Exam 1

Name Solutions

20 Questions

Select the one response that **best** answers each question.

$COP = \frac{Q_L}{W}$

$\therefore W = \frac{Q_L}{COP}$

$W = \frac{250}{4.2}$

1) A refrigerator has a coefficient of performance equal to 4.2. How much work must be done by the refrigerator in order to remove 250 J of heat from the interior?

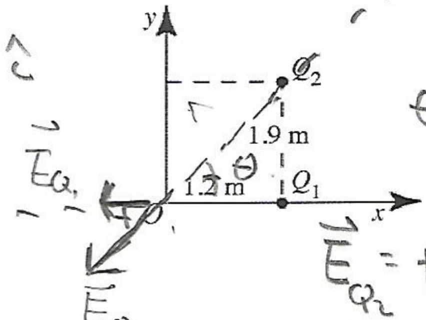
A) 120 J B) 250 J C) 60 J ✓ D) 480 J E) 1050 J

2) Two point charges, $Q_1 = -1.0\ \mu C$ and $Q_2 = +4.0\ \mu C$, are placed as shown in the figure. ($k = 8.99 \times 10^9\ N \cdot m^2/C^2$) The y-component of the electric field at the origin (shown as the point "O") is closest to ________.

$\vec{E}_{Q_1} = +\frac{k|Q_1|}{(1.2)^2}\hat{i} = +6243\hat{i}$

$r = \sqrt{1.9^2 + 1.2^2} = \sqrt{5.05}$

$\theta = \tan^{-1}\left(\frac{1.9}{1.2}\right) = 57.72°$



$\vec{E}_{Q_2} = +\left[\frac{k|Q_2|}{r^2}\right]\cos(57.72)\hat{i}$

$-\left[\frac{k|Q_2|}{r^2}\right]\sin(57.72)\hat{j}$

This is the only part asked for! Could have skipped rest ☺

A) 3.8×10^3 N/C.

B) 6.0×10^3 N/C.

C) -6.0×10^3 N/C. ✓

D) -3.8×10^3 N/C.

E) 7.1×10^3 N/C.

3) An insulated container is filled with a mix of 400 g of water at 20.0°C and 60 g of ice at 0.00°C. Assuming negligible heat is exchanged with the container, what is the temperature of the mixture when it reaches thermal equilibrium? $L_{f\ H_2O} = 334 \times 10^3$ J/kg, $c_{water} = 4190$ J/kg·K, $c_{ice} = 2100$ J/kg·K

A) 0.0°C B) 6.0°C C) 5.0°C D) 7.0°C ✓ E) 4.0°C

4) Is it possible to transfer heat from a cold reservoir to a hot reservoir?

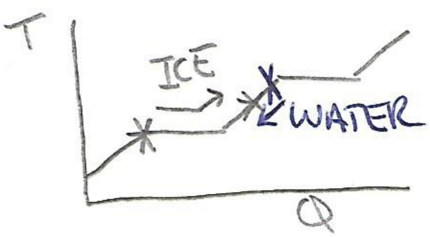
A) No; this is forbidden by the second law of thermodynamics.

B) Yes, but work will have to be done.

C) Yes; this will happen naturally.

D) Theoretically yes, but it hasn't been accomplished yet.

SEE Diagrams @ top of Formula sheet



NET heat exchange = 0

$+m_i L_f + m_i c_w (T_f - 0)$

$+m_w c_w (T_f - 20) = 0$

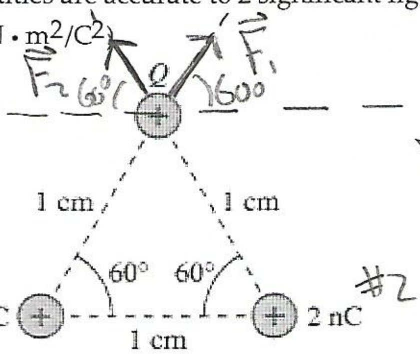
$\Rightarrow 0.06(334 \times 10^3) + 0.06(4190)T_f - 0.4(4190)20 + 0.4(4190)T_f = 0$

$1927.4\,T_f = 13480$

$T_f = 6.99\ °C$

5) In the figure $Q = 5.8$ nC and all other quantities are accurate to 2 significant figures. What is the magnitude of the force on the charge Q? ($k = 8.99 \times 10^9$ N $\cdot$ m^2/C^2)

Symmetry $\Rightarrow \hat{i}$ components Cancel



$\hat{j}$

$$\boxed{|\vec{F}_{Q,(2nC)}| = \frac{k(5.8\times10^{-9})(2\times10^{-9})}{(0.01)^2} = 1.04284\times10^{-3}}$$

$\therefore \vec{F}_Q = [F_2]\hat{j} + [F_1]\hat{j}$

$= 2[1.04284\times10^{-3}\sin(60)]\hat{j}$

A) 1.2×10^{-3} N B) 1.0×10^{-3} N C) 9.0×10^{-4} N D) 1.8×10^{-3} N ✓

1st: $Q_H = W + Q_L$

$\therefore W = 1300 - 700$

$W = 600$ J

6) A certain engine extracts 1300 J of heat (Q_H) from a hot temperature reservoir and discharges 700 J of heat (Q_L) to a cold temperature reservoir. What is the efficiency of this engine?

