delta P}{8\eta L}$

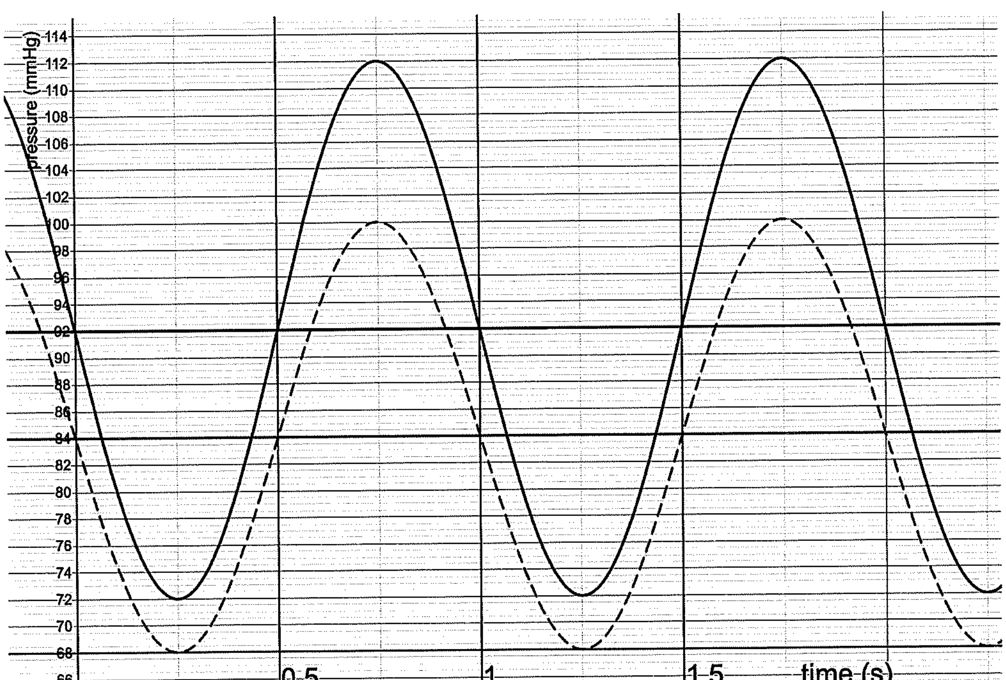
$VA = \frac{(\pi r^2) R^2 \Delta P}{8\eta L}$

$v\cancel{A} = \frac{\cancel{A} R^2 \Delta P}{8\eta L} \Rightarrow \boxed{V = \frac{R^2 \Delta P}{8\eta L}}$

We used Poiseuille's equation, the continuity equation for volume flow rate and the fact that for a circle, $A = \pi r^2$.

So, $\alpha = \frac{(0.002\,m)^2}{8(2.5\times10^{-3}\,Pa\cdot s)(0.1\,m)} = \boxed{0.002\ \frac{m^3}{N\cdot S}}$

2. Suppose that the blood is flowing from the left end of the blood vessel to its right end and that $p_1(t)$ and $p_2(t)$ are the pressures at the left and right ends respectively. The following plot shows the graphs of these pressures as functions of time. The black solid line is $p_1(t)$ and the red dotted line is $p_2(t)$. Carefully note the values of the tick marks and labels on the vertical and horizontal axes.



The plotted pressures $p_1(t)$ and $p_2(t)$ can be written in variables in the following form:

$$p_1(t) = P_1 + A_1 \cos(\omega t + \phi_0), \qquad p_2(t) = P_2 + A_2 \cos(\omega t + \phi_0) \tag{2}$$

Based on the graphs above, what are the SI values (with units) of the variables P_1, P_2, A_1, A_2, ω, and what is the value of ϕ_0 in radians? Recall that 1 mmHg ≈ 133 Pa.

The units of P_1 and P_1 is mmHg, which ~ 12,263 Pa for P_1 and ~ 11197 Pa for P_2.

