Q1(1):

The horizontal velocity is constantly $v_x = v$ as there's no horizontal acceleration.

For the vertical velocity when the ball hits the ground, we have $v^2 - u^2 = 2as$.

Therefore, we have $v_y = \sqrt{2gh}$.

Therefore, we have $\tan\theta = \frac{v_y}{v_x} = \boxed{\frac{\sqrt{2gh}}{v}}$.

Note: That $v_y = \sqrt{2gh}$ can also be obtained by considering the conservation of energy (GPE to KE).

Q1(2):

Note that the centripetal force is entirely provided by the tension of the spring.

Therefore, we have

$$F_{centripetal} = F_{spring}$$

$$\frac{mv^2}{l_0 + \alpha l_0} = k\alpha l_0$$

$$v = \boxed{\sqrt{\frac{(1+\alpha)\alpha k}{m}} l_0}$$

Q1(3):

The electric force that the charge experiences$=qE$. Therefore, the acceleration of the charge$=\frac{qE}{m}$.

By $s = ut + \frac{1}{2}at^2$, we have $d = 0 + \frac{1}{2}(\frac{qE}{m})t^2$, i.e. $t = \boxed{\sqrt{\frac{2md}{qE}}}$.

Q1(4):

For Young's double slit, we have $\Delta y = \frac{D\lambda}{a}$. Therefore, for the setting, we have the fringe separation$=\frac{L\lambda}{d}$.

As a bright fringe appears at O, the distance between O and the third dark fringe$=3(\frac{L\lambda}{d}) + \frac{1}{2}(\frac{L\lambda}{d}) = \boxed{\dfrac{5L\lambda}{2d}}$.

Q1(5):

We have $SO = 15\ cm$. Therefore, for the angle between SO and the horizontal line, call it θ, we have $\cos\theta = \frac{9}{15} = \frac{3}{5}$.

Hence, the component of the velocity of the of observer's motion in the direction SO (i.e. the direction that the sound wave propagrate)$=5\cos\theta = 3\ m/s$.

The general form of the Doppler effect is given by $f_{oberved} = \frac{V - v_{observer}}{V - v_{source}} f$.

Therefore, the heard frequency$=\frac{330-3}{330} \times 660 = 654\ Hz$.

Q2:

(1): The magnetic flux is given by $\Phi = BA$. As at the time t, the area of the coil with magnetic field passing through it$=lvt$, we have the magnetic flux $\Phi = \boxed{vBlt}$.

(2): By Faraday's law, we have the induced EMF$=\frac{d\Phi}{dt} = \boxed{vBl}$.

(3): By Ohm's law, we have $I = \frac{V}{R} = \boxed{\dfrac{vBl}{R}}$.

(4): By Fleming's right hand rule, the induced current flows in the direction $\boxed{a \to b \to c \to d}$.

Alternative By Lenz' law, the coil will have to produce a magnetic field pointing inside the paper inside the coil so as to oppose the change in magnetic flux. Therefore, by right hand grip rule, the direction of the induced current will be $\boxed{a \to b \to c \to d}$.

(5): To maintain the constant speed, we have to provide an extra force to balance the magnetic force due to the induced current.
Therefore, the magnitude of the force$=BIL = B(\frac{vBl}{R})l = \boxed{\dfrac{vB^2l^2}{R}}$.

Q3:

(1): The gravitational field strength of the Earth is given by $g = \frac{GM}{R^2}$.
Substitue the provided value, we have $M = \frac{9.8 \cdot (6.4 \times 10^6)^2}{6.67 \times 10^{-11}} \approx \boxed{6.0 \times 10^{24}\ kg}$.

(2): When an object has escaped the Earth's gravitational field, the GPE of it becomes 0.

Consider the connservation of energy: KE+GPE=KE+GPE

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

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

As $\frac{GM}{R} = gR$, we have $v = \sqrt{2gR} = \sqrt{2 * 9.8 * 6.4 \times 10^6} \approx \boxed{1.1 \times 10^4\ m/s}$

(3): By the calculation in (2), we have $v = \sqrt{2\frac{GM}{R}}$, i.e. the escape speed is directly proportional to the square root of mass and inversely proportional to the square root of radius.

