Exam 1

Name KEY

20 Questions

$\varepsilon = 0.3 = \frac{W}{Q_H}$

$\therefore Q_H = 2500/0.3 = 8333$

$Q_H = Q_L + W$

$\therefore Q_L = Q_H - W =$

Select the one response that best answers each question.

1) A heat engine with an efficiency of 30.0% performs 2500 J of work. How much heat is discharged to the low temperature reservoir?

A) 5830 J ✓ B) 8330 J C) 1350 J D) 750 J E) 7080 J

2) If 2.0 kg of water at 0°C is to be vaporized, how much heat must be added?

$c_{water} = 4190$ J/(kgK) $L_v = 2256 \times 10^3$ J/kg

$Q = mc\Delta T + mL = 2\,(4190 \times 100) + 2256 \times 10^3)$

A) 4521 J B) 5358 J C) 4772 J D) 4.52×10^6 J E) 5.35×10^6 J ✓

$H = \frac{KA\Delta T}{\ell} = 4992$ J/s

3) A solid concrete wall 4.0 m by 2.4 m and 0.30 m thick, with a thermal conductivity of 1.3 W/(m•K), separates a basement at 18°C from the ground outside at 6°C. How much heat flows through the wall in one hour?

In 1 hr, 4992 J/s $\times$ 60 s/min $\times$ 60 min/hr $= 1.79 \times 10^6$ J/hr

A) 5.0 MJ B) 5.0 kJ C) 1.8 MJ ✓ D) 500 J E) 1.8 kJ

4) If we use 67 W of power to heat 148 g of water, how long will it take to raise the temperature of the water from 15°C to 25°C? The specific heat of water is 4190 J/kg•K.

$Q_{needed} = 0.148\,(4190)\,(10) = 6201.2$ J

$\frac{6201.2 \text{ J}}{67 \text{ J/s}} \Rightarrow$

A) 93 s ✓ B) 5.3 s C) 22 s D) 114 h

5) You want to design an ideal Carnot heat engine that wastes only 35.0% of the heat that goes into it. The lowest cold–reservoir temperature available to you is +15.0°C. If 150.0 J of work is done per cycle, the heat input per cycle is closest to __________.

so it converts 65%

$\varepsilon = \frac{W}{Q_H} = 0.65$

$\varepsilon = .65 = \frac{150}{Q_H}$ $\therefore Q_H = 231$ J

A) 231 J ✓ B) 248 J C) 760 J D) 203 J E) 429 J

*That is why I underlined the word wastes!

6) A machinist needs to remove a tight fitting pin of material A from a hole in a block made of material B. The machinist heats both the pin and the block to the same high temperature and removes the pin easily. What statement relates the coefficient of thermal expansion of material A to that of material B?

So B must expand more

A) The situation is not possible because heating block B will shrink the hole in the material as the material expands with increasing temperature.

✓ B) Material B has a greater coefficient of expansion than does material A.

C) Material B has the same coefficient of expansion as does material A.

D) Material A has a greater coefficient of expansion than does material B.

7) When two point charges are 2.0 cm apart, each one experiences a 1.0–N electric force due to the other charge. If they are moved to a new separation of 8.0 cm, the electric force on each of them is closest to __________.

A) 1.0 N. B) 0.25 N. C) 4.0 N. D) 16 N. E) 0.063 N. ✓

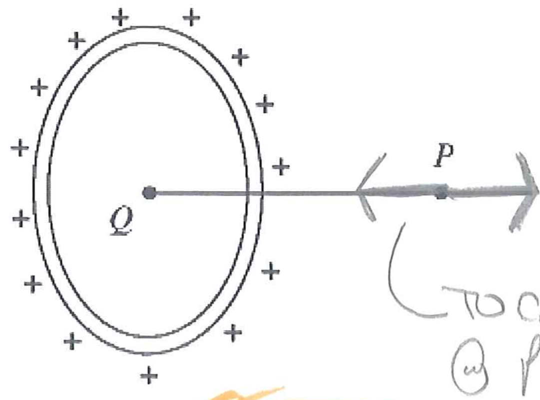
Given: $|\vec{F}| = \frac{K|q_1||q_2|}{(0.02)^2} = 1.0$

Also: $|\vec{F}| = \frac{K|q_1||q_2|}{(0.08)^2} = (?)$

From this we see:

$(?) = \frac{1.0 \times (0.02)^2}{(0.08)^2} = 0.0625$ N

8) In the figure, a ring 0.71 m in radius carries a charge of + 580 nC uniformly distributed over it. A point charge Q is placed at the center of the ring. The point P is on the axis of the ring, and 0.73 m from its center. Is it possible for the electric field at the pont P to be zero?



$\vec{E}_{ring}$ (from symmetry)

To cancel field @ P, this must be $\vec{E}_Q$.

