Student	7
Average	40.3 /100
Best	80.0 /100

12^{th} Grade Honor Physics (2018 – 19)

2^{nd}Q, Exam (January 25, 2019)

Class 12	Name Solutions

5 points/problem x 21 problems= 105 points(Max 100 points)

Exam	／[Total 100 points]
Lab Reports	
Homework	

In calculation problems, describe equations clearly and systematically enough to show how to solve the problems.

Specific Heat c [J/(kg・K)]	
Water	4186
Ice	2090
Steam	2010
Oil	1970
Copper	387
Ceramic	1090
Glass	837
Aluminum	900
Iron (Steel)	560
Lead	128

	Density [kg/m³]
Gold	19,300
Silver	13,600
Iron	7,860
Sea water	1,025
Water	1,000
Ice	917
Air	1.29
Helium gas	0.179
Hydrogen gas	0.0899

	Latent Heat of Fusion L_f [J/kg]	Latent Heat of Vaporization L_v [J/kg]
Water 水	3.35×10^5	22.6×10^5
Ethanol エタノール	1.08×10^5	8.55×10^5

Gravitational acceleration rate	$g = 9.80\ m/s^2$
Universal Gravitational Constant	$G = 6.674 \times 10^{-11}\ N \cdot m^2/kg^2$
Radius of the Earth	$R_E = 6.371 \times 10^6\ m$
Mass of the Earth	$M_E = 5.972 \times 10^{24}\ kg$
Mass of the Sun	$M_S = 1.9884 \times 10^{30}\ kg$
Radius of the Mars	$R_M = 3.39 \times 10^6\ m$
Mass of Mars	$M_M = 6.43 \times 10^{23}\ kg$
Angular speed of Earth's Rotation	$\omega = 7.292 \times 10^{-5}\ rad/s$
The circular constant	$\pi = 3.14159...$
Volume of a sphere	$V = \frac{4}{3}\pi r^3$
Avogadro's Number	$N_A = 6.022 \times 10^{23}\ mol^{-1}$
Universal Gas Constant	$R = 8.314\ J/(mol \cdot K)$
Boltzmann Constant	$k = 1.381 \times 10^{-23}\ J/K$

Name	Symbol	Atomic Mass
Hydrogen	H	1.00794(7) 2 3 4
Helium	He	4.002602(2) 2 4
Lithium	Li	6.941(2) 2 3 4 5
Beryllium	Be	9.012182(3)
Boron	B	10.811(7) 2 3 4
Carbon	C	12.0107(8) 2 4
Nitrogen	N	14.0067(2) 2 4
Oxygen	O	15.9994(3) 2 4
Fluorine	F	18.9984032(5)
Neon	Ne	20.1797(6) 2 3

(1) Find the altitude of a geosynchronous satellite.
(Equations)

$$T = 24 \times 3.6\times10^{3} = 8.640 \times10^{4}\ s$$

$$G\frac{M}{r^2} m = m r \omega^2 = m r \left(\frac{2\pi}{T}\right)^2$$

$$\frac{GM}{r^3} = \frac{4\pi^2}{T^2}$$

$$r^3 = \frac{1}{4\pi^2} T^2 GM$$

$$= \frac{1}{4\pi^2} \times 8.640^2 \times10^{8} \times 6.674\times10^{-11} \times$$

$$= 75.346\times10^{21}$$

$$r = \sqrt[3]{75.346} \times10^{7} = 4.224\times10^{7}\ (m)$$

$$r - R_E = 42.24\times10^{6} - 6.371\times10^{6}$$

$$= 35.865\times10^{6} \rightarrow 3.587\times10^{7}\ m$$

$$3.59\times10^{7}\ m$$

(1) Answer $3.59 \times10^{7}\ m$ (43%)

(2) The mass of Sputnik I, the first artificial satellite, was 83.5 kg, and its distance from the center of the Earth at apogee and perigee were 7330 km and 6610 km, respectively. Find the difference in gravitational potential energy as the Sputnik I moved from apogee to perigee.

