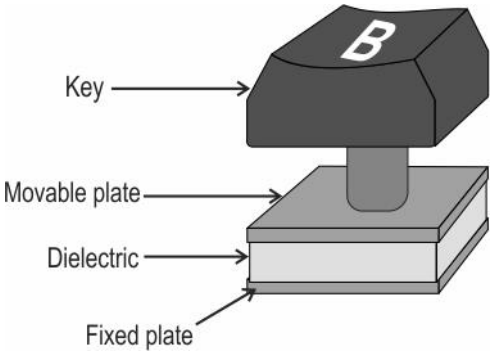
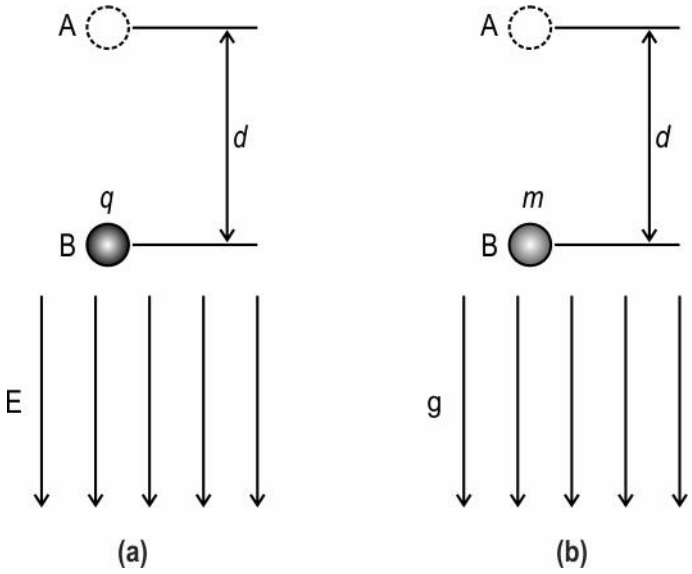
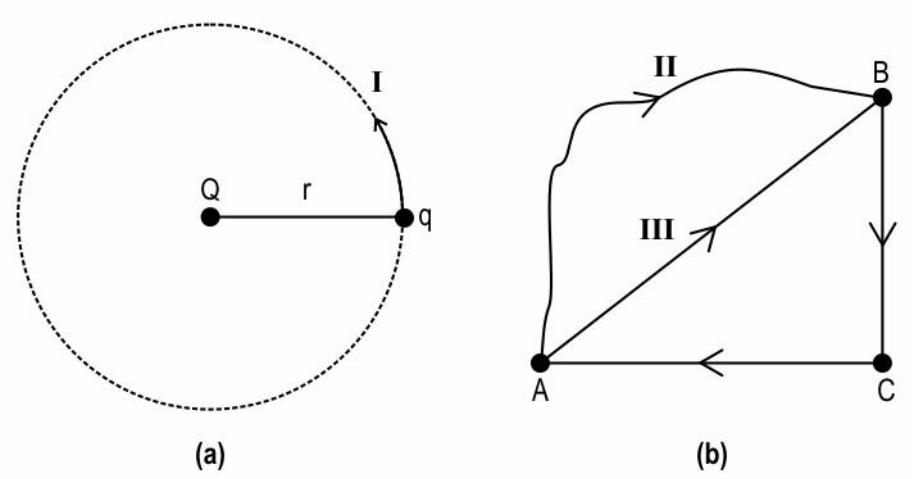
Electrostatic Potential And Capacitance

Q.No	Question	Marks
	Multiple Choice Question	
Q.20	In one kind of computer keyboard, each key is mounted on one end of a plunger. The other end of the plunger is attached to a movable metal plate. Refer to the figure given.  The dielectric material between the two plates is made of a soft material and is compressible. The combination of the two plates and the dielectric between them constitutes a capacitor. Each key on the keyboard when pressed is recognized due to which one of the following factors? A. The pressing of the key increases the capacitance of the capacitor below the key due to a decrease in separation between the plates. B. The decrease in the thickness of the soft dielectric layer decreases the capacitance of the capacitor below the key. C. The momentary decrease in the space between the plates of the capacitor is detected as a mechanical sound signal of a specific frequency. D. all of the above	1
Q.21	Given below are the representations of uniform electric and gravitational fields.	1

