20S-PHYSICS1B-2 Final exam

[redacted]

TOTAL POINTS

85 / 100

QUESTION 1

Question 1 26 pts

1.1 part (a) 4 / 4

✓ **- 0 pts** Correct

- 2 pts The sphere and the shell have the same electrostatic potential.

- 2 pts +5Q on the shell; 0 charge on the sphere.

- 4 pts Incorrect/ No answer

1.2 part (b) 4 / 4

✓ **- 0 pts** Correct

- 2 pts Q1 = Q2 = Q3

- 1 pts v2 > v1 > v3

- 1 pts p3 > p1 > p2

- 4 pts Incorrect/ No answer

1.3 part (c) 4 / 4

✓ **- 0 pts** Correct

- 0.5 pts Reflected wave: same speed as the incident wave

- 0.5 pts Reflected wave: lower amplitude than the incident wave

- 0.5 pts Reflected wave: inverted

- 0.5 pts Reflected wave: same horizontal extent as the incident wave

- 0.5 pts Transmitted wave: lower speed than the incident wave

- 0.5 pts Transmitted wave: lower amplitude than the incident wave

- 0.5 pts Transmitted wave: upright

- 0.5 pts Transmitted wave: smaller horizontal extent than the incident wave

- 4 pts Incorrect/ No answer

1.4 part (d) 4 / 4

✓ **- 0 pts** Correct

- 2 pts Part i

- 2 pts part ii

- 4 pts Incorrect/ No answer

1.5 part (e) 4 / 4

✓ **- 0 pts** Correct

- 1 pts The frequency increases.

- 2 pts The amplitude is unchanged.

- 1 pts The peak velocity increases.

- 1 pts No explanation

- 4 pts Incorrect / No answer

1.6 part (f) 6 / 6

✓ **- 0 pts** Correct

- 2 pts part i: the electric field decreases.

- 2 pts part ii: the energy stored by the capacitor decreases.

- 2 pts part iii: energy lost to the battery exceeds the work that I do to separate the plates and the net result is the energy stored in the capacitor goes down.

- 6 pts Incorrect/ No Answer

QUESTION 2

Question 2 20 pts

2.1 part (a) 6 / 6

✓ **- 0 pts** Correct

- 2 pts Electric field

- 2 pts Potential difference between the plates

- 2 pts Capacitance

- 6 pts Incorrect/ No answer

2.2 part (b) 0 / 6

- 0 pts Correct

✓ **- 3 pts** **The charge density on the plates increases over the dielectric (and decreases on either side).**

✓ **- 3 pts** **The electric field at point P increases.**

- 6 pts Incorrect/ No answer

2.3 part (c) 8 / 8

✓ **- 0 pts** **Correct**

- 2 pts Calculation error

- 3 pts The capacitance for the two ``side'' capacitors

- 5 pts The capacitance of the ``middle'' capacitor.

+ 2 pts Partial for capacitance combination/ Potential difference

- 8 pts Incorrect/ No answer

QUESTION 3

Question 3 16 pts

3.1 part (a) 8 / 8

✓ **- 0 pts** **Correct**

- 2 pts Potential energy

- 2 pts Kinetic energy

- 3 pts Equation for conservation of energy

- 1 pts solve for the angular velocity

- 8 pts N/A

3.2 part (b) 8 / 8

✓ **- 0 pts** **Correct**

- 3 pts write the equation to describe the oscillator, either from the conservation of energy or Newton's Second Law

- 3 pts Same kinetic term, different potential

- 2 pts solve for the frequency of oscillation

- 8 pts Incorrect, no work, didn't compare to physical pendulum, and/or just restated answer from part A (even if superficilally it looks similar, the angular frequency is a completely different quantity that you get by examining the equation of motion, NOT energy conservation - you only use the latter if you're comparing directly to the physical pendulum); also, if your final answer for A was \omega = ??? I graded the RHS, but that quantity is NOT \omega so simply restating it gets zero points...

QUESTION 4

Question 4 18 pts

4.1 part (a) 4 / 6

- 0 pts Correct

- 1 pts Plot of the pressure perturbation associated with the fundamental mode

✓ **- 2 pts** **Node / anti-node locations wrong or not clearly indicated**

- 3 pts Wavelength of this fundamental mode

- 6 pts N/A

4.2 part (b) 3 / 6

- 0 pts Correct

✓ **- 3 pts** **Frequency of the fundamental mode decreases.**

- 3 pts Move away from the the tube to shift the frequency down.