(Equations)

$$\Delta U = U_{perigee} - U_{apogee}$$

$$= -\frac{GmM}{r_p} - \left(-\frac{GmM}{r_a}\right)$$

$$= GmM\left(\frac{1}{r_a} - \frac{1}{r_p}\right)$$

$$= 6.674\times10^{-11}\times 83.5\times 5.972\times10^{24}\times\left(\frac{1}{7330\times10^{3}} - \frac{1}{6610\times10^{3}}\right)$$

$$= \quad {''} \quad \times\left(\frac{1}{7.33} - \frac{1}{6.61}\right)\times10^{-6}$$

$$= 3328.1\times10^{7} \times (0.\overline{1364} - 0.\overline{1513})$$

$$= \quad {''} \quad \times(-0.0\overline{149})$$

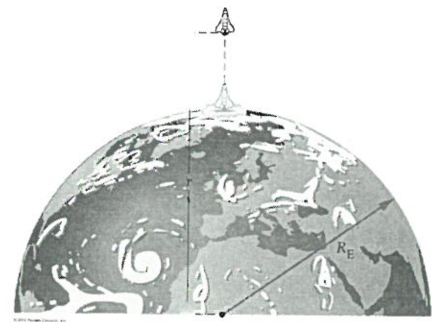
$$= -49.46\times10^{7}$$

$$\longrightarrow -4.9\times10^{8}\ \text{(J)}$$

(2) Answer

-4.9×10^{8} J (24%)

(3) What is the launch speed of a projectile that rises vertically above the Earth to an altitude equal to on Earth radius before coming to rest momentarily?
(Equations)



$$\frac{1}{2} m v^2 - G\frac{m M_E}{R_E} = -G\frac{m M_E}{2R_E}$$

at Earth surface — latitude RE

$$\frac{1}{2} v^2 = \frac{GM_E}{R_E}\left(1-\frac{1}{2}\right) = \frac{1}{2}\frac{GM_E}{R_E}$$

$$v = \sqrt{\frac{6.674\times10^{-11}\times5.972\times10^{24}}{6.371\times10^{6}}}$$

$$= \sqrt{6.256\times10^{7}}$$

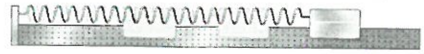
$$= \sqrt{62.56}\times10^{3}$$

$$= 7.910\times10^{3}$$

$$\rightarrow 7.91\times10^{3}\ m/s$$

(3) Answer
7.91 km/s

(24%)



(4,5) An air-track cart attached to a spring completes one oscillation every 2.4 s. At t=0 the cart is released from rest at a distance of 0.15 m from its equilibrium position.

(4) What is the position of the cart at the following times?
(4-a) t = 0.30 s
(4-b) t = 0.60 s

(5) What are the velocity and acceleration of the cart at t = 0.60 s?
(Equations)

$x = A\cos\omega t = 0.15\cos\left(\frac{2\pi}{2.4}t\right)$

(a) $x = 0.15\cos\left(\frac{2\pi}{2.4}\times 0.30\right) = 0.15\cos\left(\frac{\pi}{4}\right) = 0.15\times\frac{1}{\sqrt{2}} = 0.106$

$\rightarrow 0.11\ (m)$

(b) $x = 0.15\cos\left(\frac{2\pi}{2.4}\times 0.60\right) = 0.15\cos\left(\frac{\pi}{2}\right) = 0$

(5) $v = -A\omega\sin\omega t = -0.15\times\frac{2\pi}{2.4}\sin\left(\frac{2\pi}{2.4}\times 0.60\right)$

