Q1(1):

We have the components of the velocity:

$v_x = v\cos\theta$ and $v_y = v\sin\theta$.

Considering the vertical component, when the particle hits the ground again, we have $v\sin\theta t - \frac{1}{2}gt^2 = 0$. Therefore, $t = \frac{2v\sin\theta}{g}$.

Then, $L=$ the horizontal distance travelled during the time $= v\cos\theta \cdot \frac{2v\sin\theta}{g} = \boxed{\dfrac{2v^2\sin\theta\cos\theta}{g}}$.

Q1(2):

Consider the balance of forces: Centripetal force=Gravitational attraction.

$$m\omega^2 R = \frac{GMm}{R^2}$$

$$(\frac{2\pi}{T})^2 = \frac{GM}{R^3}$$

$$M = \boxed{\frac{4\pi^2 R^3}{GT^2}}$$

Q1(3):

For a gas expanded into a vacuum (free expansion), it has no changes in internal energy and therefore no changes in temperature.

For fixed temperature, we have the pressure inversely proportional to the volume.

Therefore, the final pressure= $\boxed{\frac{V}{V+V'}P}$.

Q1(4):

Consider the conservation of energy: KE+EPE=KE+EPE. When the particle attains the smallest distance, the kinetic energy of it becomes 0.

$$\frac{1}{2}mv^2 + \frac{1}{4\pi\epsilon_0} \cdot \frac{qQ}{L} = 0 + \frac{1}{4\pi\epsilon_0} \cdot \frac{qQ}{r}$$

$$r = \boxed{\frac{qQL}{qQ + 2\pi\epsilon_0 mv^2 L}}$$

Q1(5):

As the light ray bends away from the normal after enter the medium with refractive index n_2, we know the medium is optically less dense than that medium with refractive index n_1, i.e. $\boxed{n_1 > n_2}$.

Q2:

(1): The current flows $\boxed{\text{from } b \text{ to } a}$ by Fleming's right-hand rule.

(2): The magnitude of the B-field at the direction perpendicular to the motion= $B\cos\theta$.

By Faraday's law, we have the induced EMF

$=\frac{d\Phi}{dt} = \frac{d(B\cos\theta A)}{dt} = \frac{dx}{dt} dB\cos\theta = vdB\cos\theta.$

By Ohm's law, $V = IR$, we have $I = \boxed{\dfrac{vdB\cos\theta}{R}}$.

(3): The magnetic force $F = BIL = (B\cos\theta)(\frac{vdB\cos\theta}{R})(d) = \boxed{\dfrac{vd^2B^2\cos^2\theta}{R}}$.

(4): The magnetic force when the bar is moving at a speed u=$\frac{ud^2B^2\cos^2\theta}{R}$.

As the rod moves at a constant speed by that time, the gravitational force at the direction of motion is balanced by the magnetic force.

The gravitational force at that direction=$mg\sin\theta$.

Therefore, we have

$$mg\sin\theta = \frac{ud^2B^2\cos^2\theta}{R}$$

$$u = \boxed{\frac{mgR\sin\theta}{d^2B^2\cos^2\theta}}$$

(5): The vertical component of the velocity of the bar=$u\sin\theta = \frac{mgR\tan^2\theta}{d^2B^2}$.

The rate of work done $P = Fv = (mg)(\frac{mgR\tan^2\theta}{d^2B^2}) = \boxed{\dfrac{m^2g^2R\tan^2\theta}{d^2B^2}}$

Q3:

(1): Consider the balance of force: Tension of the spring=Weight of the mass.

$$kl = Mg$$

$$l = \boxed{\frac{Mg}{k}}$$

(2): By the conservation of momentum, we have

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

$$V = \boxed{\frac{m}{M+m}v}$$

(3): $\frac{1}{2}mv^2 - \frac{1}{2}(M+m)(\frac{m}{M+m}v)^2 = \boxed{\frac{Mm}{2(M+m)}v^2}$

(4): The acceleration of SHM is given by $a = -\omega^2 x$. Comparing it with $a = -\frac{k}{M+m}g$, we have $\omega = \sqrt{\frac{k}{M+m}}$. Therefore, $T = \boxed{2\pi\sqrt{\frac{M+m}{k}}}$.

