1-(a) \[ U_q(z=0) = 4 \left( \frac{KqQ}{0.1m} \right) \]
\[ = \frac{4 \times 9 \times 10^9 \times 10^{-5} \times (-10^{-6})}{0.1} \]
\[ = -3.6 \text{ J} \]

1-(b) At this \( z_0 \) coordinate

\[ U_q(z_0) = \frac{4KqQ}{\sqrt{(0.1)^2 + z_0^2}} \]

It should equal the total energy of the charged particle at \( z=0 \):

\[ \frac{4KqQ}{\sqrt{(0.1)^2 + z_0^2}} = U_q(z=0) + \frac{m}{2} \frac{v_0^2}{2} \]

\[ \frac{m}{2} \frac{v_0^2}{2} = \frac{1}{2} \times (0.02 \text{ ks}) \times (10 \text{ m/s})^2 = 15 \]

\[ \therefore \frac{0.36}{\sqrt{(0.1)^2 + z_0^2}} = -2.6 \quad \Rightarrow \quad z_0 = 9.6 \text{ cm} \]
2-(a) The electric field in between the rod and the shell is only determined by the charge on the rod since the charge on the shell produces zero net electric field. And the electric field produced by the charge on the rod is the same as if all the charges are on the cylindrical axis.

As a result, the electric potential difference between the rod and the shell

\[ V(\text{rod}) - V(\text{shell}) = 2k\lambda \ln \frac{b}{a} \]

\[ = 2 \times 9 \times 10^9 \text{N.m}^2\text{C}^{-2} \times (2 \times 10^{-6} \text{C/m}) \ln 3 \]

\[ \approx 40000 \text{ Volts} \]

2-(b) The electric field outside the outer surface of the shell is produced by the charges on the rod, the inner surface and the outer surface of the shell. Since there is no net electric field inside the shell, the inner surface must carry \(-2\mu\text{C per meter}\). That leaves \(-2\mu\text{C per meter}\) on the outer surface of the shell.
The charges on the rod and on the inner surface of the shell produce zero electric field at the radius beyond \( r = 6 \). Therefore the electric field beyond the outer surface of the shell is produced only by the charge on the outer surface.

Therefore the electric potential difference between the outer surface \( r = c = 4 \text{ cm} \) and a location with \( r = 1 \text{ m} \) is simply

\[
V(r = c) - V(r = 1\text{m}) = 2k \left( -2 \times 10^{-6} \text{C/m} \right) \ln \left( \frac{1\text{m}}{4 \times 10^{-2} \text{m}} \right)
\]

\[
= 2 \times 9 \times 10^9 \text{ N.m}^2/\text{C} \cdot (-2 \times 10^{-6} \text{C}) \cdot (5.5)
\]

\[
\approx -2 \times 10^5 \text{ volts}.
\]

And the work done by the electrostatic force on the electron when it is moved from the outer surface of the shell to \( r = 1\text{m} \)

\[
W = 2e \left( V(r = c) - V(r = 1\text{m}) \right)
\]

\[
= (-1.6 \times 10^{-19} \text{C}) \left( -2 \times 10^5 \text{ volts} \right)
\]

\[
= 3.2 \times 10^{-14} \text{ J}
\]

\*
3-(a) Assign two currents as shown in the rearranged circuit.

Along loop #1 (adefa):

\[ 20I_1 - 15 + 5(I_1 + I_2) = 0 \quad \text{(1)} \]

\[ 25I_1 + 5I_2 = 15 \quad \text{(1')} \]

\[ 5I_1 + I_2 = 3 \quad \text{(1'')} \]

Along loop #2 (abcdefa):

\[ -5 + 10I_1 + 15 - 20I_1 = 0 \quad \text{(2)} \]

\[ 2I_1 - I_2 = 1 \quad \text{(2')} \]

\[ 0 + 2'': \quad 7I_1 = 4 \]

\[ I_1 = \frac{4}{7} \text{ A} \]

\[ I_2 = 2I_1 - 1 = \frac{1}{7} \text{ A} \]

XX
\[ P(20 \text{ Hz}) = I_1^2 \cdot (20 \text{ Hz}) = \left(\frac{0}{7}\right)^2(20) = 6.5 \text{ Watts} \]
4-(a) Between \( c \) and \( g \),

\[
C_{cg} = 2 \mu F + \frac{1}{\frac{1}{12 \mu F} + \frac{1}{14 \mu F} + \frac{1}{12 \mu F}}
\]

\[
= 2 \mu F + 4 \mu F
\]

\[
= 6 \mu F
\]

Now between \( a \) and \( g \),

\[
C_{ag} = \frac{1}{\frac{1}{12 \mu F} + \frac{1}{C_{cg}}}
\]

\[
= 4 \mu F
\]

4-(b) We need to find the potential difference between \( c \) and \( g \)

\[
V_{cg} = V_c - V_g = \frac{Q}{C_{cg}} = \frac{1}{C_{cg}} (C_{cg} \cdot V_{ag})
\]

\[
= \frac{4 \mu F}{6 \mu F} \times 36 V = 24 V
\]

\[Q \text{ (on } 2 \mu F) = (2 \mu F) \cdot V_{cg} = 4.8 \times 10^{-5} C\]
4.- (c) After switch S is closed for a long time, the charging and discharging on all capacitors have stopped. Therefore the current from a to g only flows through the two resistors.