$= -0.15\times 2.618\sin\left(\frac{\pi}{2}\right)$

$= -0.3927 \longrightarrow -0.39\ (m/s)$

$a = -A\omega^2\cos\omega t$

$= -A\omega^2\cos\left(\frac{2\pi}{2.4}\times 0.60\right)$

$= -A\omega^2\cos\left(\frac{\pi}{2}\right)$

$= 0$

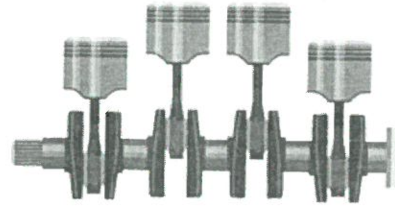
(4-a) Answer Position	0.11 m
(4-b) Answer Position	0

(64%)

(5) Answer	
Velocity	0.39 m/s
Acceleration	0

(44%)

(6) The pistons in an internal combustion engine undergo a motion that is approximately simple harmonic. If the amplitude of motion is 3.5 cm, and the engine runs 1700 rev/min, find the followings:
(6-a) the maximum acceleration of the pistons
(6-b) the maximum speed of the pistons.
(Equations)



$\omega = 1700 \text{ rev/min} \times \frac{2\pi \text{ rad}}{1 \text{ rev}} \times \frac{1 \text{ min}}{60 \text{ s}} = 178.0 \text{ rad/s}$

$a = -\omega^2 x$

$a_{max} = \omega^2 A$

$= 178.0^2 \times 3.5 \times 10^{-2}$

$= 1110 \text{ m/s}^2 \longrightarrow 1.1 \times 10^3 \text{ (m/s}^2\text{)}$

$v_{max} = A\omega$

$= 3.5 \times 10^{-2} \times 178.0$

$= 6.23 \longrightarrow 6.2 \text{ (m/s}$

(6-a) Answer	1.1×10^3 m/s^2
(6-b) Answer	6.2 m/s

(57%)

(7) A 0.85-kg mass attached to a vertical spring of force constant 150. N/m oscillates with a maximum speed of 0.35 m/s. Find the following quantities related to the motion of the mass:
(7-a) the period,
(7-b) the amplitude,
(7-c) the maximum magnitude of the acceleration.
(Equations)

(a) $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.85}{150}} = 0.4730 \rightarrow 0.47\ s$

(b) $x = A\cos\omega t$

$v = -A$ $\qquad v_{max} = A\omega = 0.35$

$A = \frac{0.35}{\omega} = \frac{T}{2\pi} \times 0.35$

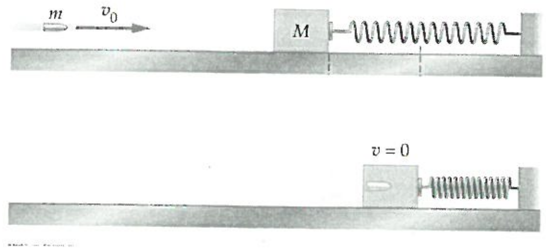
$= \frac{0.473 \times 0.35}{2\pi} = 0.02634\ m$

(c) $a_{max} = \omega^2 A = \left(\frac{2\pi}{T}\right)^2 \times 0.02634$

$= 4.648 \rightarrow 4.6\ m/s^2$

(7-a) Answer	0.47 s
(7-b) Answer	0.026 m
(7-c) Answer	4.6 m/s²

(66%)



(8) A 2.25-g bullet embeds itself in a 1.50-kg block, which is attached to a spring of force constant 785 N/m. If the initial speed of the bullet is 897 m/s, find the followings:
(8-a) the maximum compression of the spring,
(8-b) the time for the bullet-block system to come to rest.
(Equations)

