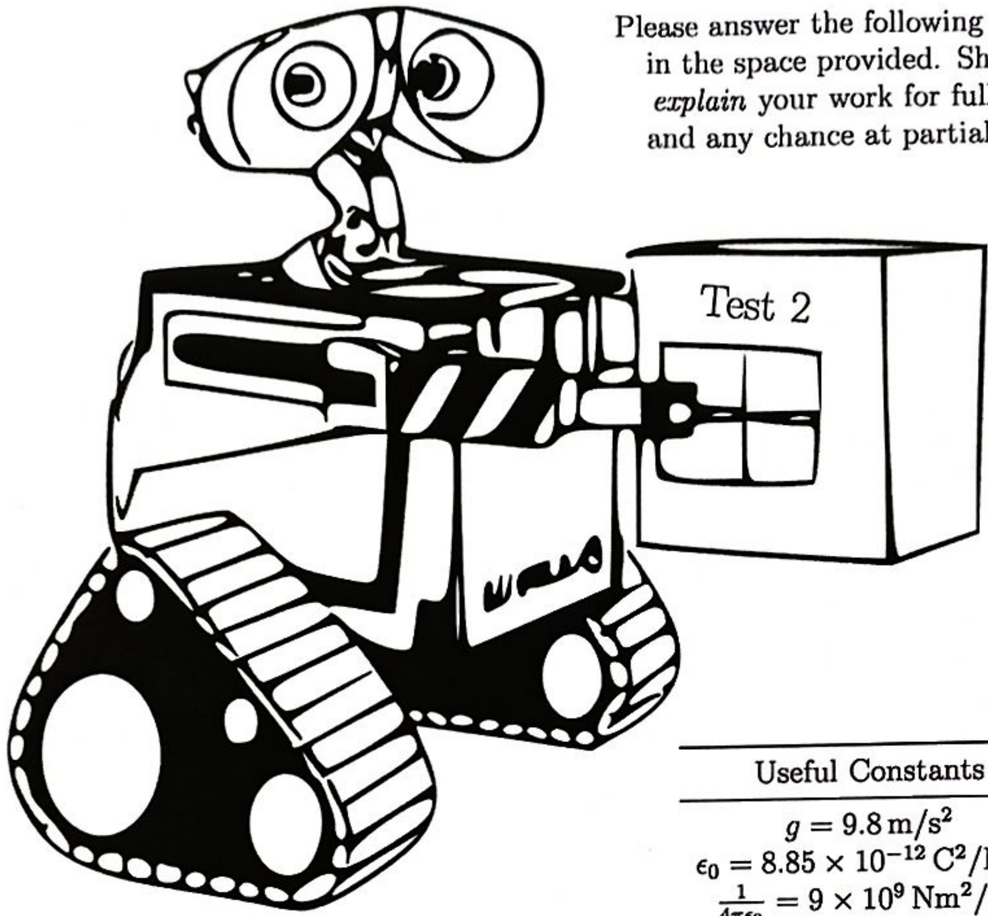
Phys 222 | Exam 2 | March 19, 2018

Name: JED'S Sols



Please answer the following questions in the space provided. Show *and explain* your work for full credit and any chance at partial credit!

Useful Constants
$g = 9.8\,\mathrm{m/s^2}$
$\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$
$\frac{1}{4\pi\epsilon_0} = 9 \times 10^{9}\,\mathrm{Nm^2/C^2}$
$\frac{\mu_0}{4\pi} = 1 \times 10^{-7}\,\mathrm{T\,s/C}$

	Mobility ($\mathrm{m^2/(V\,s)}$)	Electron Density ($e^-/\mathrm{m^3}$)
Gold	4.34×10^{-3}	5.9×10^{28}
Copper	4.39×10^{-3}	8.5×10^{28}
Silver	6.73×10^{-3}	5.86×10^{28}

p	n	µ	m	c	k	M	G
10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{3}	10^{6}	10^{9}

(2) 1. When Wall-E unfurls his solar panels, they generate an emf which Wall-E uses to charge a capacitor that he relies on to power him through the day. In an effort to improve his efficiency, Wall-E inserts a dielectric between his capacitor plates which doubles the total amount of energy capable of being stored in the capacitor. How does the maximum amount of charge stored on the plates change when the dielectric is inserted?