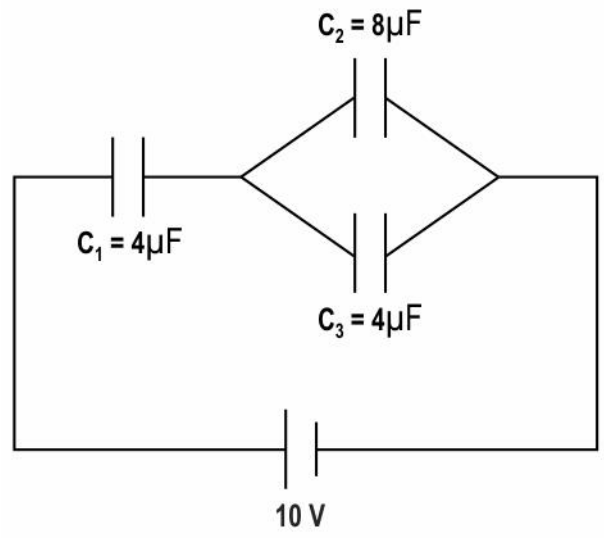
	 In fig (a), a positive charge q moves from A to B in the direction parallel to electric field **E**. The charge-field system undergoes a change in its electrical potential energy. In fig (b), a mass particle m moves from A to B in the direction parallel to gravitational field **g**. The mass-field system undergoes a change in gravitational potential energy. Identify the statement that correctly states the changes in the energies of the above two systems. A. The charge-field system loses electrical potential energy whereas the mass-field system gains gravitational potential energy. B. The charge-field system gains electrical potential energy whereas the mass-field system loses gravitational potential energy. C. Both the charge-field system and the mass-field system lose their respective potential energies. D. Both the charge-field system and the mass-field system gain their respective potential energies.	
Q.22	In Fig (a), a positive charge Q is located at a point. A unit test charge q moves along path I in one complete circle around Q. In Fig (b), II and III represent the paths along which a unit test charge is moved from point A to B in the presence of an electrostatic field.	1



Which of the following statements INCORRECTLY describes the work done in moving the unit test charge in the presence of an electric field in the above context?

A. Work done along path I is zero.
B. Total work done along path II and then along B – C – A is zero.
C. Work done along path II is more than the work done along path III.
D. Total work done along path III and then along B – C – A is EQUAL to the total work done along path II and then along B – C – A.

Q.23 Three capacitors C_1, C_2 and C_3 are connected in a combination as shown below. 1



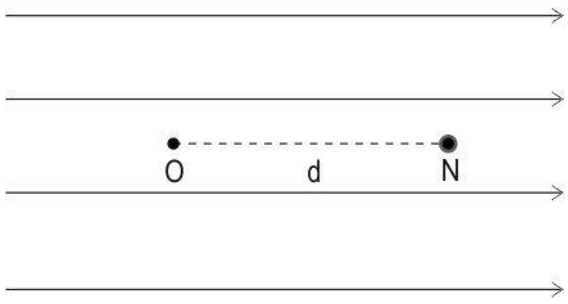
Identify the correct statement(s).

(i) The charge on capacitor C_1 is greater than that on capacitor C_2.

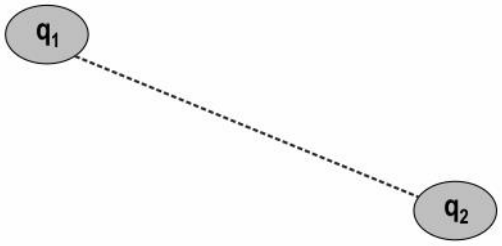
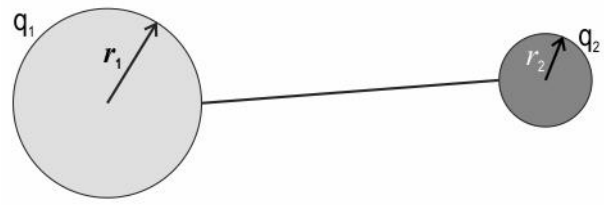
(ii) The charge on capacitor C_1 is the same as that on capacitor C_3.

