Q1(1):

Let v be the maximum velocity of the object with mass m. Then, by the conservation of momentum, the magnitude of the maximum velocity of the object with mass M=$\frac{mv}{M}$.

As all the elastic potential energy are transfered to kinetic energy, we have the equation of conservation of energy:

$$\frac{1}{2}kl^2 = \frac{1}{2}mv^2 + \frac{1}{2}M(\frac{mv}{M})^2$$

$$v = \boxed{\sqrt{\frac{Mkl^2}{m(M+m)}}}$$

Q1(2):

After escape the gravitational field from the Earth, the potential energy becomes zero. Therefore, we have the following equation of conservation of energy:

$$KE + GPE = KE + GPE$$

$$\frac{1}{2}mv^2 - \frac{GMm}{R} = 0 + 0$$

$$v = \sqrt{\frac{2GM}{R}}$$

As the gravatational field strength of the Earth is given by $g = \frac{GM}{R^2}$, we have the escape speed $v = \boxed{\sqrt{2gR}}$.

Q1(3):

By the state equation, we have $pV = nRT$, which can be rewritten as $p = \frac{\rho}{m}RT$ (m refers to the molecular mass).

Therefore, undering constant pressure, we have $\rho \propto \frac{1}{T}$.

When the temperature increases from 270K to 300K, the density of air becomes $1.3 \cdot \frac{270}{300} = 1.17\ kg\ m^{-3}$.

The volume of air escaped=(The volume of air before)-(The volume of air after)

$= 100(1.3 - 1.17)$

$= \boxed{13\ kg}$

Q1(4):

Let Q be the number of charges accumulated in the capacitor C_1. Then, the voltage across C_1 will be $\frac{Q}{C_1}$ by the defination of capacitance.

Moreover, as C_2 is in parallel with C_1, the voltage across it will also be $\frac{Q}{C_1}$.

Hence, the number of charges accumulated in C_2=$\frac{QC_2}{C_1}$.

As C_3 is in series with $C_1 - C_2$, the number of charges acculmulated in C_3 is equal to the total number of charges accumulated in C_1 and C_2, i.e.

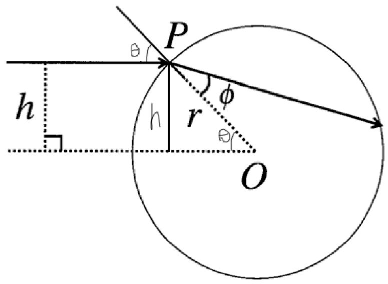
$Q + \frac{QC_2}{C_1} = \frac{Q(C_1+C_2)}{C_1}$. Then, the voltage across $C_3 = \frac{Q(C_1+C_2)}{C_1C_3}$.

Consider the total voltage consumed in the circuit, we have $E = \frac{Q}{C_1} + \frac{Q(C_1+C_2)}{C_1C_3}$.

Therefore, $Q = \boxed{\frac{C_1C_2}{C_1 + C_2 + C_3}E}$.

Q1(5):

Refer to the figure:



Consider the trigonometric ratio, we have $\sin\theta = \frac{h}{r}$.

On the other hand, by the Snell's law, we have $\sin\theta = n\sin\phi$.

Combine the above, we have $\sin\phi = \boxed{\dfrac{h}{nr}}$.

Q2:

(1): The cross section area of the strip=ab.

Across the period of time t, the electrons travelled by a distance of vt.

Therefore, the volume of electrons travelled across the period of time t=$abvt$.

As the electron density is n, the number of electrons is given by $\boxed{nabvt}$.

(2): Following (1), we have $q = nabvte$.

As $I = \frac{dq}{dt}$, we have $I = \boxed{qnabv}$.

(3): Total magnetic force received by the electrons=$BIl = B(qnabv)c = (nabc)qvB$.

As there are totally $nabc$ electrons, the average magnetic force received by each electron=$\frac{F}{nabc} = \boxed{qvB}$.

(4): As the magnetic force is balanced by the electric force, we have

$$qE = qvB$$

$$\frac{V}{b} = vB$$

$$V = \boxed{Bvb}$$

(5): By (2), we have $n = \frac{I}{qabv}$.

By (4), we have $b = \frac{V}{Bv}$. Therefore, $n = \boxed{\dfrac{BI}{qaV}}$.

Q3:

(1): Setting the potential energy as 0 at the point B.