- 6 pts N/A

4.3 part (c) 2 / 6

- 0 pts Correct

- 2 pts frequencies

✓ **- 2 pts** **application of Doppler shift**

✓ **- 2 pts** **Final answer**

- 6 pts N/A

- 1 pts Final answer not a number...

QUESTION 5

Question 5 20 pts

5.1 part (a) 10 / 10

✓ **- 0 pts** **Correct**

- 4 pts Setup: simplify resistors in series/parallel; assign current loops, etc.

- 3 pts Loop equations.

- 3 pts Current through bulb 1

- 2 pts No final answer OR not in terms of E(MF) & R only OR zero current (w/ work), etc.

- 10 pts N/A

5.2 part (b) **10 / 10**

✓ **- 0 pts** **Correct. Note: part B independent of A.**

- 4 pts Setup (see part A)

- 3 pts Loop equations

- 3 pts Current through bulb 1. Note: current is half the total current in the loop (see solutions). Wrong factor of 2 = -2 below

- 2 pts No final answer OR not in terms of E(MF) & R only OR zero current (w/ work), etc.

- 10 pts N/A

Name: [redacted]

Student ID number:

Discussion section:

FINAL EXAM
PHYSICS 1B, SPRING 2020
JUNE 10, 2020

READ THE FOLLOWING CAREFULLY:

- ▷ Sign on the second page to affirm that you observe the academic integrity.
- ▷ Open book. Make sure that you work independently on the exam, i.e., no discussion with others.
- ▷ The exam time is between 3pm and 6pm on June 10, Pacific Time.
- ▷ You will have an additional 30 minutes to upload your exam packet. Make sure to submit your exam packet via GradeScope by 6:30pm, June 10, Pacific Time. **No credit will be given for late submissions.**
- ▷ To submit your exam, you have the following three options: (a) Download the PDF from CCLE, print out the PDF, write your solutions in the space provided on the exam packet, scan your packet using a smart phone scanning app such as Adobe Scan, upload your scan to Gradescope. (b) View the PDF on CCLE, write your solutions to all of the problems on loose-leaf, lined or blank paper in precisely the locations you would have written your responses if that paper were the exam packet. Scan and upload your packet of solutions to Gradescope. (c) Download the PDF from CCLE, use a tablet to digitally write your solutions on the PDF, save the PDF with solutions and upload it to Gradescope.
- ▷ **You must make sure that your submission has exactly the same number of pages as the posted exam PDF (including this page and the second page).**
- ▷ **You must justify your answers to each question.** Simply giving the correct answer without proper justification (can be brief) will not result in full credit.
- ▷ Mistakes in grading: If you find a mistake in the grading of your exam, alert the instructor within one week of the exams being returned.

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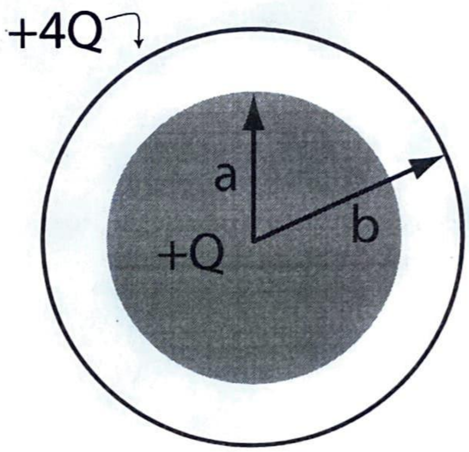
[redacted]

6/10/20
Date

[redacted]
UID

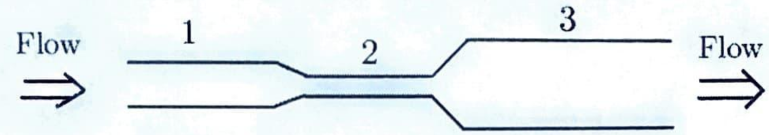
[1.] Short Answer/Conceptual questions. (26 pts) (Provide *concise* answers to the questions below; you should write enough to explain your answer, but an essay is not required).

(a) (4 pts) A metal sphere of radius a is surrounded by a concentric spherical shell of radis $b > a$ (see below). The metal sphere is given charge $+Q$ and the spherical shell is given charge $+4Q$. A thin conducting wire is used to connect the sphere to the shell and is then taken away. After this, what are the charges on the sphere and the spherical shell? Explain.