A. It doubles
B. It quadruples
C. It gets cut in half
D. It decreases by a factor of 4

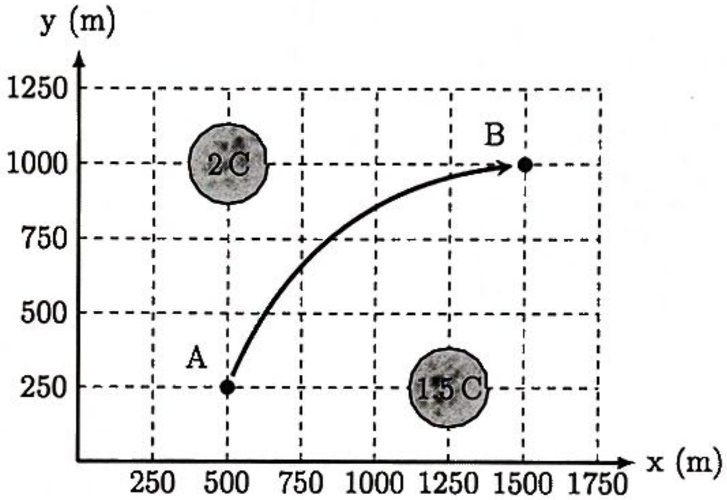
ΔV stays the same

$\Rightarrow U = \frac{1}{2} C (\Delta V)^2$

so U doubling $\Rightarrow$ C must double

$Q = C\Delta V \Rightarrow Q$ must double

(2) 2. Most of the towers of trash that Wall-E builds seem to be made of largely metal. Suppose during a lightning storm some of these towers were struck by lightning, giving them a residual charge. Treating the towers as point charges located at the locations below, what is the potential difference in moving from point A to point B?



A. −16.4 kV
B. −6.9 MV
C. −1.7 GV
D. 6.4 GV

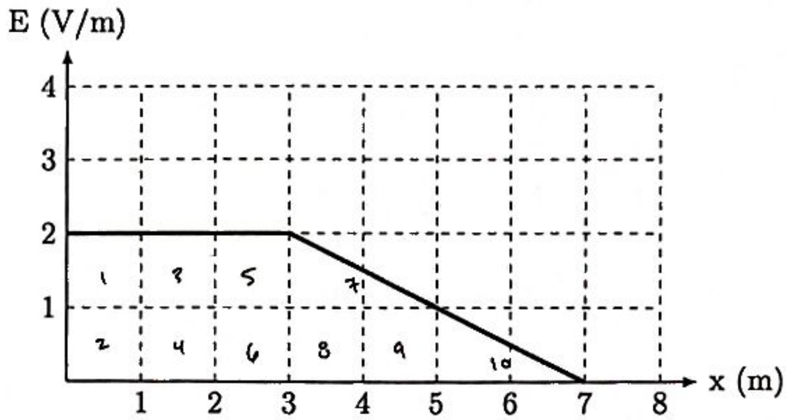
$V_A = \frac{1}{4\pi\varepsilon_0}\frac{2}{750} + \frac{1}{4\pi\varepsilon_0}\frac{1.5}{750} = 4.2\times10^7\,V$

$V_B = \frac{1}{4\pi\varepsilon_0}\frac{2}{1000} + \frac{1}{4\pi\varepsilon_0}\frac{1.5}{\sqrt{250^2+750^2}} = 3.507\times10^7\,V$

(4) 3. Eve has a charge of 0.5 C and a mass of 1.25 kg. She flies horizontally through two regions of electric field:

$$E = \begin{cases} 2 & \text{when } 0 < x < 3 \\ -\frac{x}{2} + 3.5 & \text{when } x > 3 \end{cases}$$

which can be plotted as below:



If Eve enters the region ($x = 0$) traveling at 1 m/s, how fast is she traveling at the point $x = 7$?

$\Delta V = -\underbrace{\int \vec{E} \cdot d\vec{x}}$

in 1 dimension, this is just area under the curve.

$= -10\text{ V}$

$\Delta U = q\Delta V = -5\text{ J}$

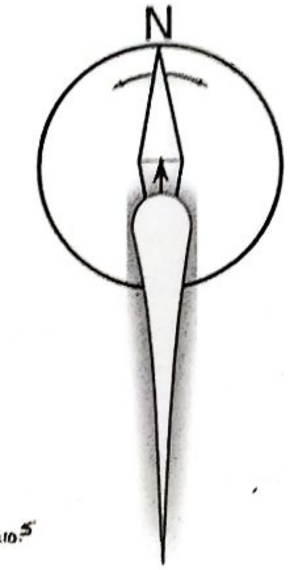
$\Delta K + \Delta U = 0 \Rightarrow \Delta K = -\Delta U = 5\text{ J}$

$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = 5$

$v_f^2 = \frac{2(5)}{1.25} + (1)^2 = 9$

$v_f = 3\text{ m/s}$

(5) 4. Eve's blaster shot carries a charge of 100 mC and travels at 500 m/s. Suppose it travels over an old compass at a height of 50 cm while traveling North. By what angle does the compass needle deflect when the bolt is directly above it and in what direction (left or right)? The magnetic field of the Earth is 2×10^{-5} T.



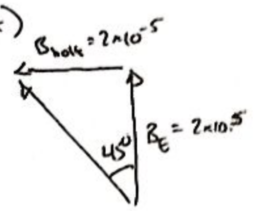
Moving charge ⇒ Biot-Savart

$$B = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

$$= \frac{\mu_0}{4\pi} \frac{qv}{r^2}$$ and I'll get direction by rhr

$$= (1\times10^{-7}) \frac{(100\times10^{-3})(500 \text{ m/s})}{(50\times10^{-2})^2}$$

$$= 2\times10^{-5}\,\text{T}$$ to the left (west)



So it will deflect 45° to the left.