Conservation of momentum

$$m v_0 = (m + M) V$$

$$V = \frac{m v_0}{m+M} = \frac{0.00225 \times 897}{0.00225 + 1.50} = 1.3455$$

Conservation of energy

$$\frac{1}{2}(m+M)V^2 = \frac{1}{2} k x^2$$

$$x = V\sqrt{\frac{m+M}{k}} = 1.3455\sqrt{\frac{1.5025}{785}}$$

$$= 1.3455 \times 0.04375 = 0.05887\,m = 5.887\,cm$$

$$\rightarrow 5.89\,cm$$

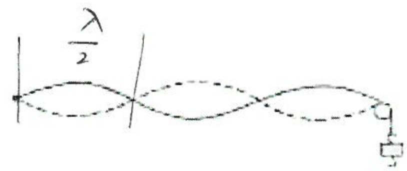
$$T = 2\pi\sqrt{\frac{m+M}{k}} = 2\pi \times 0.04372 = 0.2747$$

$$\frac{T}{4} = 0.06867\,s$$

$$\rightarrow 0.0687\,s$$

(8-a) Answer	5.89 cm
(8-b) Answer	0.0687 s

(13%)



(9) A string 1.5 m long with a mass of 2.6 g is stretched between two fixed points with a tension of 93 N. Find the frequency of the third harmonic on this string.
(Equations)

$$\mu = \frac{2.6\times10^{-3}}{1.5} = 1.73\times10^{-3}\ kg/m$$

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{93}{1.73\times10^{-3}}} = \sqrt{53.76\times10^{3}}$$

$$= 231.9\ (m/s)$$

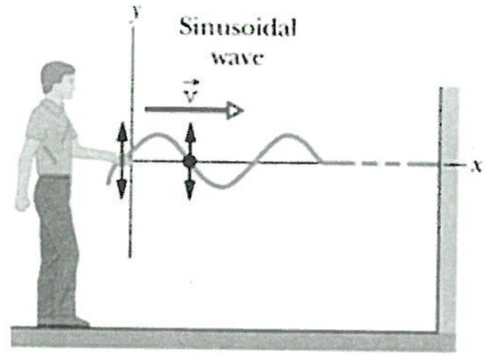
$$\frac{\lambda}{2}\times3 = 1.5\ (m) \rightarrow \lambda = 1.00\ m$$

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{231.9}{1.00} = 231.9 \rightarrow 230\ Hz$$

(9) Answer 230 Hz

(0%)

(10) Write an expression for a transverse harmonic wave that has a wavelength of 2.8 m and propagates to the right with a speed of 15.3 m/s. The amplitude of the wave is 0.13 m, and its displacement at t = 0 and $x = 0$ is 0.13 m. (Equations)



$$y = A\cos(kx - \omega t)$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{2.8\ m}$$

$$v = f\lambda = \frac{\lambda}{T} \rightarrow T = \frac{\lambda}{v} = \frac{2.8}{15.3} = 0.183 \rightarrow 0.18\ s$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.18\ s}$$

(10) Answer

$$y = (0.13\ m)\cos\left(\frac{2\pi}{2.8\ m}x - \frac{2\pi}{0.18\ s}t\right)$$

(27%)

(11) The intensity level of sound in a class is 98 dB. What is the intensity of this sound?
(Equations)

$$\beta = 10 \log(I/I_0)$$

$$\frac{98}{10} = \log(I/10^{-12})$$

$$9.8 = \log I - (-12)$$

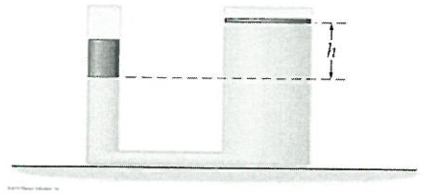
$$\log I = 9.8 - 12 = -2.2$$

$$I = 10^{-2.2}$$

$$= 0.00631 \ (W/m^2)$$

$$\rightarrow 6.3 \ mW/m^2$$

(11) Answer
6.3 mW/m^2 (56%)



(12) In the hydraulic system shown in the figure, the piston on the left has a diameter of 4.4 cm and a mass of 1.8 kg. The piston on the right has a diameter of 12 cm and a mass of 3.2 kg. If the density of the fluid is 750 kg/m³, what is the height difference h between the two pistons?

