Q1(1):

By $F = kx = mg$, the spring extended by $x = \frac{mg}{k}$ $m$ in length after the mass is hung. Setting the gravitational potential energy to be zero at the natural length of the spring. Then, we have:

Total mechanical energy at the equilibrium position=EPE+GPE=$\frac{1}{2}kx^2 - mgx = \frac{1}{2}k(\frac{mg}{k})^2 - mg(\frac{mg}{k}) = -\frac{m^2g^2}{2k}$ $J$.

Total mechanical energy at the natural length of the spring=EPE+GPE=0+0=0 $J$.

Then, the work done$= 0 - (-\frac{m^2g^2}{2k}) = \frac{m^2g^2}{2k}$ $J$. The answer is $\boxed{(c)}$.

---

Q1(2):

The vectors of electric fields of negative charge and positive charge are pointing at a direction toward and outward the charge respectively. As the triangle is a equilateral triangle, we have each internal angle is equal to $60°$. Therefore, the angle between the positive x-axis and the vectors of electric fields of the $-q$ charge and the $+q$ charge at the point $P$ are $180+60 = 240°$ and $180-60 = 120°$ respectively.

On the other hand, the magnitudes of the two vectors are the same, which is $k\frac{q}{d^2}$ $N/C$.

Now, the vector sum of the two vectors is pointing towards the direction $D$ and with a magnitude of $2k\frac{q}{d^2}\cos 60° = k\frac{\sqrt{3}q}{d^2}$ $N/C$. Hence the answers are $\boxed{(d)}$ and $\boxed{(f)}$ respectively.

---

Q1(3):

As particles in a longitudinal wave is travelling at the same direction of the wave. The positive direction of displacement of particle (i.e. positive y direction) is in the positive x direction.

Consider the graph of the wave right afterwards, which is obtained by horizontally translate the graph to the positive x direction by a bit. Finding the corresponding positions of each particle, we have the displacements of $A$ and $D$ decreased and the displacements of $B$ and $C$ increased. Hence only particles $B$ and $C$ are travelling to the positive x direction. Moreover, as $C$ is at the trough, it has the greatest acceleration.

Given the above, the particle that has the greatest acceleration in the positive x direction is $C$ and the answer is $\boxed{(c)}$.

---

Q1(4):

We have the equation: ${}^{238}_{92}U \to ? + x\ {}^{4}_{2}\alpha + y\ {}^{0}_{-1}\beta$, where $x, y \in \mathbb{N}$ and ? is the final stable nucleus.

As the mass number and the number of protons must be conserved. Let $m$ be the mass number of the final stable nucleus, we have $238 = m + 4x$, or $m = 238 - 4x$. Note that among the four options, only for $m = 206$ (take $x = 8$) we can find a corresponding $x \in \mathbb{N}$. Therefore, we have the answer is ${}^{206}_{82}Pb$, $\boxed{(c)}$.

---

Q2:

(1): Right after the switch $S_1$ is closed, as the capacitor is uncharged, we have the resistance of it is 0 $\Omega$ and all the voltages are consumed by the resistor $R_1$. Hence, by Ohm's law, we have $6 = I(4)$, i.e. $I = 1.5\ A$. The answer is $\boxed{(a)}$.

(2): After the capacitor is fully charged, it has infinite resistance and all the voltages are consumed by it. By the defination of capacitance, we have $C = \frac{Q}{V}$, i.e. $Q = CV = (2\mu)(6) = 12\ \mu C$. The answer is $\boxed{(b)}$.

(3): The work done by the battery is equal to $V\Delta Q$. In this case, the charges consumed is equal to the charges stored in the capacitor, i.e. $\Delta Q = 12\ \mu C$. Therefore, we have $W = 6(12\mu) = 72\ \mu J$. The answer is $\boxed{(d)}$.

(4): The internal energy of the fully charge capacitor=$U = \frac{1}{2}QV = \frac{1}{2}(12\mu)(6) = 36\ \mu J$. Therefore, the energy loss=$W - U = 72 - 36 = 36\ \mu J$. All the energy loss are transfered to heat energy released by the resistor. Hence, the heat energy=36 $\mu J$. The answer is $\boxed{(c)}$.

(5): The equivalent resistance of the capacitor and the resistor $R_2 = \frac{1}{\frac{1}{\infty}+\frac{1}{2}} = 2\ \Omega$. Therefore, the voltage across the capacitor becomes $\frac{2}{4+2} \cdot 6 = 2\ V$ after switch $S_2$ closed. By $C = \frac{Q}{V}$, we have $Q = (2\mu)(2) = 4\ \mu C$. The answer is $\boxed{(a)}$.