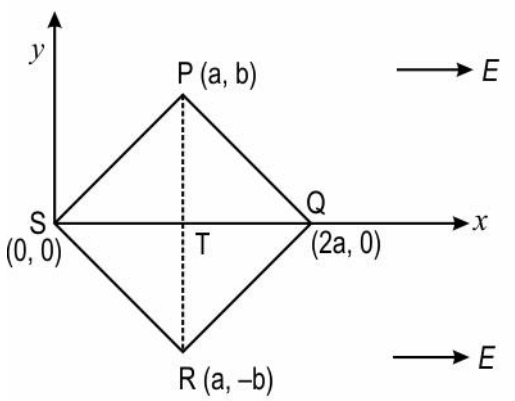
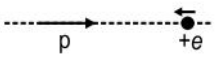
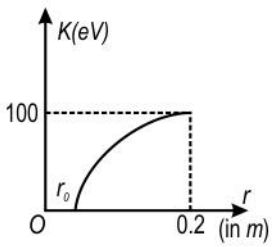
(iii) The charge on capacitor C_1 is 30 μC.

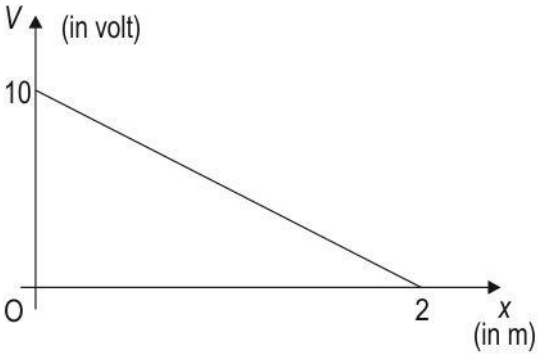
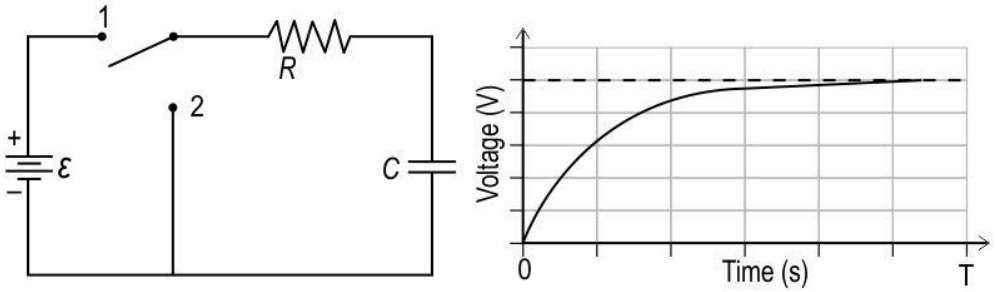
A. Only (i) is correct.

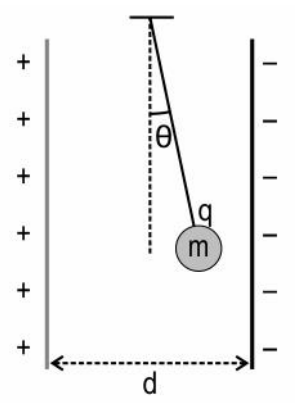
	B. Only (iii) is correct. C. Both (i) and (iii) are correct. D. Both (i) and (ii) are correct.	
Q.24	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The charge-to-voltage ratio increases on insertion of a dielectric material between the capacitor plates, when either the voltage or charge is kept constant. Reason (R): The capacitance of a capacitor increases when it is filled with a dielectric material with a dielectric constant greater than 1. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	1
Q.25	The electric potential at point N in a uniform electric field is V_0. Now, an electric dipole of dipole moment 'p', charge 'q', and dipole length '2a' is placed in this field with its centre (O) at a distance 'd' (d>>a) from point N as shown in the figure. If the orientation of the dipole is such that its potential energy is maximum, what will be the new electric potential at point N?  A. $V_0-(q/4\pi\epsilon_0 d)$ B. $V_0+(q/4\pi\epsilon_0 d)$ C. $V_0+(p/4\pi\epsilon_0 d^2)$ D. $V_0-(p/4\pi\epsilon_0 d^2)$	1
Q.26	An electron is introduced in a region of an electric field. The charge starts accelerating in the direction opposite to that of the field. Which of the following statements is true?	1

