12. Practice Exam

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12

1/1 point (ungraded)
A given quantity of liquid has pressure P, volume V, and temperature T. The pressure, volume, and temperature satisfy a continuously differentiable state equation of the form

$$F(P,V,T)=0, \quad F_P, F_V, F_T \neq 0.$$

The **thermal expansivity** a and **isothermal compressibility** b are defined by the partial derivatives

$$a=\frac{1}{V}V_T \qquad b=\frac{-1}{V}V_P$$

Compute $P_T=\dfrac{\partial P}{\partial T}$ in terms of a, b, P, V, and T.

Hint: Compute the total differential dF and find expressions for dP and dV assuming $P=h(V,T)$, $V=g(P,T)$, and $T=f(P,V)$.

a/b

Answer: a/b

$\frac{a}{b}$

? INPUT HELP

Solution:

We start by computing the total differential of the state function

$$dF=F_P\,dP+F_V\,dV+F_T\,dT=0$$

Next we know that

$$dV=g_P\,dP+g_T\,dT$$

However, we also know from the differential of the state equation that

$$dV=\frac{-F_P}{F_V}\,dP+\frac{-F_T}{F_V}\,dT$$

Therefore $V_P=g_P=\dfrac{-F_P}{F_V}=-bV$ and $V_T=g_T=\frac{-F_T}{F_V}=aV$.

Similarly, we know that

$$dP=h_V\,dV+h_T\,dT$$

However, we also know from the differential of the state equation that

$$dP=\frac{-F_V}{F_P}\,dV+\frac{-F_T}{F_P}\,dT$$

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Therefore, $\dfrac{\partial P}{\partial T} = \dfrac{-F_T}{F_P}$.

However, we can rewrite this in terms of the partial derivative of V that we know because

$$\begin{aligned}\frac{-F_T}{F_P} &= \frac{-F_T/F_V}{F_P/F_V} \\ &= \frac{V_T}{-V_P} \\ &= \frac{aV}{bV} = \frac{a}{b}\end{aligned}$$

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Answers are displayed within the problem

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[STAFF] Simpler with triple product rule

In future iterations of this course you might consider adding an exercise in which the triple product rule for partial derivatives is deriv... 5

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