A) 54% B) 13% C) 46% ✓ D) 86% E) 27%

$\varepsilon = \frac{W}{Q_H} = \frac{600}{1300} = 0.46$

7) What is the maximum theoretical efficiency, or "Carnot Efficiency", for an engine operating between 100°C and 400°C?

$\varepsilon = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H} \Rightarrow 1 - \frac{T_L}{T_H} \Rightarrow 1 - \frac{373}{673} \Rightarrow 0.445$ CARNOT

A) 55% B) 25% C) 65% D) 75% E) 45% ✓

8) The walls of an ice chest are made of 2.00-mm-thick insulation having a thermal conductivity 0.00300 W/m$\cdot$K. The total surface area of the ice chest is 1.20 m^2. If 4.00 kg of ice at 0.00°C are placed in the chest and the temperature of the outside surface of the chest is 20.0°C, how long does it take the ice to melt under steady state conditions? The latent heat of fusion of water is 334×10^3 J/kg.

See attached

A) 10.3 h ✓ B) 17.6 h C) 4.22 h D) 1.33 d E) 22.1 h

9) Suppose that a steel bridge, 1000 m long, were built without any expansion joints. Suppose that only one end of the bridge was held fixed. What would the difference in the length of the bridge be between winter and summer, taking a typical winter temperature as 0°C, and a typical summer temperature as 40°C? The coefficient of thermal expansion of steel is 10.5×10^{-6} /K. $\Delta L = \alpha L_0 \Delta T = 10.5\times10^{-6}(1000)(40) = 0.42$ meters

A) 0.42 mm B) 0.11 mm C) 0.37 cm D) 0.11 m E) 0.42 m ✓

10) If 167440 joules of heat are added to 2.0 kg of water, what is the resulting temperature change? c_{water}= 4190 J/kg$\cdot$K

$Q = mc\Delta T \Rightarrow \Delta T = Q/mc = \frac{167440}{2(4190)} = 19.9°C$

A) 80 °C B) 0.05 °C C) 60 °C D) 40 °C E) 20 °C ✓

11) A point charge Q is located a short distance from a point charge ($3Q$), and no other charges are present. If the electrical force on Q is F, what is the electrical force on ($3Q$)? To be clear, you are being asked about two point charges.

A) F ✓ B) $F/3$ C) $\sqrt{3}F$ D) $F/\sqrt{3}$ E) $3F$

q ------ (3q)

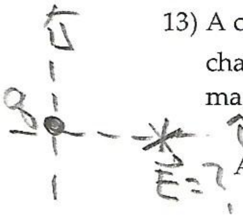
$|\vec{F}| = \frac{k(q)(3q)}{r^2}$

SEE NOTES

$H = \frac{A\Delta T}{l_1/k_1 + l_2/k_2} = \frac{0.0004(240)}{\frac{.5}{205}+\frac{.9}{385}} = 20.1$ watts

12) A heat conducting rod, 1.40 m long, is made of an aluminum section that is 0.50 m long and a copper section that is 0.90 m long. Both sections have cross-sectional areas of 0.00040 m^2. The aluminum end and the copper end are maintained at temperatures of 40°C and 280°C, respectively. The thermal conductivity of aluminum is 205 W/m•K of copper is 385 W/m•K. The rate at which heat is conducted in the rod is closest to _____.

A) 20 W. ✓ B) 28 W. C) 18 W. D) 25 W. E) 23 W.



13) A certain region of space contains a uniform, constant electric field given by the vector $\mathbf{E} = 5\hat{\mathbf{i}} - 7\hat{\mathbf{j}}$. A point charge of -25×10^{-9} coulombs is placed at the origin of a coordinate system in this region of space. What is the magnitude of the electric field at the point (x=10, y=0, z = 0)? The electric field units are SI.

A) 10.1 N/C B) 7.5 N/C ✓ C) 2.25 N/C D) 4.5 N/C

$\vec{E}_q$ @ point $= -\frac{k(25\times10^{-9})}{10^2}\hat{i} = -2.25\hat{i}$

$\vec{E}_{@point} = \vec{E}_{q\,@point} + \vec{E} = (5-2.25)\hat{i} - 7\hat{j}$

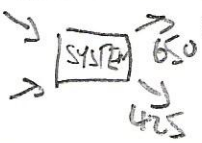
$|\vec{E}_{@point}| = 7.52$

14) Is it possible to transfer heat from a hot reservoir to a cold reservoir?

See diagram @ top of Formula sheet

A) Theoretically yes, but it hasn't been accomplished yet.
B) Yes, but work will have to be done.
C) Yes; this will happen naturally.
D) No; this is forbidden by the second law of thermodynamics.