By the conservation of energy, we have

$$KE + GPE = KE + GPE$$

$$0 + mga = \frac{1}{2}mv^2 + 0$$

$$v = \boxed{\sqrt{2ga}}$$

(2): Consider the balance of force: Centripetal force=(Tension)-(Weight)

$$\frac{mv^2}{a} = T - mg$$

$$t = \frac{m(\sqrt{2ga})^2}{a} + mg = \boxed{3mg}$$

(3): By the conservation of energy, we have

$$mga = \frac{1}{2}mv^2 + mg(2(a-b))$$

$$mv^2 = (-2a+4b)mg$$

Moreover, consider the balance of force: Centripetal force=(Tension)+(Weight)

$$\frac{mv^2}{a-b} = T + mg$$

$$T = (\frac{-2a+4b}{a-b} - 1)mg = \boxed{\frac{-3a+5b}{a-b}mg}$$

(4): The small ball reaches D without any bending if the tension at D is greater than 0, i.e.

$$\frac{-3a+5b}{a-b}mg > 0$$

$$a < \boxed{\frac{5}{3}b}$$

(5): Suppose the string bend at the height h. By the conservation of energy, we have

$$mga = \frac{1}{2}mv^2 + mgh$$

$$mv^2 = 2mg(a-h)$$

Moreover, as the string bended, the tension of it is equal to 0. Therefore, we have the component of the centripetal force at the direction of weight=weight.

The component of the centripetal force at the direction of weight

$=\frac{mv^2}{r}\cos\theta = \frac{2mg(a-h)}{\frac{a}{2}} \cdot \frac{\frac{a}{2}}{h-\frac{a}{2}} = \frac{4mg(a-h)}{2h-a}$, by considering the cosine ratio.

Therefore, we have $\frac{4mg(a-h)}{2h-a} = mg$, i.e. $h = \frac{5}{6}a$.

Now, substitue it back to $mv^2 = 2mg(a-h)$, we have $v = \boxed{\sqrt{\frac{ga}{3}}}$.

Q4:

(1): As $\frac{pV}{T}$ is constant for fixed number of moles, we have

$$\frac{p_0V_0}{T_A} = \frac{4p_0 3V_0}{T_C}$$

$$T_C = \boxed{12}T_A$$

(2): By $W = p\Delta V$, $W_{A\to B} = p_0(3V_0 - V_0) = \boxed{2p_0V_0}$.

(3): By the first law of thermodynamics, we have $Q = \Delta U + W_{gas}$. Therefore, we have the table (ΔU is given by $\frac{3}{2}\Delta pV$):

	ΔU	W_{gas}	Q
$A\to B$	$3p_0V_0$	$2p_0V_0$	$5p_0V_0$
$B\to C$	$\frac{27}{2}p_0V_0$	0	$\frac{27}{2}p_0V_0$
$C\to D$	$-12p_0V_0$	$-8p_0V_0$	$-20p_0V_0$
$D\to A$	$-\frac{9}{2}p_0V_0$	0	$-\frac{9}{2}p_0V_0$

Therefore, the thermal heat the gas receives from outside in process $\boxed{B\to C}$ is at a maximum.

(4): $\boxed{\dfrac{27}{2}p_0V_0}$.

(5): The net thermal heat received=$5p_0V_0+\frac{27}{2}p_0V_0-20p_0V_0-\frac{9}{2}p_0V_0=-6p_0V_0$.

Therefore, the net thermal heat emitted=$\boxed{6p_0V_0}$.

Alternative The net change in internal energy=0 after the full cycle.

The net work done to the surrounding by the gas

=The area bounded by the cycle=$(3p_0)(2V_0)=6p_0V_0$.

Therefore, the net thermal heat emitted=$\boxed{6p_0V_0}$.

Q5:

Background: The general formula of Doppler effect is $f_{observed}=\frac{V-v_{observer}}{V-v_{source}}f$.

(1): $\boxed{f\dfrac{V}{V-v}}$

(2): Note that the reflected wave travelled in the opposite direction as the source before the reflection. Therefore, the observed frequency=$\boxed{f\dfrac{V}{V+v}}$.

(3): Number of beats per second=$|f_1-f_2|=|f\frac{V}{V-v}-f\frac{V}{V+v}|=\boxed{f\dfrac{2Vv}{V^2-v^2}}$.

(4): Note that the wave travells in the opposite direction as the observer. Therefore, the observed frequency=$\boxed{f\dfrac{V+v}{V}}$.

(5): The frequency before reflection=$f\frac{V+v}{V}$.

The frequency after reflection (i.e. heard)=$(f\frac{V+v}{V})(\frac{V}{V-v}) = \boxed{f\frac{V+v}{V-v}}$.