(Equations)

$$P = P' \rightarrow \frac{F}{A} = \frac{F'}{A'} \qquad \frac{m_1 g}{\pi\left(\frac{D_1}{2}\right)^2} = \frac{m_2 g}{\pi\left(\frac{D_2}{2}\right)^2} + \rho h g$$

$$\frac{1.8}{\pi \times 0.022^2} = \frac{3.2}{\pi \times 0.06^2} + 750\,h$$

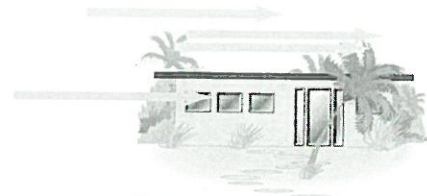
$$h = \frac{\frac{1.8}{0.022^2} - \frac{3.2}{0.06^2}}{750\,\pi}$$

$$= 1.201 \rightarrow 1.2$$

(12) Answer 1.2 m

(46%)

(13) During a thunderstorm, winds with a speed of 47.7 m/s blow across a flat roof with an area of 668 m². Find the magnitude of the force exerted on the roof as a result of this wind.
(Equations)



$$P + \frac{1}{2}\rho v^2 = P' + \frac{1}{2}\rho v'^2$$

$$\Delta P = P - P' = \frac{1}{2}\rho(v'^2 - v^2)$$

$$\Delta P = \frac{F}{A}$$

$$\therefore F = \frac{1}{2}\rho A(v'^2 - v^2)$$

$$= \frac{1}{2} \times 1.29 \times 668 \times (47.7^2 - 0)$$

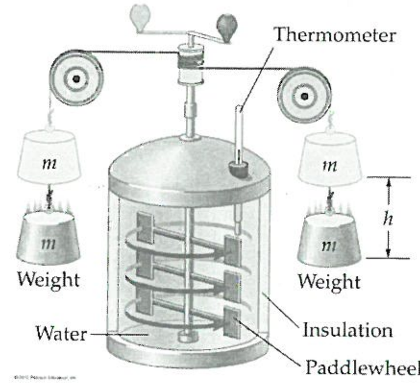
$$= 9.803 \times 10^5$$

$$\rightarrow 9.80 \times 10^5 \text{ N}$$

(13) Answer
9.80×10^5 N

(61%)

(14) The figure at the right shows the apparatus Joule used in his experiments on the mechanical equivlent of heat. Suppose both blocks have a mass of 9.5 kg and that they fall through a distance of 1.9 m. Find the expected rise in temperature of the 330 g water. (Equations)



$U = 2 \times mgh$

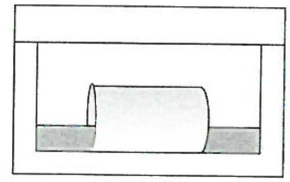
$= 2 \times 9.5 \times 9.80 \times 1.9$

$= 353.78$ (J)

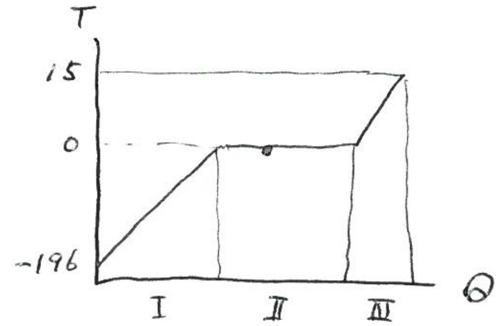
$U = Q = mc\Delta T$

$\Delta T = \frac{U}{mc} = \frac{353.78}{0.330 \times 4186} = 0.256^\circ \rightarrow 0.26^\circ$

(14) Answer $0.26^\circ C$ (40%)