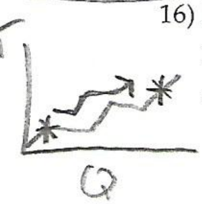
From NOTES



15) An athlete doing push-ups performs 650 kJ of work and loses 425 kJ of heat. What is the change in the internal energy of the athlete? Note: In the answers, a negative sign indicates a decrease in internal energy. A positive sign indicates an increase in internal energy.

loss $-(650+425)$

A) 225 kJ B) 1075 kJ C) −225 kJ D) −1075 kJ ✓ E) 276 kJ



16) How much heat is required to change one gram of 0°C ice to 120°C steam?
$L_{f\ H2O} = 334 \times 10^3$ J/kg, $L_{v\ H2O} = 2256 \times 10^3$ J/kg, $c_{water} = 4190$ J/kg•K, $c_{ice} = 2100$ J/kg•K, $c_{steam} = 2108$ J/kg•K

$Q = mL_f + mc_{water}(100-0) + mL_v + mC_{steam}(120-100)$

A) 508 J B) 3050 J ✓ C) 2260 J D) 6280 J E) 210 J

$Q = 3051$ J

17) A certain region of space contains a uniform, constant electric field given by the vector $\mathbf{E} = 5\hat{\mathbf{i}} - 7\hat{\mathbf{j}}$. A charge of −5 coulombs is placed at the origin of a coordinate system in this region of space. What is the magnitude of the force experienced by this charge while it is at the origin? The electric field units are SI. $\vec{F} = q\vec{E} = -25\hat{i} + 35\hat{j}$

A) 8.6 N B) 43 N ✓ C) 60 N D) 10 N

$|\vec{F}| = \sqrt{25^2+35^2} = 43$ N

18) A small glass bead has been charged to 8.0 nC. What is the magnitude of the electric field 2.0 cm from the center of the bead? ($k = 8.99 \times 10^9\ N \cdot m^2/C^2$)

A) 1.8×10^5 N/C ✓ B) 3.6×10^3 N/C C) 3.6×10^{-6} N/C D) 1.4×10^{-3} N/C

$|\vec{E}| = \frac{k|q|}{r^2} = \frac{8.99\times10^9(8\times10^{-9})}{(0.02)^2} = 1.798\times10^5$

19) You are given a linear rod which has a charge of +Q uniformly distrubuted along its length, which is L. You are asked to find the electric field at a point that is 8 meters from one end of the rod. Take the origin of your coordinate system to be at one end of the rod and imagine the rod extending horizontally along the +x axis. The observation point is along the +x axis, 8 meters beyond the end of the rod. In calculating the answer, the formula you will use is the infinitesimal form of that for the electric field due to a point charge. Which of the following correctly expresses the "r^2" for that formula?

A) $(L + 8 - x)^2$ ✓ B) $(x + L - 8)^2$ C) x^2 D) $(x-8)^2$

20) A nuclear fission power plant has an actual efficiency of 39%. If 0.25 MW of power are produced by the nuclear fission, how much electric power does the power plant output?

A) 9.8 MW B) 0.098 MW ✓ C) 35 MW D) 0.35 MW

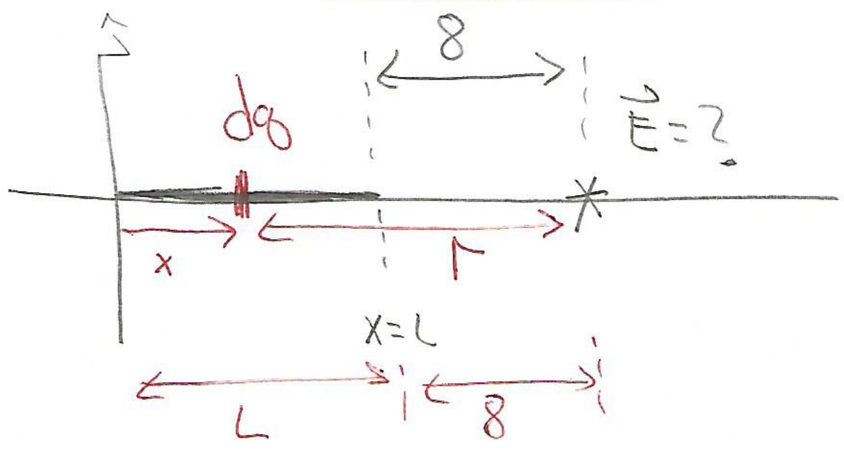
Read the question. You do not need to know any "physics" to answer it. ☺

Power out = 0.39 * (0.25 MW) = 0.098 MW

$\boxed{\text{OR}}$ $Q_H = 0.25 \times 10^6$ J per second

$\varepsilon = 0.39 = \dfrac{W}{Q_H}$

$\therefore W = 0.39\,Q_H = 0.098 \times 10^6$ J per second



$r = (L + 8 - x)$

$|d\vec{E}| = \dfrac{k|dq|}{r^2}$

distance from dq to observation point.

8.) $H = \frac{KA\Delta T}{l} = \frac{0.003(1.2)(20)}{2*10^{-3}} = 36$ watts (joules/second)

$Q_{\text{from ice to melt}} = 4(334.10^3) = 1336000$ joules

$\text{Time to melt} = \frac{1336000\ J}{36\ J/sec} = 37111.1\ sec * \frac{1hr}{3600 sec}$

$= \underline{10.3\ \text{hours}}$ Ans