~~[illegible]~~ ω has units of rad/sec or hertz.

The value of φ_0 in radians is $-\pi$. We see that $p_1(t)$ and $p_2(t)$ do not experience a horizontal shift, instead, they experience like a reflection. caused by a factor of −1.

~~[illegible]~~

A_1 has value 20 mmHg which is 2666 Pa. A_2 has an amplitude of 16 mmHg, which is ~ 2133 Pa.

frequency is 2.5 cycles in 1.5 sec → 1.67 Hz ⇒ W = 2πf → 2π(1.67Hz) = 10.5 Hz

P_1 = 12263 Pa | P_2 = 11197 Pa | A_1 = 2666 Pa | A_2 = 2133 Pa | ω = 10.5 Hz or rad/s | ϕ_0 = $-\pi$

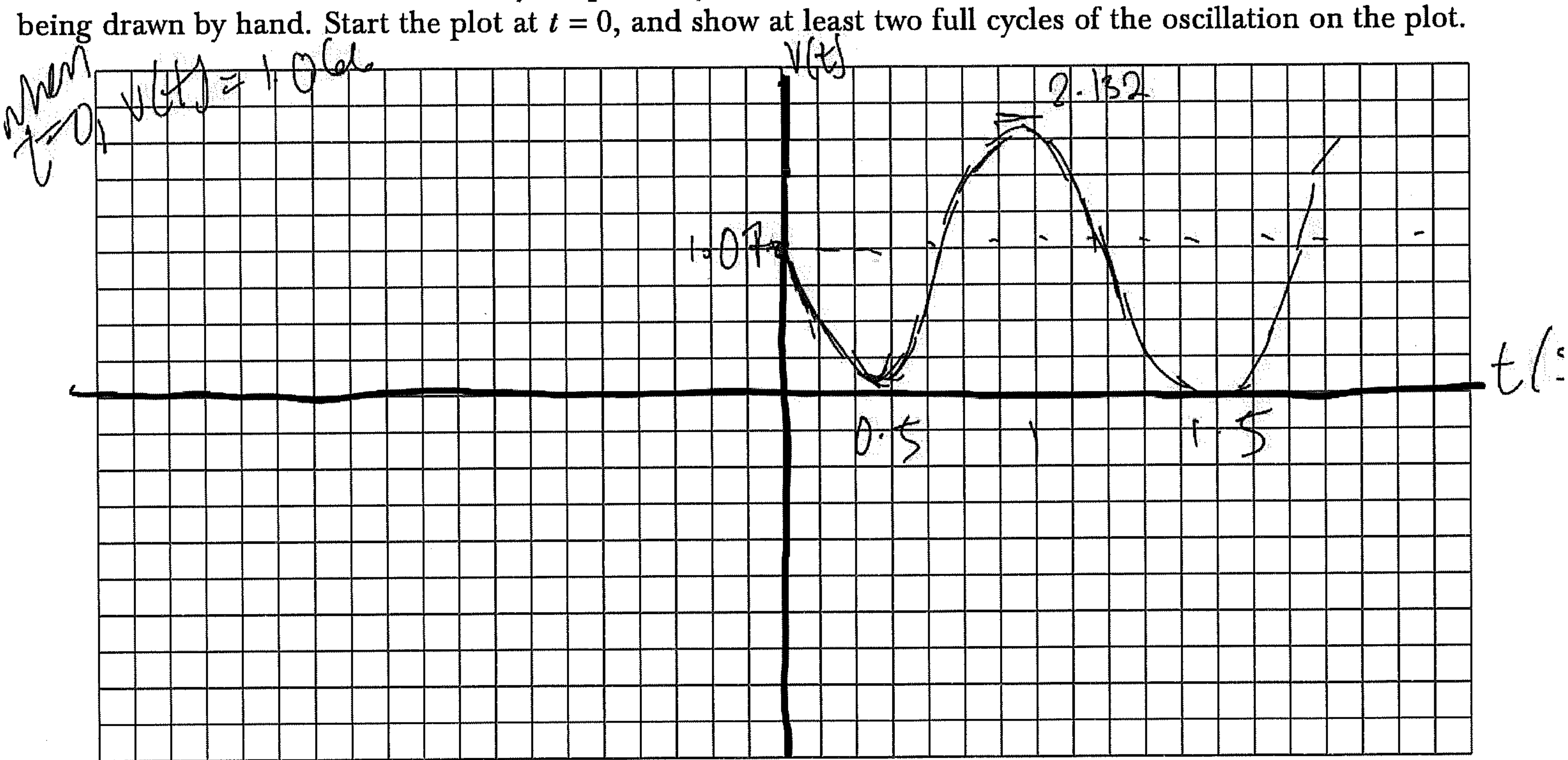
3. Using equations (1) and (2) it can be shown that the speed as a function of time $v(t)$ of the blood in the vessel can be written as follows:

