pe 22 forces - version A

(1) Get Larmor radius from 1st principles:

$$ma = \frac{mv^2}{r} = qvB \quad \text{since } \vec{B} \perp \vec{v}$$

solve for $\boxed{r = \frac{mv}{qB}}$

want r

Given: $B = 5.7E{-6}$ Tesla

$K = 361E3\ eV = 3.61E5\ eV$

where K = Kinetic Energy

and $1\,eV = 1.602E{-19}$ Joules

Alpha particle = 2 protons + 2 neutrons.

The mass of protons/neutrons depends on relativistic binding energy. To within about 1% we take:

$$m = 4\ amu = 4(1.66E{-27}\ kg)$$

$$\boxed{m = 6.64E{-27}\ kg}$$

$$q = 2e = 2(1.6E{-19}) = \boxed{3.2E{-19}\ Coul = q}$$

To find v: $\frac{1}{2}mv^2 = K = 3.61E5\ eV\left(\frac{1.6E{-19}\ Joules}{1\,eV}\right)$

Solve for $v^2 = \frac{2K}{m} = \frac{(2)(3.61E5)(1.6E{-19})}{6.64E{-27}}$

$$\Rightarrow \boxed{v = 4.17E6\ m/s}$$

$$r = \frac{(6.64E{-27})(4.17E6)}{(3.2E{-19})(5.7E{-6})} = \boxed{1.52 \times 10^4\ m}$$

(2) Since the wires are close together we can use Ampere's law to find $\vec{B}$ near the wire: $\oint \vec{B} \cdot d\vec{\ell} = 2\pi r B = \mu_0 I_1 \Rightarrow \boxed{B = \frac{\mu_0 I_1}{2\pi r}}$

Force law: $F = I_2 B \ell$ since $\vec{I_2} \perp \vec{B}$

Putting it all together:

$$\boxed{F = \frac{\mu_0 I_1 I_2 \ell}{2\pi r}}$$

$\mu_0 = 1.26E-6$ SI units

$I = 13.7$ amps

$\ell = 7.2$ meters

$r = 6.9E-3$ meters

$$F = \frac{(1.26E-6)(13.7)^2(7.2)}{(2\pi)(6.9E-3)} = \boxed{.039\ N}$$

(3) Electric and magnetic forces must cancel so that ions in the blood stay in the flow.

$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B} \Rightarrow E = vB$

(E ← E-field, v ← blood speed, B ← B-field)

$\Delta V = -\vec{E} \cdot \vec{\ell}$

(ΔV ← voltage drop, $\vec{\ell}$ ← diameter of artery)

$\Delta V = E\ell = vB\ell$

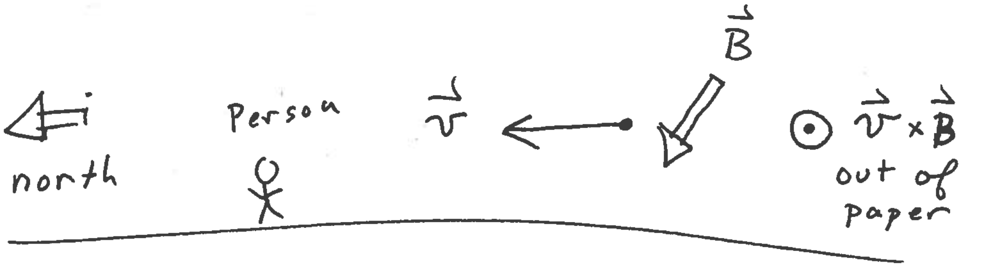
(ℓ ← 3.5 mm = 3.5E-3 meters; B ← 0.11 Tesla; v ← $21.5 \frac{cm}{s} \frac{1m}{100\ cm} = .215$ m/s)

$\Delta V =$

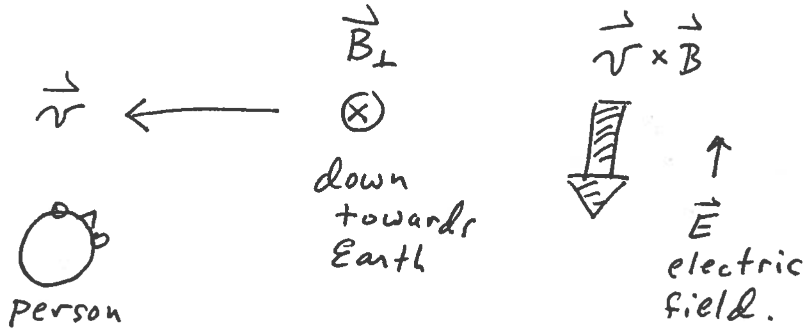
$(3.5E-3)(.11)(.215)$

$\boxed{\Delta V = 8.28E-5 \text{ volts}}$

(4) $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) = 0$



Top-down view:



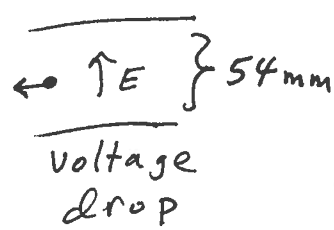
$\ell = 54\,mm$

$\Delta V = E\ell$ where $E = vB\sin\theta$

$v = .07c = (.07)(2.998E8\ m/s)$

$B = 45\,\mu T = 45E\text{-}6$ Tesla

$\theta = 22.5^\circ \rightarrow \sin\theta = .3827$



ΔV = voltage drop = $\ell v B \sin\theta$

$= (54E\text{-}3)(.07)(3\ E8)(45E\text{-}6)(.3827)$

$= \boxed{19.5 \approx 20 = 2 \times 10^1 \text{ volts}}$