PHYSICS 203 **EXAM #1** NAME KEY
14 October 2011

General Instructions: For each problem your solution must be readable and your logic followable. Put a box around any numerical answers.

Constants: $\mu_0 = 1.26 \times 10^{-6}$ H/m e = 1.60×10^{-19} C $\varepsilon_o = 8.85 \times 10^{-12}$ F/m
Prefixes: c = 10^{-2} m = 10^{-3} $\mu = 10^{-6}$

PART I - SHORT ANSWER QUESTIONS.

Do the 4 short questions/problems. Worth 6 points each.

1. If you measure the voltage across, and current through, a light bulb while you vary the voltage from zero to the normal operating voltage, a calculation of the resistance will show that the resistance is not constant over this voltage range. Why not?

Resistance varies with temperature & the filament goes from room temp to white hot.

2. An RLC series circuit consists of a variable frequency generator that produces an emf of (5.00 V)*sin($\omega_d t$), a 150 Ω resistor, a 65 mH inductor, and a 2.0 μF capacitor.
a) What value for the driving angular frequency will cause the greatest amplitude current to flow?
b) If the generator is set at an angular frequency of <u>one half of the value you found in part a)</u>, what is the amplitude of the resulting current?

a) $\omega_d = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(65\times10^{-3})(2\times10^{-6})}}\ s^{-1} = \boxed{2774\ s^{-1}}$

b) $\omega_d = 1387\ s^{-1}$ $Z = \sqrt{R^2 + (\omega_d L - \frac{1}{\omega_d C})^2} = \sqrt{(150\Omega)^2 + \left(65\times10^{-3}\cdot 1387 - \frac{1}{1387\cdot 2\times10^{-6}}\right)^2}$

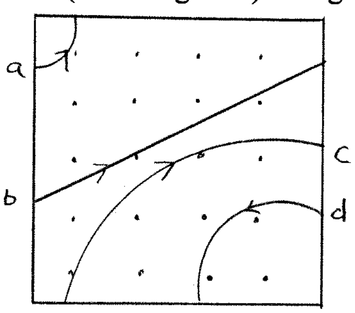
$Z = 309\ \Omega$

$I_m = \frac{\mathcal{E}_m}{Z} = \frac{5.00V}{309\Omega} = \boxed{0.0162\ A}$

3. In a particular RLC series circuit that is driven by a sinusoidally varying emf, the following peak (maximum) voltages are measured across each element: $E_m = 170$ V (source), $V_{R,max} = 119$ V (resistor), $V_{C,max} = 211$ V (capacitor), and $V_{L,max} = 89$ V. These peak voltages do not obey Kirchhoff's loop rule. Why not?

The peaks are reached at different times — Kirchhoff's loop rule is obeyed at any instant.

4. The diagram below indicates a rectangular region where a uniform magnetic field, directed upwards out of the page, exists. The four curves, labeled a-d, show the paths traveled by four particles that all enter the field with the same speed and all have the same mass. The arrow on the curve gives the direction of the motion. Arrange the particles in order of charge from lowest (most negative) to highest (most positive). Explain your reasoning.



$qvB = \frac{mv^2}{r}$ $r = \frac{mv}{qB}$ → greater charge ⇒ smaller r

Also use RHR to see if + or − ⇒ a + d are neg, c is +, b is neutral.

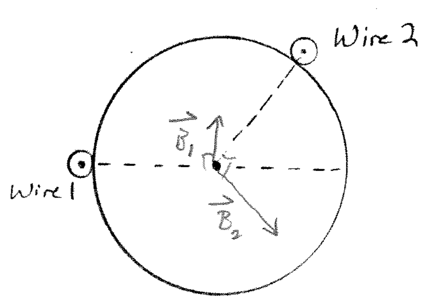
so a, d, b, c

Part II – Shorter Questions: Do any **eight** of the twelve questions based on your presentations and your readings from Fischer's book. Be very clear which ones you are omitting or the first 8 with any markings at all will be graded. Worth 2 points each.