---

Q3:

(1): Set the gravitational energy to be zero at the heigh $y = 0$. Then, the gravitational energy at the point $P = mgY\ J$ (note that the y-axis is at the same direction as the gravitational acceleration). We have:

Total mechanical energy at the point $O = KE + GPE = \frac{m}{2}v_0^2 + 0 = \frac{m}{2}v_0^2\ J$.

Total mechanical energy at the point $P = KE + GPE = \frac{m}{2}v^2 + mgY\ J$.

By the conservation of energy, we have $\frac{m}{2}v^2 + mgY = \frac{m}{2}v_0^2$. The answer is $\boxed{(a)}$.

(2): The perpendicular length of $P$ to the horizontal line $y = R$ (i.e. the horizontal line passes through the centre of the circle) equals to $R - Y\ m$. The distance between the centre of the circle and $P$ equals to the radius of the circle (i.e. R). Consider the sine ratio of this right-angled triangle, we have $\sin\theta = \frac{R-Y}{R}$.

(3), (4): By $\frac{m}{2}v^2 + mgY = \frac{m}{2}v_0^2$, we have $mv^2 = mv_0^2 - 2mgY$. Substitue it and $\sin\theta = \frac{R-Y}{R}$ into the provided equation, we have:

$$mg\frac{R-Y}{R} = \frac{mv_0^2 - 2mgY}{R}$$

$$g(R-Y) = v_0^2 = 2gY$$

$$3gY = gR - v_0^2$$

$$Y = \frac{1}{3}R - \frac{1}{3}\frac{v_0^2}{g}$$

Therefore, the answers for part (3) and (4) are $\boxed{(b)}$ and $\boxed{(d)}$ repsectively.

(5): As the object undergoes free fall after separated from the sphere, we have its path is a parabola with constant accerelation ($a = g$). The answer is $\boxed{(d)}$.

---

Q4:

(1): Note that the pressure inside is constant as the volume is variable. Then, by $pV = nRT$, work done by the gas (to the piston)$=p\Delta V = nR\Delta T = R \times 1\ mol \times 1\ K$. The answer is $\boxed{(b)}$.

(2): By $Q = Cn\Delta T$, where $C$ is the molar heat capacity of gas, we have $Q = C \times 1\ mol \times 1\ K$. The answer is $\boxed{(a)}$.

(3): By $U = \frac{3}{2}nRT$, we have the change in internal energy of the gas $\Delta U = \frac{3}{2}nR\Delta T$. Then, by the first law of thermaldynamics, we have $\Delta U = Q - W_{gas}$. Therefore, $Q = \Delta U + W_{gas} = \frac{3}{2}Rn\Delta T + Rn\Delta T = \frac{5}{2}Rn\Delta T$. Therefore, $C = \frac{5}{2}R > R$. The answer is $\boxed{(a)}$.

(4): By $P = IV$ and $V = IR$, we have $P = \frac{V^2}{R} = \frac{E^2}{R_0}\ J/s$. Therefore, the heat per unit time$=P = \frac{E^2}{R_0}\ J/s$. The answer is $\boxed{(d)}$.

---

Q5:

(1): By the general form of Doppler's effect $f_{observed} = \frac{v-v_{observer}}{v-v_{source}}f$. Therefore, we have the frequency of wave moving in front of the ship when the ship is moving$=\frac{bT}{bT-V_0}f$ and the ratio $\frac{\text{frequency of wave moving in front of the ship when the ship is moving}}{\text{frequency of wave moving in front of the ship when the ship is stationary}} = \frac{\frac{bT}{bT-V_0}f}{f} = \frac{bT}{bT-V_0}$. By $v = f\lambda$, for fixed wave speed $v$, we have $\lambda$ is proportional to $\frac{1}{f}$. Hence, the required ration$=\frac{bT-V_0}{bT}$. The answer is $\boxed{(c)}$.

(2): Similar to that in part (1), we have the frequency of wave moving behind the ship when the ship is moving$=\frac{bT}{bT-(-V_0)}f = \frac{bT}{bT+V_0}f$. Therefore, the ratio $\frac{\text{frequency of wave moving behind the ship when the ship is moving}}{\text{frequency of wave moving behind the ship when the ship is stationary}} = \frac{\frac{bT}{bT+V_0}f}{f} = \frac{bT}{bT+V_0}$ and the required ratio$=\frac{bT+V_0}{bT}$. The answer is $\boxed{(e)}$.