The shell would have +5Q charge, and the metal sphere would have 0 charge. This is because when the wire is added, charge flows so that there is no potential difference between the shell and sphere.

(b) (4 pts) A pipe is made up of three cylindrical segments with different cross sections as shown below. The cross-sectional area of each segment can be ranked as $A_3 > A_1 > A_2$. The pipe is placed in the horizontal direction. An incompressible, steady flow passes through this pipe.



i. Rank the volume flow rate Q (i.e., the volume of the flow per unit time through a cross section) in each segment (compare Q_1, Q_2 and Q_3).

ii. Rank the fluid velocity v in each segment (compare v_1, v_2 and v_3).

iii. Rank the fluid pressure p in each segment (compare p_1, p_2 and p_3).

i. $Q_3 = Q_1 = Q_2$

The flow rate is constant throughout

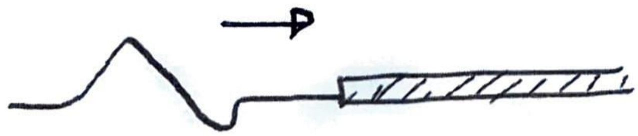
ii $v_2 > v_1 > v_3$

speed is inversely proportional to area

iii $p_2 < p_1 < p_3$

pressure is inversely proportional to velocity.

(c) (4 pts) The wave pulse drawn below travels on a taught rope as shown below. It encounters a knot between the rope and a rope which has a larger mass per unit length. Draw the reflected and transmitted waves that results and compare the following properties of these waves to the incident wave: wave speed, amplitude, polarity (upright or inverted), "wavelength" (horizontal extent of the wave).



Reflected

- same speed
- Smaller amplitude
- inverted
- same wavelength

Transmitted

- slower speed
- smaller amplitude
- upright
- Smaller wavelength

(d) (4 pts) Two speakers are placed a distance L apart from one another in a room. They both are driven by the same audio amplifier, creating sound waves at frequency f. As you walk around the room you hear maxima and minima in sound intensity.

i. Explain briefly why the sound intensity varies at different locations in the room. What determines where a maximum will occur?

ii. You sit down at a spot which is not equidistant from each speaker, but where the intensity is maximum. The room is then filled with a different gas (you hold your breath). The speed of sound in the gas is smaller than in air. The speakers continue to broadcast at the same frequency and intensity. The intensity at your location is still a maximum after the room is filled with the new gas (you walk around to confirm). What has to be true about the speed of sound in the new gas for this to have occurred?

i. Depending on the position, there may be constructive or destructive interference. There are maxima where there is constructive interference and the sound waves line up exactly.

ii. The distances to the speakers need to have the same remainder when divided by the new speed of sound.

(e) (4 pts) Two blocks of mass M are stacked one on top of the other, with the lower block attached to a horizontal spring with spring constant k (on a frictionless surface). The two masses are put into oscillation with amplitude A (about $x = 0$), which is low enough such that the two masses do not slip relative to one another. If the top block is removed at the instant the masses reach $x = A$, what happens to: (1) the frequency of the oscillation, (2) the amplitude of the oscillation, and (3) the peak velocity associated with the oscillation? Explain.

(1) The frequency increases, as it is proportional to $\frac{1}{\sqrt{m}}$

(2) The amplitude does not change, as the max potential energy is the same.

(3) The peak velocity increases, as the energy ($\frac{1}{2}mv^2$) is the same, but the mass has decreased.

(f) (6 pts) Two large conducting plates are separated by a distance d and are held at a constant potential difference using a battery (which provides EMF $\mathcal{E}$). If I pull the plates apart so that they are now separated by a distance 2d:

i. What happens to the value of the electric field between the plates and the value of the charge on the plates? (Explain)

ii. What happens to the energy stored by the capacitor? (Explain)

