Question 4: Qualitative Quantitative Translation (QQT) — 8 points

A

For indicating that $F_2 > F_1$ — **Point A1**

For correctly relating the magnitude of the magnetic force to the magnitude of the magnetic field — **Point A2**

For indicating that the magnitude of the magnetic field at the location of Sphere 2 is greater than the magnitude of the magnetic field at the location of Sphere 1 by referring to either: — **Point A3**

- The relative distance from the spheres to Wires S and T
- The direction of the magnetic fields from Wires S and T at the locations of the spheres

Example Response

The magnitude of the magnetic force exerted on a sphere is directly proportional to Q, v, and B. Because Q and v are the same for both spheres, the difference in the magnitudes of the magnetic forces is due to the difference in the magnitudes of the magnetic fields at the locations of the spheres. The magnitude of the magnetic field is greater at the location of Sphere 2 than at the location of Sphere 1 because the fields from the wires are in the same direction. Therefore, $F_2 > F_1$.

B

For a multistep derivation that includes the equation $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{\text{enc}}$ or — **Point B1**

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\left(d\vec{\ell} \times \hat{r}\right)}{r^2}$$

Scoring Note: Vector notation is not required for this point to be earned. A multistep derivation that includes $B = \frac{\mu_0 I}{2\pi d}$ can earn this point.

For a correct expression for the magnitude of the magnetic field due to the current in one wire at the location of Sphere 2 — **Point B2**

For indicating that the magnitude of the total field is twice that due to one wire — **Point B3**

Example Response

Determine the magnitude B of the magnetic field due to one wire.

$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{\text{enc}}$

$B(2\pi d) = \mu_0 I$

$B = \frac{\mu_0 I}{2\pi d}$

Determine B_{tot}.

$B_{\text{tot}} = \frac{\mu_0 I}{2\pi d} + \frac{\mu_0 I}{2\pi d}$

$B_{\text{tot}} = \frac{\mu_0 I}{\pi d}$

C	For indicating $F_{new} = F_2$	**Point C1**
	For indicating $B_{tot} = \frac{3\mu_0 I}{2\pi d} - \frac{\mu_0 I}{2\pi d}$ OR For indicating that the net magnitude of the magnetic field at the location of Sphere 2 will remain the same even though the field from Wire T will change	**Point C2**
	Example Response *The magnetic field at the location of Sphere 2 due to the current in Wire T is in the opposite direction to the magnetic field due to the current in Wire S. The current in Wire T is increased by a factor of 3. Therefore,* $B_{tot} = \frac{3\mu_0 I}{2\pi d} - \frac{\mu_0 I}{2\pi d} = \frac{\mu_0 I}{\pi d}$ *in this scenario. Thus,* $F_{new} = F_2$.	