(5) 5. Wall-E has what is called a thermistor inside him that helps him keep track of temperatures. The thermistor is just a special resistor whose electron density scales in a particular way with temperature:

$$n(T) = \beta T$$

where β is some constant and T is the temperature in Celsius. When the thermistor is connected directly to a 10 V emf, Wall-E notices that 2 A of current flows at room temperature (20 °C). Some time later, Wall-E notices that only 1.8 A of current is flowing. What is the temperature now?

Know $\Delta V = Es = EL$ in circuit

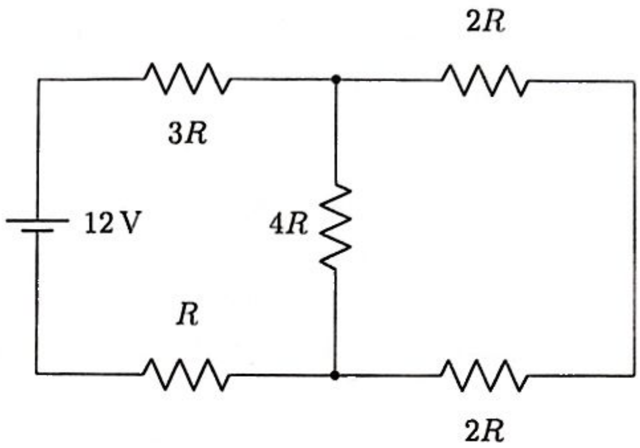
$$= \frac{I}{qnAu} L$$

$$= \frac{I}{q\beta TAu} L = \underbrace{\left(\frac{L}{q\beta Au}\right)}_{\text{doesn't change (constant)}} \frac{I}{T}$$

$$10\text{ V} = (\text{constant}) \frac{2\text{ A}}{20\,°\text{C}} \Rightarrow \text{constant} = \frac{10(20)}{2} = 100$$

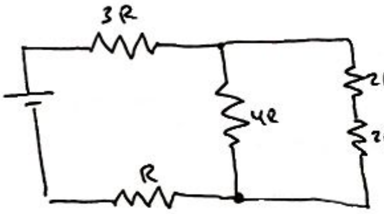
$$\Rightarrow 10\text{ V} = (100)\frac{1.8\text{ A}}{T} \Rightarrow T = \frac{100}{10} 1.8 = \underline{18\,°\text{C}}$$

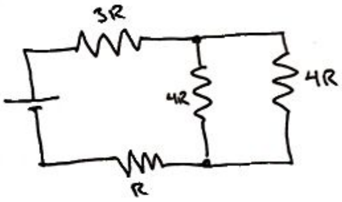
(6) 6. The circuit that controls Wall-E and Eve's handholding strength is shown below. Determine the amount of current that passes through the ideal battery if $R = 10\,\Omega$.

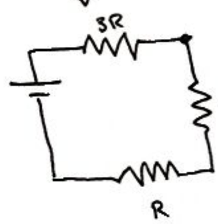


Only a single battery, so could do this either with equivalent resistance or loop/node rules.

I'll use eq. resistance:

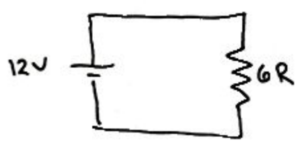






$\frac{1}{R_{eq}} = \frac{1}{4R} + \frac{1}{4R} = \frac{2}{4R} \Rightarrow R_{eq} = \frac{4R}{2}$

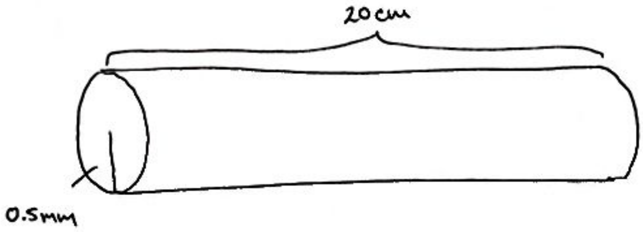
$= 2R$



$\Delta V = I R_{eq} \Rightarrow 12\,V = I\,(60\,\Omega)$

$I = 0.2$ Amps

(bonus)) 7. Wall-E finds a spare piece of round silver wire that measures 20 cm long and has a radius of 0.5 mm. If he connects it to his power supply such that a current of 5 A runs through the wire, what is the total amount of energy stored in the silver wire?



$$\Delta U = \frac{1}{2}\varepsilon_0 E^2 \times \text{Volume} = \frac{1}{2}\varepsilon_0 E^2 (\pi r^2 L)$$

$$I = qnAuE \Rightarrow E = \frac{I}{qnAu} = \frac{I}{qn\pi r^2 u}$$

$$= \frac{1}{2}\varepsilon_0 \left(\frac{I}{qn\pi r^2 u}\right)^2 (\pi r^2 L)$$

$$= \frac{1}{2}\frac{\varepsilon_0 I^2 L}{q^2 n^2 u^2 \pi r^2}$$

$$= \frac{(0.5)(8.85\times10^{-12})(5)^2(20\times10^{-2})}{(1.6\times10^{-19})^2(5.86\times10^{28})^2(6.73\times10^{-3})^2\pi(0.5\times10^{-3})^2}$$

$$= 7.075\times10^{-21}\ \text{J}$$