(15) A 155-g aluminum cylinder is removed from a liquid nitrogen bath, where it has been cooled to −196℃. The cylinder is immediately placed in an insulated cup containing 80.0 g of water at 15.0℃. What is the equilibrium temperature of this system? If your answer is 0℃, determine the amount of water that has frozen. The average specific heat of aluminum over this temperature range is 653 J/(kg・K).
(Equations)



$Q_I = mc\Delta T = 0.155 \times 653 \times (0-(-196)) = 19838.14$

$Q_{III} = mc\Delta T = 0.0800 \times 4186 \times (0-15) = -5023$

$Q_I + Q_{III} = 14814.94$

m [kg] frozen

$Q_{II} = -mL_f = -3.35\times10^5 m$

$Q_I + Q_{II} + Q_{III} = 0$

$-3.35\times10^5 m + 14814.94 = 0$

$m = \dfrac{14814.94}{3.35\times10^5}$

$= 0.04422$ (kg)

$\rightarrow 44.2$ g

(15) Answer
0°C 44.2 g frozen (23%)

(16,17) A cylindrical flask of cross-sectional area A is fitted with an airtight piston that is free to slide up and down. Contained within the flask is oxygen gas. Treat it as an ideal gas.

(16) Initially the pressure applied by the piston is 130 kPa and the height of the piston is 25 cm. When additional mass is added to the piston, pressure increases to 170 kPa. Assuming the system is always at the temperature 17℃, find the new height of the piston.

(17) Next, the temperature is changed from an initial value of 17℃ to a final value of 57℃. The pressure exerted on the gas remains constant at 130 kPa, and the initial height of the piston is 25 cm. Find the final height of the piston.

(Equations)

(16) Boyle's law $PV = P'V'$

$$V' = \frac{P}{P'} V = \frac{130}{170} \times 25 \cdot A = 19.1 \times A$$

19 cm

(17) Charles' law $V/T = V'/T'$

$$V' = \frac{T'}{T} V = \frac{273.15 + 57}{273.15 + 17} \times 25 \cdot A$$

$$= \frac{330.15}{290.15} \times 25 \times A$$

$$= 28.446 \cdot A$$

28 cm

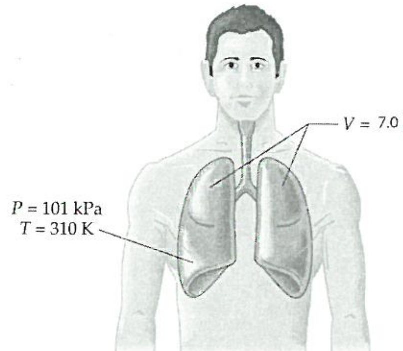
(16) Answer
19 cm

(31%)

(17) Answer
28 cm

(44%)

(18) A person's lungs might hold totally 7.0 L (1L = 10^{-3} m^3) of air at body temperature (310 K) and atmospheric pressure (101kPa). Air is 21% oxygen.
(18-a) Find the number of oxygen gas molecules in the lungs.
(18-b) Find the rms speed of oxygen gas molecules in the lungs.
(Equations)



$PV = NkT$

(a) $N = \frac{PV}{kT} = \frac{101 \times 10^{3} \times 7.0 \times 10^{-3}}{1.381 \times 10^{-23} \times 310}$

$= 1.651 \times 10^{23}$

$1.651 \times 10^{23} \times 0.21 = 0.3468 \times 10^{23}$

$\rightarrow 3.5 \times 10^{22}$

(b) $\frac{1}{2} m v^2 = \frac{3}{2} kT$

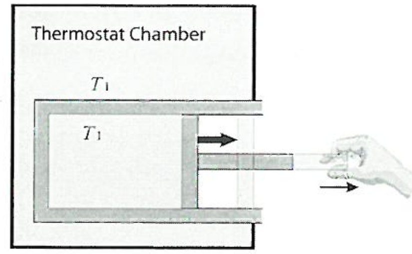
$v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 N_A k T}{N_A m}} = \sqrt{\frac{3RT}{M}}$

