

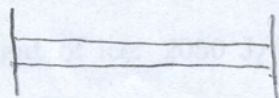
Name: _____ Activity ID: _____

1. A aluminum rod of density $\rho = 2700 \text{ kg/m}^3$ has a length of 3.0 m and cross sectional area 9.0 cm^2 . It is bolted at both ends between two immobile supports. Initially, there is no tension in the rod because the rod just fits between the supports. Through cooling, the rod loses 3500 J of heat.

a) Find the temperature change from the heat loss.

b) Find the force on the rod that develops from the heat loss.

Useful constants $c_{Al} = 910 \text{ J/(kgK)}$, $Y_{Al} = 65 \times 10^9 \text{ Pa}$, $\alpha_{Al} = 22 \times 10^{-6} \text{ K}^{-1}$.



a) $Q = mc \Delta T$

and $m = \rho l A$

$$\therefore \Delta T = \frac{Q}{mc} = \frac{Q}{\rho l A c} = 0.53 \text{ } ^\circ\text{C}$$

b) $\frac{F}{A} = Y \frac{\Delta L}{L}$

and

$$\frac{\Delta L}{L} = \alpha \Delta T = \frac{\alpha Q}{\rho l A c}$$

$$F = \frac{Y A \Delta L}{L} = \frac{Y A \alpha Q}{\rho l A c} = \frac{Y \alpha Q}{\rho l c} = 680 \text{ N}$$

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2. A Russian nuclear icebreaker named "50 Let Pobedy", has a length of about 160 m, width of about 30 m and 2 nuclear reactors delivering about 60 MW of power. It can clear a 35 m wide path in 2m thick ice (at -10°C) for other ships moving at a speed of 5 knots (2.5 m/s). Somebody suggested that instead of breaking the ice one should melt it with a gigantic heater mounted at the front of the ship.

- What power heater would be required?
- Explain in one sentence whether or not such a heater would work on this or a similar ice breaker.

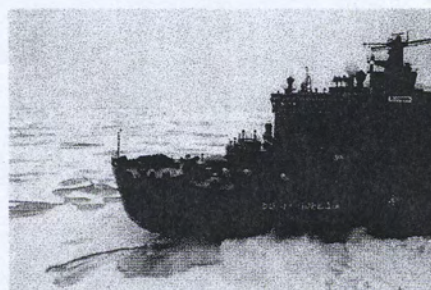
Specific heat of ice: 2050 J/(kgK) , latent heat of ice $334 \times 10^3 \text{ J/kg}$; density of ice 916 kg/m^3

- Amount of ice to melt per second

$$\frac{dm}{dt} = \rho \frac{dV}{dt}$$

$$= \rho w L v = 1.603 \times 10^5 \text{ kg/s}$$

$\underbrace{\quad}_{\text{width}} \underbrace{\quad}_{\text{thickness}} \underbrace{\quad}_{\text{velocity}}$



50 Let Pobedy cutting through ice.

$$\frac{dQ}{dt} = \frac{dm}{dt} c_i \overset{\substack{\text{heat need to warm} \\ \text{ice to } 0^{\circ}\text{C}}}{(0 - -10)} + \frac{dm}{dt} L_i$$

$$= 5.7 \times 10^{10} \text{ W}$$

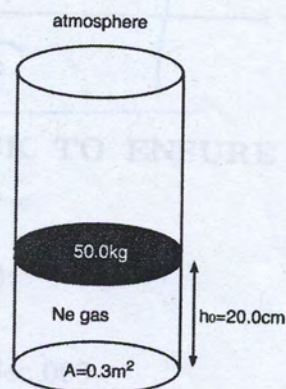
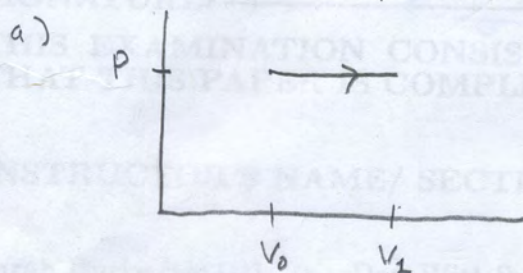
- No. The reactors on the icebreaker provide only $6 \times 10^6 \text{ W}$ for its entire operation - orders of magnitude less than that required to melt the ice.

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3. A cylinder filled with Neon gas has a base area of 0.300m^2 with a 50.0kg piston that can move freely but prevents the gas from escaping. Above the piston, the cylinder is open to the atmosphere. The cylinder is being heated, causing the piston to rise at a constant speed. An uncalibrated pressure gauge reads a constant value for the pressure of the Neon gas throughout the process. When the Neon is at a temperature of 27.0°C , the piston is at a height of 20.0cm . After 10 minutes, the piston has moved by 10.0cm .

Note: $C_V = 12.5\text{Jmol}^{-1}\text{K}^{-1}$ for Neon and atmospheric pressure is $1.01 \times 10^5\text{Pa}$.

- Sketch pressure vs. volume for the Neon gas during this process and indicate the direction by an arrow.
- Calculate the pressure of the Neon gas.
- How much work was done by the Neon gas in 10 minutes?
- How much heat was added to the Neon gas in 10 minutes?



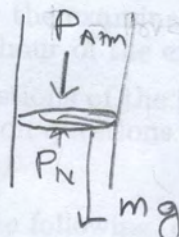
pressure is constant and as heat is added, volume must increase

$$V_1 = .09\text{ m}^3$$

$$V_0 = .06\text{ m}^3$$

b) $P_N = P_{\text{Atm}} + \frac{mg}{A}$

as net force is zero
to have constant velocity



$$P_N = (101 + 1.63)\text{kPa} = 1.03 \times 10^5\text{Pa to sig figs}$$

c) $W = P_N \Delta V = P_N(V_1 - V_0) = 3090\text{J}$
 area under curve

d) $Q = \Delta U + W$ now

$$\Delta U = n C_V \Delta T$$

$$n = \frac{P_N V_0}{R T_0} = 2.48\text{ mol}$$

$$T_1 = \frac{P_N V_1}{n R} = 450\text{ K}$$

$$\text{so } \Delta U = n C_V (T_1 - T_0) = 4650\text{ J}$$

thus $Q = \Delta U + W$
 $= 7740\text{ J}$

Alternately

$$\begin{aligned} \Delta U &= n C_V \Delta T \\ &= \frac{C_V}{R} (n R T_1 - n R T_0) \\ &= \frac{C_V}{R} (P_N V_1 - P_N V_0) \\ &= \frac{C_V}{R} W \\ &= 4650\text{ J} \end{aligned}$$

(true only for 1st order process)