Therefore, the ratio$=\sqrt{\frac{320}{11}} \approx \boxed{5.4}$.

(4): The centripetal force of the satellite is entirely provided by the gravitational attraction of the Earth. Therefore, we have

$$m(\frac{2\pi}{T})^2 r = \frac{GMm}{r^2}$$

$$R = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{6.67 \times 10^{-11} \cdot 6.0 \times 10^{24} \cdot (24 \cdot 3600)^2}{4\pi^2}} \approx \boxed{4.2 \times 10^7}$$

Note: For this question, as the values between options are quite significant, the numerical error allowed is very large. As we are not allowed to use a calculator, we can simply calculate the power of 10 first, and then estimate the numerical part with approximations like $g = 10$, $6.67 = 7$, $\pi = 3$, etc. to find out the range of the answer instead of doing the clumsy calculation.

Q4:

(1): For the process AB, the work done by gas is equal to 0. Therefore, by the first law of thermodynamics, the thermal energy transferred into the system=$\Delta U = \frac{3}{2}(4P_0)V_0 - \frac{3}{2}P_0V_0 = \boxed{\frac{9}{2}P_0V_0}$.

Alternative The molar heat capacitor for constant volume is given by $\frac{3}{2}R$.

By $pV = nRT$, the temperature difference for the process $AB = 3\frac{P_0V_0}{R}$.

Therefore, the thermal energy transferred into the system=$(\frac{3}{2}R)(3\frac{P_0V_0}{R}) = \boxed{\frac{9}{2}P_0V_0}$.

(2): The work done by the gas in process BC=The signed area under the $p-V$ graph=$(4P_0)(4V_0 - V_0) = 12P_0V_0$.

Moreover, the change in internal energy for the process

$=\frac{3}{2}(4P_0)(4V_0) - \frac{3}{2}(4P_0)V_0 = 18P_0V_0$.

By the first law of thermodynamics, we have $Q = \Delta U + W_{gas} = \boxed{30P_0V_0}$.

Alternative The molar heat capacity for fixed pressure is given by $\frac{5}{2}R$.

By $pV = nRT$, the temperature difference for the process $BC = 12\frac{P_0V_0}{R}$.

Therefore, the thermal energy transferred into the system

$=(\frac{5}{2}R)(12\frac{P_0V_0}{R}) = \boxed{30P_0V_0}$.

(3): The work done by the gas=The signed area under the $p-V$ graph

$=(4P_0 - P_0)(4V_0 - V_0)$

$= \boxed{9P_0V_0}$.

(4): As for process CD and DA, heat is released, the total heat income for the system$=\frac{9}{2}P_0V_0 + 30P_0V_0 = \frac{69}{2}P_0V_0$.

Therefore, $\eta = \frac{W_{gas}}{Q_{in}} = \frac{9P_0V_0}{\frac{69}{2}P_0V_0} = \boxed{\frac{6}{29}}$.

Alternative Similarly to (1) and (2), the thermal heat transferred into the system for processes CD and DC are $-18P_0V_0$ and $-\frac{15}{2}P_0V_0$.

Therefore, $\eta = \frac{Q_{in}-Q_{out}}{Q_{in}} = \frac{\frac{9}{2}P_0V_0+30P_0V_0-18P_0V_0-\frac{15}{2}P_0V_0}{\frac{9}{2}P_0V_0+30P_0V_0} = \boxed{\frac{6}{29}}$.

Q5:

(1): By the graph, the amplitude of $\Delta P = \boxed{A}$.

(2): By the graph, the half period$=t_2 - t_1$. Therefore, the period$=\boxed{2(t_2 - t_1)}$.

(3): $\lambda = vT = \boxed{2v(t_2 - t_1)}$.

(4): As the pressure is directly proportional to the density, the higher the pressure the higher the density. Therefore, $\boxed{d}$ is the highest density point.