A) Yes, if Q is a negative charge.
B) The only way to know would be to do an integral.
C) No, because Q is only a point charge.
D) No, because there is no charge located at P.
E) Yes, if Q is a positive charge.

YES there is! My miss

Everyone gets credit!

FROM 10°. Not enough information to respond

9) A rod has a length 2.00000 m at 10.0°C. The length of the rod increases to 2.00060 m when the temperature increases to 30.0°C. What is the coefficient of linear expansion of the material from which the rod is made?

$\Delta L = \alpha L_0 \Delta T$

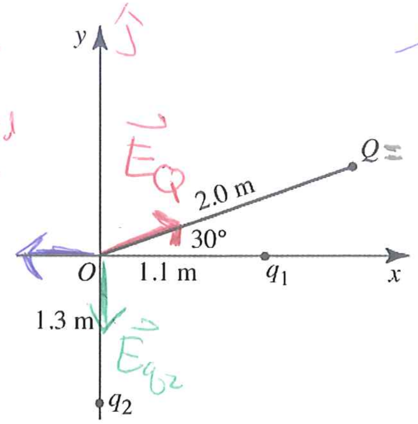
$\therefore \alpha = \frac{\Delta L \, \Delta T}{L_0}$

A) 1.5 × 10^{-5}/K B) 1.0 × 10^{-3}/K C) 2.0 × 10^{-5}/K D) 1.0 × 10^{-5}/K E) 2.5 × 10^{-5}/K

10) A point charge Q = -500 nC and two unknown point charges, q_1 and q_2, are placed as shown in the figure. The electric field at the origin O, due to charges Q, q_1 and q_2, is equal to zero. The charge q_1 is closest to _____.

NOTE: From placement, q_2 must cancel $\hat{j}$ part of $\vec{E}_Q$ and q_1 must cancel $\hat{i}$ part of $\vec{E}_Q$.

$\therefore q_1$ is positive and $+\rightarrow$



$* \; |\vec{E}_{q_1}|_{@O} = |\vec{E}_Q|_{@O} \cos(30)$

$\frac{k|q_1|}{(1.1)^2} = \frac{k|Q|}{(2)^2}\cos(30)$

$|q_1| = \frac{|Q|(1.1)^2 \cos(30)}{4}$

$|q_1| = 130.99$ nC

A) -76 nC. B) 130 nC. C) 76 nC. D) -130 nC. E) 150 nC.

11) An air conditioner with a coefficient of performance of 3.5 uses 30 kW of power. How much power is it discharging to the outdoors?

A) 135 kW B) 105 kW C) 210 kW D) 30 kW E) 75 kW

$C.O.P. = \frac{Q_L}{W} = 3.5$

$\therefore Q_L = 3.5 \times 30$ kJ $= 105$ kJ "per second"

$Q_L + W = Q_H$ "discharged outdoors"

$Q_H = 105 + 30 = 135$ kJ "per second"

12) When a vapor condenses ________________.

A) heat energy enters the substance.
B) the temperature of the substance increases.
C) the temperature of the substance decreases.
D) heat energy leaves the substance.

$Q = mc\Delta T$

13) If 167440 J of heat is added to 2.0 kg of water, what is the resulting temperature change? $c_{water} = 4190$ J/(kgK)

$\Delta T = \frac{Q}{mc}$

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

14) A 10.0 m^2 area wall is constructed of three layers. The first layer is 2.00 cm thick and has a thermal conductivity 0.500 W/m•K. The second layer is 15.0 cm thick and has a thermal conductivity 0.100 W/m•K. The third layer is 3.00 cm thick and has a conductivity 1.00 W/m•K. How much heat flows through this wall per hour if one side of the wall is at 20.0°C and the other side is at 0.00°C? $R_1 = \frac{0.02}{0.5} = 0.04$, $R_2 = 1.5$, $R_3 = 0.03$

$H = \frac{A\Delta T}{(R_1+R_2+R_3)}$

A) 3.22×10^5 J B) 1.14×10^5 J C) 1.73×10^5 J D) 2.68×10^5 J E) 4.59×10^5 J ✓

$H = 127.39$ J/s $\rightarrow * 60$ s/min $* 60$ min/hr $= 4.59 * 10^5$ J/hr (note the underline)

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?

A) athelete gains 276 kJ
B) athelete loses225 kJ
C) athelete loses 1075 kJ
D) athelete gains 1075 kJ
E) athelete gains 225 kJ

work done on 0 → Athelete → work done by 650 kJ
0 → heat in; heat out 425 kJ

SEE NOTES

$\Delta E = -650 - 425 = -1075$ kJ

16) Which of the following is the expression for the Carnot efficiency of a heat pump?