\[ I_{ag} = \frac{V_{ag}}{6R + 3R} = \frac{36V}{9R} = 4A. \]

Thus, the potential difference \( \overline{bc} \) between c and g is now

\[ V_{cg} = I_{ag} \cdot (3R) = (4A) (3R) = 12 \text{ volts} \]

\[ Q(\text{on } 2 \mu F) = (2 \mu F) \cdot V_{cg} = 2.4 \times 10^{-5} \text{ C} \]
5-(a) From $\mathbf{t} = \mathbf{\mu} \times \mathbf{B}$, the maximum torque equals the product of the magnetic dipole moment $|\mathbf{\mu}| = \mu$ and the magnetic field $|\mathbf{B}|$.

\[ \therefore \mu = \frac{T_{\text{max}}}{B} = \frac{0.25 \text{ N.m}}{0.4 \text{ T}} = 0.625 \text{ A.m}^2 \]

5-(b) For a single current loop with diameter $d = 1 \text{ cm}$, the magnetic dipole moment

\[ \mu_{\text{loop}} = I - \left(\frac{\pi}{4} d^2\right) \]

Let $\mu_{\text{loop}} = \mu = 0.625 \text{ A.m}^2$, the required current

\[ I = \frac{\mu}{\frac{\pi}{4} d^2} = \frac{0.625 \text{ A.m}^2}{\left(\frac{3.14}{4}\right) \left(0.01 \text{ m}\right)^2} \approx 80 \text{ A} \]
6-(1) At point P with 
\( x = 0.1 \text{ m}, y = -0.2 \text{ m} \) 
The magnetic 
field produced 
by the current 
along the negative \( x \)-axis 
is pointing along 
the negative \( z \)-direction with a magnitude 
\[ B_1 = \frac{\mu_0 I}{2\pi (0.2 \text{ m})} = 2 \times 10^{-6} \text{T} \] 
The magnetic field produced by the current along the positive \( z \)-axis is pointing along 
the positive \( \hat{z} \) direction with a magnitude 
\[ B_2 = \frac{\mu_0 I}{2\pi (0.1 \text{ m})} = 4 \times 10^{-6} \text{T} \] 
So the net magnetic field at P is pointing 
along the positive \( z \) direction, 
\[ \vec{B} = B_1 + B_2 = 2 \times 10^{-6} \hat{z} \text{T} \]

6-(2) At \( z = 0.2 \text{ m} \) on the \( z \)-axis, the magnetic field 
produced by the current along \( x \)-axis is 
\[ \vec{B}_1 = (-\hat{j}) \frac{\mu_0 I}{2\pi (0.2 \text{ m})} = (-\hat{j}) 2 \times 10^{-6} \text{T} \]
the magnetic field produced by the current along the negative y-direction is
\[ B_2 = (-\hat{i}) \frac{N_0}{2\pi} \cdot \frac{I}{(0.2m)} = (-\hat{i}) \times 10^{-6} \text{ T.} \]

So the total magnetic field at this location is
\[ B = B_1 + B_2 = 2 \times 10^{-6} \hat{i} + (-\hat{i}) = 2 \sqrt{2} \times 10^{-6} \hat{i} \cdot \left(\frac{\hat{i} + \hat{j}}{\sqrt{2}}\right) \cdot (-) \]

\[ = 2 \sqrt{2} \times 10^{-6} \hat{i} \cdot \left(\frac{\hat{i}}{\sqrt{2}}\right) \cdot (-) \]
7-(a) The motion starts in the direction from b to a, and has a magnitude
\[ E_{\text{induced}} = \beta \cdot l \cdot \mathbf{V} = \int_{b}^{a} (\mathbf{V} \times \mathbf{B}) \cdot d\mathbf{l} \]

7-(b) The current produced by \( E_{\text{induced}} = \beta l \mathbf{V} \) in the close loop acdb is
\[ I = \frac{E_{\text{induced}}}{R} = \frac{\beta l \mathbf{V}}{R} \]

When \( I \) flows through the sliding rod ba, the rod experiences a magnetic force
\[ \mathbf{F}_m = I \mathbf{I} \times \mathbf{B} = \frac{\beta^2 l^2 \mathbf{V}}{R} \mathbf{\hat{z}} \]
which points in the opposite direction of the velocity (caused by the external force).

7-(c) The external force and the magnetic force both act on the sliding rod. The increase in the rod velocity stops when the magnetic force equals the external force, and the rod reaches the terminal velocity \( V_t \).
This means

\[ F_{\text{ext}} = \frac{B^2 - d^2}{R} \cdot V_t \]

\[ V_t = \frac{F_{\text{ext}} \cdot R}{B^2 - d^2} = \frac{(20N) \cdot (2m)}{(0.5T)^2 \cdot (0.5m)^2} \]

= 640 m/s

**