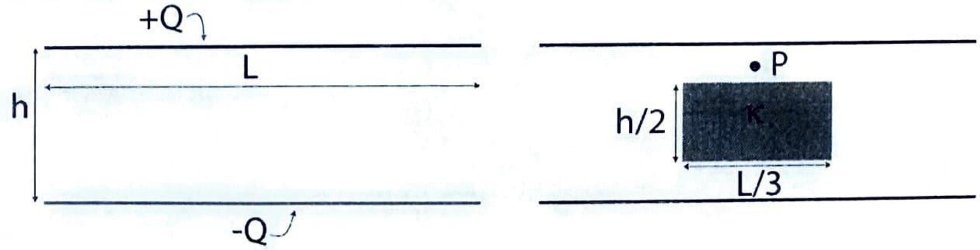
iii. Is this change consistent with the fact that it is difficult for me to separate the plates (I have to do work to separate the plates)? (Explain)

i) The value of the electric field decreases, as it causes the same potential difference over a larger distance. The value of charge decreases, as it is proportional to the value of the electric field.

ii) The capacitance decreases while the voltage stays the same, so the energy stored decreases.

iii) This change is not consistent, as doing work to separate the plates should increase the energy in the system. However, energy is actually absorbed by the battery.

[2.] (20 pts) Two identical square metal plates with side L are placed a distance h from one another as shown (not drawn to scale, you can assume that $h \ll L$). A battery is connected to give total charge Q to the top plate and $-Q$ to the bottom plate. The battery is then disconnected (and remains disconnected).



(a) What is the electric field between the plates? What is the potential difference between the plates? What is the capacitance of the two plates?

$$E = \frac{Q}{\epsilon_0 A} = \boxed{\frac{Q}{\epsilon_0 L^2}}$$

$$V = Ed = \left(\frac{Q}{\epsilon_0 L^2}\right)(h) = \boxed{\frac{Qh}{\epsilon_0 L^2}}$$

$$C = \frac{Q}{V} = \frac{Q}{\left(\frac{Qh}{\epsilon_0 L^2}\right)} = \boxed{\frac{\epsilon_0 L^2}{h}}$$

(b) I now insert a block of Teflon between the two plates (Teflon has a dielectric constant κ). The block is rectangular and is L deep, $h/2$ tall and $L/3$ wide. It is placed as shown in the figure above. The block is placed so that its center coincides with the center of the two plates (both vertically and horizontally). Consider the point P as shown in the diagram. What happens to the electric field at that point after I place the dielectric block? Does it increase, decrease, or stay the same relative to the value before the block is inserted? Explain.

It becomes smaller, because the dielectric acts as a smaller capacitor, giving it a lower electric field than when it was part of the larger capacitor.

(c) What is the capacitance of the two plates with the dielectric block present? (Hint: you can ignore "fringing" fields; that is you can assume the electric field retains planar symmetry even with the dielectric block present).

$$C = \frac{\epsilon_0 A}{d}$$

For in dielectric:

$$C = \frac{k\epsilon_0 \, L^2/3}{h/2} = \frac{2k\epsilon_0 L^2}{3h}$$

Outside:

$$C = \frac{\epsilon_0 \, L^2/3}{h/4} = \frac{4\epsilon_0 L^2}{3h}$$

Total for middle:

$$C_{mid} = \frac{1}{\frac{3h}{2k\epsilon_0 L^2} + 2 \cdot \frac{3h}{4\epsilon_0 L^2}} = \frac{1}{\left(\frac{k+1}{k}\right)\frac{3h}{2\epsilon_0 L^2}}$$

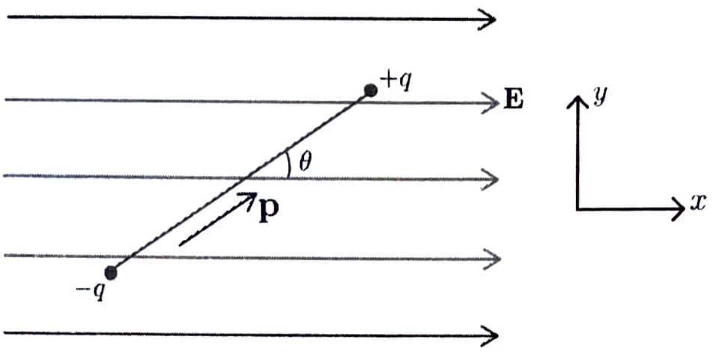
$$= \frac{k}{k+1}\left(\frac{2\epsilon_0 L^2}{3h}\right)$$

Side:

$$C_{side} = \frac{\epsilon_0 \, L^2/3}{h} = \frac{\epsilon_0 L^2}{3h}$$

$$C_{total} = C_{mid} + 2C_{side} = \boxed{\frac{2k+1}{k+1}\left(\frac{2\epsilon_0 L^2}{3h}\right)}$$

[3.] (16 pts) Consider an electric dipole located in a region of uniform electric field of magnitude E pointing in the $+x$ direction, as shown below. The positive and negative ends of the dipole have charges $+q$ and $-q$, respectively, and the two charges are a distance D apart. The dipole has moment of inertia I about its center of mass. The dipole is released from the angle $\theta = \theta_0$, and it is allowed to rotate freely.