HINT: A heat pump does work to remove heat from the air outside your home and supply it to the air inside your home. The high temperature reservoir is your home, & that in which you are interested. Q_H

Q_H, W, Q_L

$COP = \frac{get}{Pay} = \frac{Q_H}{W}$

A) $\frac{T_L}{T_H - T_L}$ B) $\frac{\text{Get}}{\text{Pay}}$ C) $1 - \frac{T_L}{T_H}$ D) $\frac{T_H}{T_H - T_L}$ ✓

↳ Substituting from 1st Law → $\frac{Q_H}{Q_H - Q_L}$ → Substituting for "ideal"

17) A point charge of 5.00 nC is fixed at the origin of a coordinate system, unable to move. The region of space in which it is located contains the electric field $\mathbf{E} = -8\hat{\mathbf{i}} - 7\hat{\mathbf{j}} + 4\hat{\mathbf{k}}$. If a 10.0 C charge is placed on the x-axis at the point x=7.0 meters, what is the magnitude of the force experienced by this charge?

5nC, 10C, $\hat{i}$

A) 120 N B) 9.17 N C) 20.5 N D) 107 N ✓

18) A refrigerator removes heat from the freezing compartment at the rate of 20 kJ and ejects 24 kJ into a room per cycle. How much work is required in each cycle?

Q_L, Q_H

A) 22 kJ B) 44 kJ C) 20 kJ D) 4 kJ ✓ E) 24 kJ

1st ⇒ $Q_L + W = Q_H$

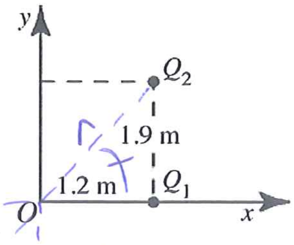
$\therefore W = Q_H - Q_L = 4$ kJ

$\vec{F}_{10c} = \vec{F}_{from\,5c} + \vec{F}_{from\,\vec{E}}$

$\vec{F}_{10c} = \frac{k(5\times10^{-9})(10)}{(7)^2}\hat{i} + 10(-8\hat{i} - 7\hat{j} + 4\hat{k}) = -70.83\hat{i} - 70\hat{j} + 40\hat{k}$

$\therefore |\vec{F}_{10c}| = 107.3$ N

19) Two point charges, $Q_1 = -1.0\ \mu C$ and $Q_2 = +4.0\ \mu C$, are placed as shown in the figure. The y component of the electric field, at the origin O, is closest to ________________.



$\hat{j}$

$5.05 = r^2$

$57.72°$

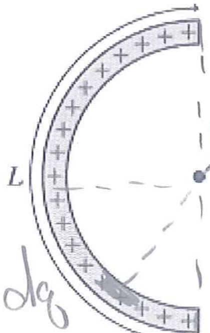
$\hat{i}$

[Q_1 has no $\hat{j}$ component @ origin!]

A) 7.1×10^3 N/C.
B) 3.8×10^3 N/C.
C) 6.0×10^3 N/C.
D) -6.0×10^3 N/C. ✓
E) -7.1×10^3 N/C.

$$\left(E_{Q_{2y}}\right)_{@\text{origin}} = -\frac{k|Q_2|}{r^2}\sin(57.72°) = -6.02 \times 10^3\ \text{N/C}$$

20) A thin, flexible rod of length $L = 10$ cm carries charge $Q = 91$ nC uniformly along its length. The rod is then bent into a semicircle, as shown in the figure. Note that the radius of this semicircle is L/π. Also recall that arc length is given by $S = R\Theta$. What is the magnitude of the electric field at the center?



$\hat{j}$

$d\vec{E}$

θ

$\hat{i}$

*From symmetry, only a $+\hat{i}$ part @ origin.

$\lambda \frac{L\,d\theta}{\pi} = d\ell\lambda = dq$

$\lambda = \frac{Q}{L}$

A) 4.3×10^5 N/C
B) 5.1×10^5 N/C ✓
C) 4.6×10^5 N/C
D) 4.9×10^5 N/C

$$* \ dE_x = |d\vec{E}|\cos\theta$$

$$\int dE_x = \int \left[\frac{k|dq|}{r^2}\right]\cos\theta$$

$$E_x = \int \frac{k\lambda L\,d\theta}{\pi r^2}\cos\theta$$

REALLY? Range of θ is $+\pi/2$ to $-\pi/2$ (or visa versa) ☑ Cos(θ) is positive over range.

$$= \frac{kQ}{\pi\left(\frac{L^2}{\pi^2}\right)}\int_{\pi/2}^{-\pi/2}\cos\theta = \frac{k\pi Q}{L^2}\Big[-\sin\theta\Big]_{\pi/2}^{-\pi/2} = \frac{2k\pi Q}{L^2} = 5.08 \times 10^5\ \frac{N}{C}$$

$$\underbrace{(-(-1)-(-1))}_{2}$$

Know this should be "+" SEE NOTES.