= 0.002(1066) = 2.132 → cos(10.5Ht − π)

$$v(t) = \alpha(P_1 - P_2) + \alpha(A_1 - A_2)\cos(\omega t + \phi_0) \tag{3}$$

0.002(533) = 1.066

You can take this expression for granted. Use this expression and some intermediate calculations on scratch paper to plot $v(t)$ in meters per second versus t in seconds on the grid below. Make sure to include tick marks with values and axis labels with units on your plot. Try to make it as numerically accurate as you can given that it's being drawn by hand. Start the plot at $t = 0$, and show at least two full cycles of the oscillation on the plot.



80 for the sketch

Name (please print): Ron Weasly

UID: 16180

Lecture Section, 3 (1PM) or 4 (3PM): 3

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Please sign here: RW

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$$\frac{v = \alpha \Delta p,}{\alpha \quad \alpha} \qquad \text{were} \quad \alpha = \frac{R^2}{8\eta L} \qquad \Delta p = \frac{8\eta L Q}{\pi R^4} \tag{1}$$

1. Derive Faaizah's equation (1) using (i) Poiseuille's equation for viscous flow, (ii) an appropriate expression for volume flow rate, and (iii) a fact about circles. After deriving equation (1), use it to compute the numerical value of α (in SI units) for the blood vessel Faaizah is measuring.

i) $v = \frac{R^2}{8\eta L}\left(\frac{8\eta L Q}{\pi R^4}\right) = \frac{Q}{\pi R^2} \Rightarrow \alpha = \frac{v}{\Delta p} = \frac{\frac{Q}{\pi R^2}}{\frac{8\eta L Q}{\pi R^4}} = \frac{Q}{\pi R^2} \cdot \frac{\pi R^4}{8\eta L Q} = \frac{R^2}{8\eta L}$

$= \frac{2\text{mm}}{8(2.5\times10^{-3}\text{Pa})(10\text{cm})}$

0.0025

ii) $Q = \frac{\pi R^4}{8\eta L}\Delta p$ $\qquad v = \frac{Q}{\pi R^2}$ $\qquad Q = \frac{v}{\pi R^2}$