	A. The field does positive work on the electron and its potential energy increases. B. The field does positive work on the electron and its potential energy decreases. C. The field does negative work on the electron and its potential energy increases. D. The field does negative work on the electron and its potential energy decreases.	
Q.27	Assertion: The potential at a point is characteristic of the electric field at a point only whereas electric potential energy at a point is characteristic of the charge–field system. Reason: The potential is independent of a charged test charge placed in the field and the electric potential energy is due to an interaction between the electric field at the point and the charged particle placed in the field at that point. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.28	Assertion: The electric potential is constant everywhere inside a charged conductor and is equal to its value at the surface. Reason: A constant work has to be done to move a test charge from the interior of a charged conductor to its surface. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.29	Assertion: A thin uncharged metallic plate placed in between the two charged plates of a capacitor results in an arrangement equivalent to two capacitors in a series combination. The equivalent capacitance of this combination stays the same irrespective of the position of the metallic plate in between the plates of the capacitor. Reason: The change in the position of the central metallic plate, results in the decrease in plate separation of one capacitor that is compensated by the increase in plate separation for the other. Select the correct option. A. Both A and R are true and R is the correct explanation of A	1

	B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	
Free Response Questions/Subjective Questions		
Q.30	Two-point charges are placed along the x-axis as shown.  Along the line joining the two charges, how many points are possible at which the total potential due to the charges is zero? Predict the probable locations.	3
Q.31	Given are two charges, q_1, a negative source charge, and q_2, a test charge. The test charge q_2 is initially positive and then changed into a negative charge of the same magnitude.  (a) Will the potential at the position of charge q_2 due to the source charge q_1 (i) remain the same, (ii) increase or (iii) decrease? (b) Will the potential energy of the q_1 & q_2 charge system (i) remain the same, (ii) increase or (iii) decrease? Give an explanation in each case.	3
Q.32	A conducting wire connects two charged conducting spheres such that they attain equilibrium with respect to each other. The distance of separation between the two spheres is very large as compared to either of their radii.  Find the ratio of the magnitudes of the electric fields at the surfaces of the two spheres.	2
Q.33	A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored in the capacitor. The battery is then disconnected, and the distance between the plates of the capacitor is increased by a small amount.	6

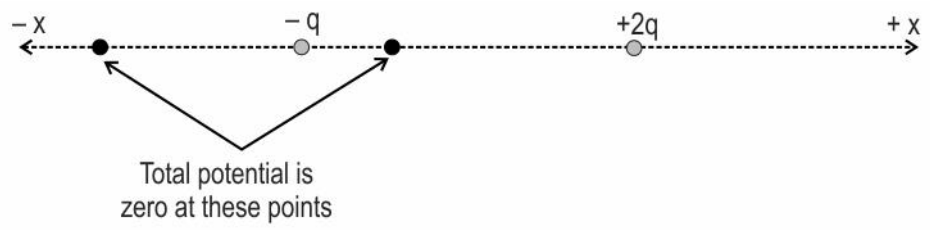
	What changes will occur in each of the following quantities? Will they increase, decrease or remain the same? Give an explanation in each case. (a) Capacitance (b) Charge (c) Potential difference (d) Electric field (e) Energy stored in the capacitor	
Q.34	Test charge q moves along a path P -> Q -> R -> S in a uniform electric field region directed along +x-axis. The coordinates of the points are as follows: P (a, b, 0), Q (2a, 0, 0), R (a, -b, 0) and S (0, 0, 0).  (a) Identify the plane of motion of the test charge. (b) Determine the work done by the electric field as the test charge moves from P to S. Use diagram, if necessary.	3
Q.35	A proton (e) approaches a short fixed electric dipole (p) moving along the dipole axis as shown in the figure. At a large distance from the dipole, the kinetic energy of the proton was K_0 = 400 eV.  The graph below shows the variation of kinetic energy (K) of the proton at points close to the dipole. Find the value of r_0 (r_0>> length of the dipole). In the graph r is the distance from the centre of the dipole. 	3

