(p) **(1 pt.)** Coulomb's friction law is **exact/highly accurate/approximate/wrong**.

(q) **(1 pt.)** The range for μ_s, the coefficient of static friction, is $0 \leq \mu_s \leq 1$. **True/False**.

(r) **(1 pt.)** Electromagnetic repulsion of two protons is **much weaker/weaker/stronger/-much stronger** than their gravitational attraction.

(s) **(2 pts.)** The first measurement of the "universal gravitational constant" G in 1798 by Cavendish and recent (year 2000^+) experiments of G are estimated to be accurate to approximately:

Experiments in 1798	10%	1%	0.001%	10^{-7}%	infinite
Experiments in 2000^+	10%	1%	0.001%	10^{-7}%	Infinite

(t) **(2 pts.)** What **two** questions does statics answer?

-
-

(u) **(3 pts.)** What are the **two** steps in a free-body diagram?

-
-

(v) **(2 pts.)** What are the **two** vector equations used for **static equilibrium** of a system S?

-
-

(w) **(8 pts.)** **Replacement of contact forces on a baseball bat.**

The figure to the right shows a forearm and hand modeled as a single rigid body A that uses a complex set of muscles, bones, ligaments, and tendons to grip a baseball bat B in such a way that a point Q of B cannot translate relative to a point P of A and B is only free to rotate relative to A about B's long axis.

Note: Point Q is on the butt-end of the bat and is on B's symmetry axis.

Note: Point P is the point of A coincident with Q.

- Draw and label contact and distance forces on B (think three-dimensional)
- **Fully describe** your **contact** force and/or torque measures on B.
- To facilitate your analysis, introduce helpful unit vectors.

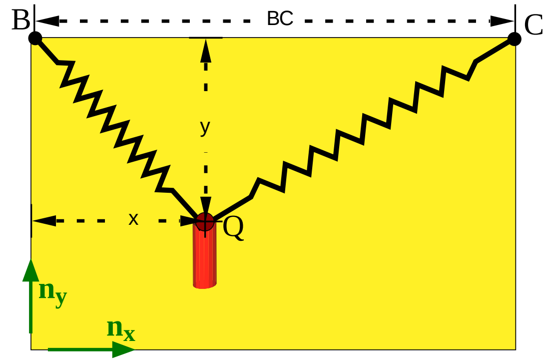
Complete description of force/torque measures (**think 3D**)	Scalar symbol

2. **(19 pts.)** **Design and statics of hanging a picture.**

A heavy picture Q is attached to pegs B and C by two light flexible cables. Ed, the construction contractor, has cut two cables and wants to know where the picture will be with these two cables.

In addition to a horizontally right unit vector $\mathbf{n}_{\mathrm{x}}$ and a vertically upward unit vector $\mathbf{n}_{\mathrm{y}}$, the following table of systems facilitate this analysis.

Description	Symbol
Local gravitational constant	g
Mass of Q	m
Distance from B to C	BC
Natural length of cable $\overline{BQ}$	L_n^B
Natural length of cable $\overline{CQ}$	L_n^C
Material constant associated with springs	κ
$\mathbf{n}_{\mathrm{x}}$ measure of the position vector of Q from B	x
Vertical distance from B to Q	y



(a) **(3 pts.)** Find the distance between B and Q and the distance between C and Q.
Result:

$d_B \;=$ $\qquad\qquad$ $d_C \;=$

(b) **(8 pts.)** Express $\mathbf{F}^{Q/B}$ and $\mathbf{F}^{Q/C}$, (the contact forces on Q from the springs connecting Q to B and Q to C) and $\mathbf{F}^{Q/gravity}$ (the distance force on Q from gravity) in terms of symbols in the table, d_B, d_C, the spring constant k_B of the linear spring connecting Q to B, the spring constant k_C of the linear spring connecting Q to C, and $\mathbf{n}_{\mathrm{x}}$ and $\mathbf{n}_{\mathrm{y}}$.
Result:

$$\vec{\mathbf{F}}^{Q/B} \;=$$

$$\vec{\mathbf{F}}^{Q/C} \;=$$

$$\vec{\mathbf{F}}^{Q/gravity} \;=$$

(c) **(5 pts.)** Using free-body diagrams, form equations that govern **static equilibrium** of Q in N in terms of symbols in the table and κ.
Note: The spring constants k_B and k_C depend on the constant κ as $k_B = \frac{\kappa}{L_n^B}$ and $k_C = \frac{\kappa}{L_n^C}$.
Result:

$$= \mathbf{0}$$

$$= \mathbf{0}$$

(d) **(2 pts.)** With known values of symbols in the table, the equations governing the **static equilibrium** values of x and y simplify to (you do not need to show this)

$$1.6 \;-\; 0.16667\,x \;+\; \frac{x}{\sqrt{x^2+y^2}} \;-\; \frac{15-x}{\sqrt{(15-x)^2+y^2}} \;=\; 0$$

$$981 \;-\; 55051\,y \;+\; 330304\,\frac{y}{\sqrt{x^2+y^2}} \;+\; 330304\,\frac{y}{\sqrt{(15-x)^2+y^2}} \;=\; 0$$

With a pencil, paper, and a simple calculator, find numerical values for x and y that satisfy both equations. Alternately, describe how you would solve these equations.

(e) **(1 pt.)** Sketch two or more configurations that may satisfy the previous set of equations.