(5): Set the GPE as 0 at the height of the point of collision. The height of the highest position will be $\frac{Mg}{k}$ by the calculation in (1). Then, the GPE at the highest position will be $mg(\frac{Mg}{k})$.

Moreover, the elastic potential energy is 0 at the equilibrium position and $\frac{1}{2}k(\frac{Mg}{k})^2$ at the highest position.

Consider the conservation of energy, we have KE+GPE+EPE=KE+GPE+EPE.

$$\frac{1}{2}(M+m)(\frac{m}{M+m}v)^2 + 0 + 0 = 0 + mg(\frac{Mg}{k}) + \frac{1}{2}k(\frac{Mg}{k})^2$$
$$\frac{1}{2}mv^2 = \boxed{\frac{M(M+m)(M+2m)g^2}{2km}}$$

Q4:

(1): The force due to pressure difference is $(2p_0 - p_0)S = p_0 S$ N pointing upwards.

Consider the balance of forces: The wight of the piston is balanced by the above force.

$$Mg = p_0 S$$

$$M = \boxed{\frac{p_0 S}{g}}$$

(2): The initial volume=Sh.

Then, by the ideal gas equation $pV = nRT$, the initial temperature of the gas=$\frac{2p_0 Sh}{1 \cdot R} = \boxed{\frac{2p_0 Sh}{R}}$.

(3): The work done by gas for finxed pressure is given by $p\Delta V$.

For the process, $\Delta V = \frac{3}{2}hS - hS = \frac{1}{2}hS$.

Therefore, the work done=$(2p_0)(\frac{1}{2}hS) = \boxed{p_0 Sh}$.

(4): The change in internal energy of the gas is given by

$\Delta U = \frac{3}{2}\Delta pV = 3p_0\Delta V = \frac{3}{2}p_0 Sh$.

By the first law of thermodynamics, we have $\Delta U = Q - W_{gas}$.

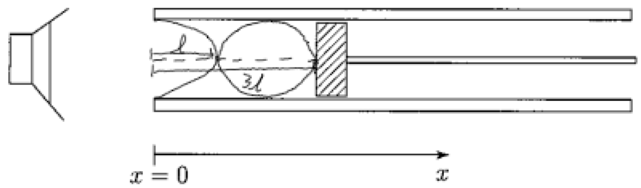
Therefore, $Q = \Delta U + W_{gas} = \frac{3}{2}p_0 Sh + p_0 Sh = \boxed{\frac{5p_0 Sh}{2}}$

Alternative As for constant pressure, the temperature is directly proportional to the volume, the temperature after the process=$\frac{2p_0 Sh}{R} \cdot \frac{\frac{3}{2}hS}{hS} = \frac{3p_0 Sh}{R}$.

By $Q = \frac{5}{2}R\Delta T$, we have $Q = \frac{5}{2}R(\frac{3p_0 Sh}{R} - \frac{2p_0 Sh}{R}) = \boxed{\frac{5p_0 Sh}{2}}$.

Q5:

(1): Refer to the graph:



The distance between the first and the second nodes=$\frac{1}{2}\lambda = 3l - l$. Therefore, we have $\lambda = \boxed{4l}$.

(2): $v = f\lambda = \boxed{4fl}$.

(3): The time variation of the air density is at a maximum when the air particles are most compressed.

As the air particles surrounding the nodes are most compressed for a stationary longitudinal wave, the required distance=the distance from the left end to the first node=$\boxed{l}$.

(4): When the temperature rises, the density of air particles rises. As the densier the medium the faster logitudinal wave spread, the wave speed is increased.

However, as the frequency of wave is independent on the medium, the wave length is hence increased.

As the longer the wave length, the larger the value of l, we have the value $\boxed{\text{increases}}$ when the temperature rises.

(5): A large sound would next be heard when the number of nodes increases to 3.

By that time, $3l = \frac{5}{4}\lambda$, i.e. $\lambda = \frac{12}{5}l$.

As the speed of the wave remains uncharged, we have $f'(\frac{12}{5}l) = 4fl$, i.e. $f' = \boxed{\dfrac{5}{3}f}$.