Q.36	The variation of electric potential in a region is shown in the graph below. Find the magnitude and direction of the force on a particle having a charge of +2 μC just after it is released at a point x = 1 m in this region.  	3
Q.37	The circuit below shows a resistor and an air-filled capacitor connected to a battery. The graph below shows the variation of voltage across the capacitor with time when the switch is moved to position 1.  (a) Draw a graph to show the variation of the voltage across the resistor. (b) At time T, what is the current in the circuit? Give a reason for your answer. (c) When the switch is moved to position 2, how does the voltage across the resistor and the capacitor change? (d) The capacitor in the circuit above is replaced by another capacitor with the same area of plates and distance between the plates but with a dielectric material between the plates. What happens to the following quantities when the switch is in position 1? (i) capacitance (ii) charge (iii) potential difference between plates (iv) energy stored by capacitor	5
Q.38	A parallel plate capacitor is given as in the diagram. A small ball is suspended by an insulated thread in the space between the plates of the capacitor. The thread makes an angle θ with the vertical at equilibrium.	2



What is the potential difference between the capacitor plates?

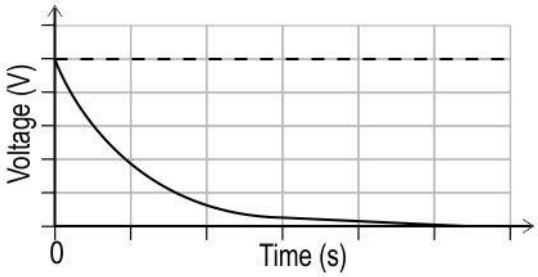
Answer key and Marking Scheme

Q.No	Answers	Marks
Q.20	A. The pressing of the key increases the capacitance of the capacitor below the key due to a decrease in separation between the plates.	1
Q.21	C. Both the charge-field system and the mass-field system lose their respective potential energies.	1
Q.22	C. Work done along path II is more than the work done along path III.	1
Q.23	C. Both (i) and (iii) are correct.	1
Q.24	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.25	D. V0-(p/4π∈0d2)	1
Q.26	B. The field does positive work on the electron and its potential energy decreases.	1
Q.27	A. Both A and R are true and R is the correct explanation of A	1
Q.28	C. A is true but R is false	1
Q.29	A. Both A and R are true and R is the correct explanation of A	1
Q.30	Two places. [1 mark for stating the number of probable locations of zero potential] Location 1: As the two charges are opposite, in between the two charges, there is a location, where the individual electric potentials balance. As the charges are not of equal magnitude, this point of zero potential occurs a little closer to the smaller charge, that is, -q. [1 mark for identification of the first location] Location 2: To the left of the smaller charge, -q, there is another location at which the individual potentials due to –q and +2q will exactly balance each other.  [1 mark for identification of the second location]	3
Q.31	(a) Remains the same.	3

	The potential at a location depends on the source charge. It is independent of the test charge at the location. [0.5 mark for the correct change] [1 mark for the correct explanation] (b) Increases. The initial potential energy of q1 & q2 charge system was negative. When the test charge is changed from positive to negative, the potential energy becomes positive. So it increases. [0.5 mark for the correct change] [1 mark for the correct explanation]	
Q.32	At equilibrium, the potential on the surface of a larger sphere = potential on the surface of a smaller sphere. $V = \frac{kq_1}{r_1} = \frac{kq_2}{r_2}$ So, $\frac{q_1}{q_2} = \frac{r_1}{r_2}$ [1 mark for the correct ratio of q1 to q2] Since the two charges are very far from each other, the electric fields on the surfaces of the two spheres will be: $E_1 = \frac{kq_1}{r_1^2}$ and $E_2 = \frac{kq_2}{r_2^2}$ The ratio of the electric fields is, $\frac{E_1}{E_2} = \frac{r_2}{r_1}$ [1 mark for the correct ratio of E1 to E2]	2
Q.33	(a) Capacitance decreases. Capacitance is inversely proportional to the distance of separation. [0.5 mark for the correct change] [0.5 mark for the correct explanation] (b) Charge remains the same. The battery is disconnected. So charge cannot move into or out of the plates of the capacitor. [0.5 mark for the correct change] [0.5 mark for the correct explanation]	6