$= \sqrt{\frac{3 \times 8.314 \times 310}{32}}$

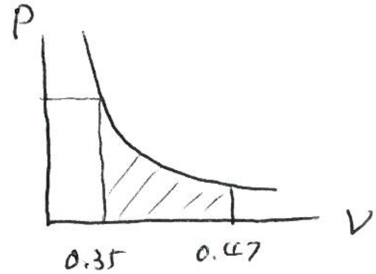
$= 15.54 \rightarrow 15.5$

(18-a) Answer
3.5×10^{22} molecules
(18-b) Answer
15.5 m/s

(37%)



(19) A cylinder holds 0.60 mol of a monatomic ideal gas at a temperature of 320 K. The gas expands isothermally (at constant temperature) from an initial volume of 0.35 m^3 to a final volume of 0.47 m^3.
(19-a) Find the work done.
(19-b) Find the heat flow into or out of the gas.
(Equations)



$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

$$= 0.60 \times 8.314 \times 320 \ln\left(\frac{0.47}{0.35}\right)$$

$$= \quad " \quad \times 0.295$$

$$= 470.6 \longrightarrow 470 \text{ (J)}$$

$$\Delta U = Q - W, \quad \Delta U = 0$$

$$\therefore Q = W = 470 \text{ (J)}$$

(19-a) Answer
470 J
(19-b) Answer
470 J into the cylinder

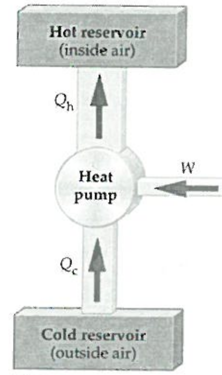
(37%)

1/25/2019 By Tohei Moritani

(20) To keep a room at a confortable 21.0℃, a Carnot heat pump does 345 J of work and supplies it with 3240 J of heat.

(20-a) How much heat is removed from the outside air by the heat pump?

(20-b) What is the temperature of the outside air? (Equations)



(d) Heat pump

(a) $Q_c = Q_h - W$

$= 3240 - 345$

$= 2895$ (J) $\longrightarrow$ 2900 J

(b) $\frac{T_c}{T_h} = \frac{Q_c}{Q_h}$

$\rightarrow T_c = T_h \frac{Q_c}{Q_h}$

$= 294.15 \times \frac{2895}{3240}$

$= 262.83$ (K)

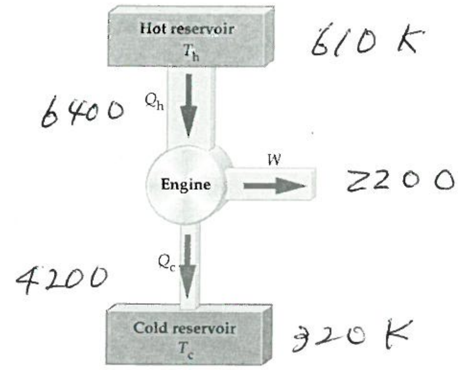
$= -10.3$ (°C)

$\rightarrow -10$°C

(20-a) Answer	2900 J
(20-b) Answer	−10 °C

(41%)

(21) A heat engine operates between a high-temperature reservoir at 610 K and a low-temperature reservoir at 320 K. In one cycle, the engine absorbs 6400 J of heat from the high-temperature reservoir and does 2200 J of work. What is the net change in entropy as a result of this cycle?
(Equations)



$$Q_c = 6400 - 2200$$
$$= 4200\ (J)$$

$$\Delta S_h = \frac{Q_h}{T_h} = \frac{-6400}{610} = -10.5$$

$$\Delta S_c = \frac{Q_c}{T_c} = \frac{4200}{320} = 13.1$$

$$\Delta S = \Delta S_h + \Delta S_c$$
$$= -10.5 + 13.1$$
$$= 2.6$$

(21) Answer
2.6 J/K

(26%)

一応OKで +2