(a) What is the magnitude of the dipole's angular velocity $d\theta/dt$ when it is pointing along the x axis (i.e., $\theta = 0$)? Hint: Use conservation of energy and notice that the electrostatic energy of the dipole in a uniform electric field is $U = -qDE \cdot \cos\theta$.

$U_i = -qDE\cos\theta_0$

$K_f = \frac{1}{2} I \left(\frac{d\theta}{dt}\right)^2$

$U_f = -qDE\cos(0) = -qDE$

$-qDE + \frac{1}{2} I \left(\frac{d\theta}{dt}\right)^2 = -qDE\cos\theta_0$

$\frac{1}{2} I \left(\frac{d\theta}{dt}\right)^2 = qDE(1-\cos\theta_0)$

$\frac{d\theta}{dt} = \boxed{\sqrt{\frac{2qDE(1-\cos\theta_0)}{I}}}$

(b) If θ_0 is small, the dipole will exhibit simple harmonic motion after it is released. What is the frequency of oscillation? Hint: Draw an analogy between this case and the physical pendulum in a gravitational field.

The equivalent potential energy equation for physical pendulum: $U = -mgL\cos\theta$

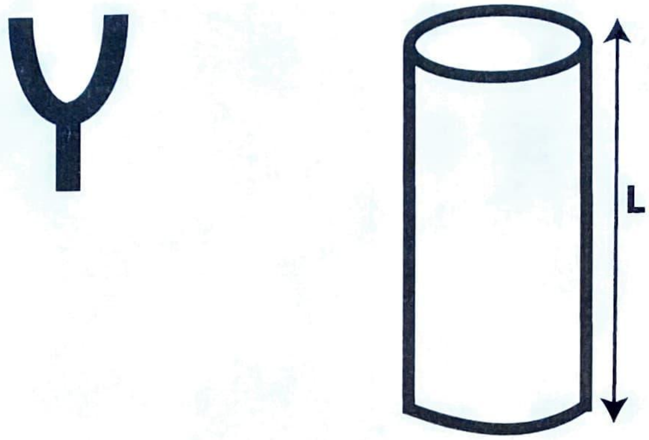
Frequency of phys. pendulum: $\omega = \sqrt{\frac{mgL}{I}}$

Equivalent for the dipole:

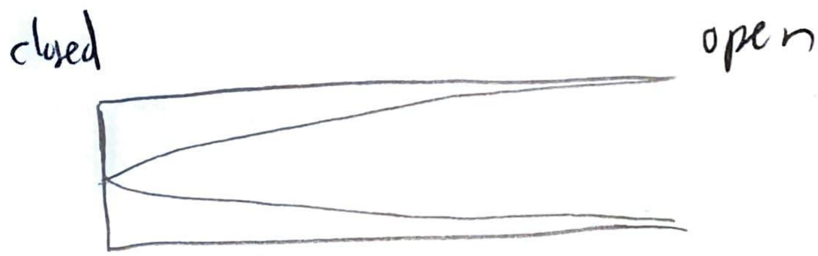
$$\omega = \sqrt{\frac{qDE}{I}}$$

$$F = \frac{1}{2\pi}\sqrt{\frac{qDE}{I}}$$

[4.] (18 pts) A tuning fork is found to resonate with the fundamental mode of a tube of length L which is closed on one end.



(a) Draw the pressure perturbation associated with the fundamental mode of this tube (clearly indicate the location of the closed and open ends of the tube). What is the wavelength of this standing sound wave?



wavelength is 4L

(b) The tube is then filled with pure Carbon Dioxide gas (CO_2) which has a speed of sound smaller than the sound speed in air. I now want to use the tuning fork to excite the fundamental standing sound wave of the CO_2-filled tube; I try to do this by moving the fork with a steady velocity. In which direction should I make this velocity (toward or away from the tube) and why?