$\alpha = \frac{0.002\text{m}}{8(2.5\times10^{-3}\text{Pa})(0.1\text{m})}$

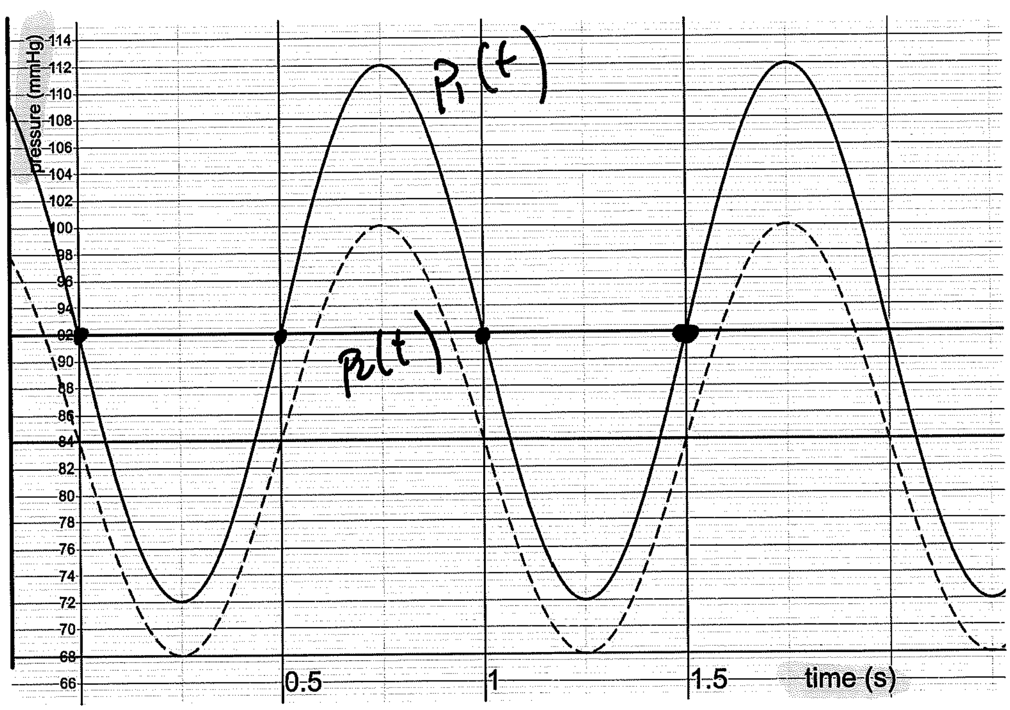
$\alpha = \frac{0.002}{0.002\text{ Pa}}$

$\boxed{\alpha = 1\ \text{Pa}^{-1}}$

iii) $C = 2\pi r$
circumference

left right

2. Suppose that the blood is flowing from the left end of the blood vessel to its right end and that $p_1(t)$ and $p_2(t)$ are the pressures at the left and right ends respectively. The following plot shows the graphs of these pressures as functions of time. The black solid line is $p_1(t)$ and the red dotted line is $p_2(t)$. Carefully note the values of the tick marks and labels on the vertical and horizontal axes.



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Based on the graphs above, what are the SI values (with units) of the variables P_1, P_2, A_1, A_2, ω, and what is the value of ϕ_0 in radians? Recall that 1 mmHg ≈ 133 Pa.

$A_1 = 112 - 92$
$= 20$ mmHg
$= 2660$ Pa

$A_2 = 100 - 84$
$\simeq 16$ mm Hg

$T = \frac{\text{sec}}{\text{cycle}}$

$f = \frac{1}{T}$

$\omega = 2\pi f$

$p_1(1s) = 12{,}236\,\text{Pa} + 2660\,\text{Pa} \cos(\omega)$

$-12{,}236 = 2660\,\text{Pa} \cos(\omega)$

$\cos(\omega) = 4.6$

P_1 = 12,236 Pa, P_2 = 11,172 Pa, A_1 = 2660 Pa, A_2 = 2128 Pa, ω = , ϕ_0 = $-0.5 \frac{\text{rad}}{\text{s}}$

3. Using equations (1) and (2) it can be shown that the speed as a function of time $v(t)$ of the blood in the vessel can be written as follows:

$$v(t) = \alpha(P_1 - P_2) + \alpha(A_1 - A_2)\cos(\omega t + \phi_0) \tag{3}$$

You can take this expression for granted. Use this expression and some intermediate calculations on scratch paper to plot $v(t)$ in meters per second versus t in seconds on the grid below. Make sure to include tick marks with values and axis labels with units on your plot. Try to make it as numerically accurate as you can given that it's being drawn by hand. Start the plot at $t = 0$, and show at least two full cycles of the oscillation on the plot.