	(c) Potential difference increases. As Q =CV Charge Q is constant, C decreases, so V increases. [0.5 mark for the correct change] [0.5 mark for the correct explanation] (d) Electric field remains the same. E due to a plane sheet of charge = σ/∈o is independent of the distance from the sheet. Charge density σ on the plate remains the same because the charge on capacitor plates remains the same. So, E also remains the same. OR As E = V/d = Q/Cd = Q/∈oA Since Q and A remain unchanged, E remains the same. [0.5 mark for the correct change] [0.5 mark for the correct explanation] (e) Energy stored in the capacitor increases. Energy stored is proportional to both charge and potential difference. Charge is constant but the potential difference has increased. [0.5 mark for the correct change] [0.5 mark for the correct explanation]	
Q.34	(a) As the z-coordinate of each of the points is zero, the plane of motion from P to Q to R to S is in x-y plane. [1 mark for the identification of the correct plane] (b) Since E is conservative, the work done is path independent, so replace the path P -> Q -> R -> S with a simpler path as P -> T -> S. [1 mark for suggesting a simpler path] Work done along P -> T = 0, as the path is perpendicular to the direction of E. Work done along T -> S = -qEa So total work done = 0 - qEa = -qEa [1 mark for correct calculation and result] OR Since E is conservative, the work done is path independent, so replace the path P -> Q -> R -> S with a simpler path P -> S. [1 mark for suggesting a simpler path] W = qE. PS. cos (90 + θ) Here, (90 + θ) is the angle between the electric field E and displacement vector PS. θ is the ∠SPT.	3

	$W = -qE\sqrt{a^2+b^2}\sin\theta$ $= -qE\sqrt{a^2+b^2}\frac{a}{\sqrt{a^2+b^2}}$ $= -qEa$ [1 mark for correct calculation and result] (Note: Award full marks even if students calculate the work done along P -> Q -> R -> S without suggesting a simpler path.)	
Q.35	Given: Initial kinetic energy of proton = K0 = 400 eV As the proton approaches the dipole its kinetic energy reduces and the potential energy increases, however, the total energy is conserved. Electric potential due to the dipole at axial point = p/4π∈0r2 Let P and K be the potential and kinetic energy of the proton at any instant, respectively. From the graph, at r = 0.2 m, K = 100 eV Applying conservation of energy: K + P = K0 100 + ep/(4π∈0 x 0.22) = 400 This implies ep/4π∈0 = 300 × 0.22 = 12 At r = r0 the kinetic energy is zero and thus we have, ep/4π∈0r02 = 400 12/r02 = 400 r20 = 12/400 r0 = √3/10 m ≈ 0.17 m	3
Q.36	Electric field in this region is given by: E = -dV/dx Here, dV/dx is the slope of the given graph. dV/dx = -10/2 = -5 volt/m Thus, E = -dV/dx = 5 volt/m (0.5 marks for formula and 0.5 marks for correct value of E) Charge on the particle is 2 μC, thus the force on the charge is F = qE = 2 × 10-6 × 5 = 10-5 N (0.5 marks for formula and 0.5 marks for correct value of F)	3

	As the electric field is in the direction in which the electric potential decreases, we can say that the direction of the electric field is along +x direction as V is decreasing as we move towards +x direction. Now, as the particle has a positive charge, it will experience a force in the direction of the electric field i.e., +x direction. (1 mark for correct direction of force)	
Q.37	(a) (1 mark)  (b) Current is zero as the capacitor is fully charged and does not allow the flow of any more charge. (1 mark) (c) The voltage across both the capacitor and the resistor decreases with time till the capacitor is completely discharged and the voltage across both the capacitor and resistor becomes zero. (1 mark) (d) (i) capacitance - increases (ii) charge - increases (iii) potential difference between plates - remain the same (iv) energy stored - increases (0.5 marks each)	5
Q.38	At equilibrium, the forces on the ball are balanced along x-axis and y-axis. Let T be the tension in the thread. $\Sigma F_y = 0$, so $T\cos\theta = mg$ $\Sigma F_x = 0$, so $T\sin\theta = qE$ [0.5 mark for each equation] Dividing, $\tan\theta = qE/mg$ $E = mg\tan\theta/q$ [0.5 mark for finding E or writing the expression for tanθ] Potential difference $V = Ed = mgd\tan\theta/q$ [0.5 mark for writing correct expression of V]	2