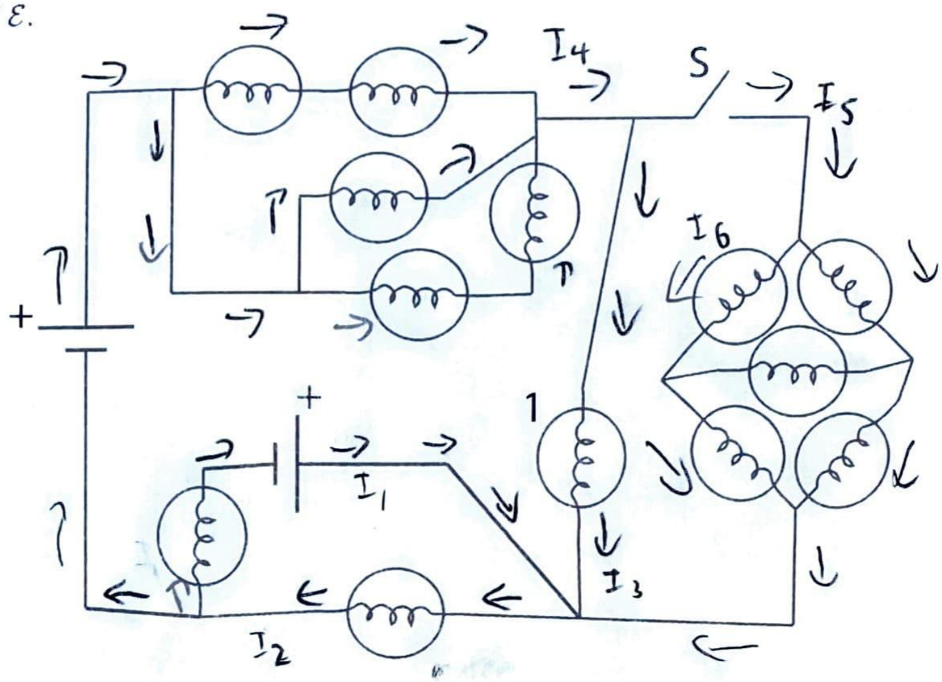
speed is directly proportional to wavelength, so the lower speed decreases the wave length. You should move away from the tube so that the doppler effect causes a larger wave length, restoring it to 4L

(c) If the speed of sound in CO_2 is 267 m/s, what is the velocity of the tuning fork that results in exciting the fundamental of the CO_2-filled tube?

$\lambda = (v + v_{fork}) \frac{1}{f} = (343 \, m/s) \frac{1}{f}$

$\rightarrow v_{fork} = 343 \, m/s - 267 \, m/s = \boxed{76 \, m/s}$

[5.] (20 pts) Consider the circuit below; all bulbs shown have equal resistance R and the batteries provide EMF $\mathcal{E}$.



(a) With the switch S open, what is the current flowing through bulb 1?

$R_{top} = \frac{1}{\frac{1}{2R} + \frac{1}{R} + \frac{1}{2R}} = \frac{R}{2}$

$R_{bot} = \frac{1}{\frac{1}{R} + \frac{1}{R}} = \frac{R}{2}$

$R_{tot} = R_{top} + R_{bot} + R = 2R$

$E_{total} = \mathcal{E} + \frac{\mathcal{E}}{2} = \frac{\mathcal{E}}{2}$ (the parallel circuit halves the effect)

$I_3 = \frac{E_{total}}{R_{tot}} = \boxed{\frac{\mathcal{E}}{4R}}$

(blank page for extra work space)

(b) If I close switch S (so now it conducts current), what is the new current through bulb 1?

$$R_{right} = \frac{1}{\frac{1}{2R} + \frac{1}{2R}} = R$$

$$R_{right+1} = \frac{1}{\frac{1}{R} + \frac{1}{R}} = \frac{R}{2}$$

$$R_{tot} = R_{top} + R_{bot} + R_{right+1} = \frac{3R}{2}$$

$$I_4 = \frac{\mathcal{E}_{total}}{R_{tot}} = \frac{\mathcal{E}}{3R}$$

$$2 I_6 R = I_3 R \rightarrow I_3 = 2 I_6 = I_5$$

$$\rightarrow I_3 = \frac{I_4}{2} = \boxed{\frac{\mathcal{E}}{6R}}$$