1) A long plastic cylinder of radius R has two current carrying wires parallel to the axis of the cylinder, as shown. Wire 1 carries a current of 50 mA out of the paper, wire 2 carries 100 mA, also out of the paper. At the center of the cylinder, sketch vectors that show B_1 (due to wire 1) and B_2 (from wire 2) with the appropriate relative magnitue and direction.

From RHR $\vec{B}$ ⊥ line from wire to center

$B_2 = 2 B_1$



2) A long hollow conductor has outer radius of a, inner radius of b. As shown in class, the magnetic field at a distance r from the center (and a<r<b) is given by:
$B = \mu_0 i(r^2-b^2)/[2\pi r(a^2-b^2)]$. Show this yields the expected result if b=0.

If $b = 0$ $\quad B = \frac{\mu_0 i r^2}{2\pi r a^2} = \frac{\mu_0 i r}{2\pi a^2}$ which is what you have for a uniform current density wire with r inside

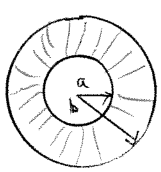
3) How does Fischer define science?

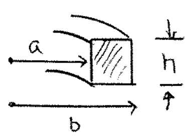
its the body of knowledge based on observation.

4) What does it mean to say that God is immanent?

That He dwells in the universe — He's not solely outside it.

5) The toroid shown carries a current i through N turns. Set up the correct integral that would enable you to calculate the magnetic flux through the shaded region (which is a slice through the toriod. You do not need to perform the integration.





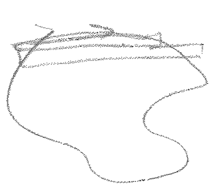
$B = \frac{\mu_0 N i}{2\pi r}$

$\Phi = \oint \vec{B} \cdot dA = \int_0^h \int_a^b \frac{\mu_0 N i}{2\pi r}\, dr\, dz$

6) According to Fischer, stating that we accept the Bible as authoritative is not a simple statement to make. Why not?

The Bible's words are symbols that require interpretation - believers differ on exactly what some passages mean.

7) In class, we showed that the torque on an N turn rectangular loop of current carrying wire in an external magnetic field is given by $\tau = NiAB\sin\theta$. It was shown that this formula also works for an arbitrarily shaped loop. What method was used to show this?



Treat the loop as a combination of long narrow rectangles.

8) Michael Faraday was thought (by some) to compartmentalize his faith and scientific work. Explain why this is an incorrect characterization.

He belonged to the Sandemanians which emphasized a quiet faith – not prone to sharing

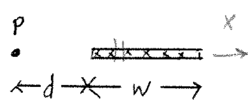
9) A wire segment carries 2.00 A of current along the x axis from x = 0 to x = 2.00 m. It is in a non-uniform magnetic field given by $\vec{B}$ = 0.00200 T î + 0.00500*x T/m ĵ. Find the net force on the segment.

$d\vec{F} = i\,d\vec{L} \times \vec{B}$ $\quad d\vec{L} = dx\,\hat{i}$ $\quad \hat{i}\times\hat{i} = 0,\ \hat{i}\times\hat{j} = \hat{k}$

so $d\vec{F} = i\,0.00500x\,\hat{k}\,dx \rightarrow \vec{F} = 2.00A(0.00500\tfrac{T}{m})\hat{k}\int_0^2 x\,dx$

$\vec{F} = (2.00A)(0.005\tfrac{T}{m}\hat{k})\,\frac{x^2}{2}\Big|_0^2 = \boxed{0.0200\ N\hat{k}}$

10) A long thin ribbon of wire of thickness w is directed into the paper and carries a current I spread uniformly through its width. Show that at point P, a distance d away, the magnetic field is given by B = (μ_0i/2πw)ln[(d+w)/d].



$dB = \frac{\mu_0 i}{2\pi w x}dx$ $\quad + \quad B = \int_d^{d+w} \frac{\mu_0 i}{2\pi w x}dx$

$= \frac{\mu_0 i}{2\pi w}\ln x\Big|_d^{d+w} = \frac{\mu_0 i}{2\pi w}\ln\frac{d+w}{w}$

11) In the last few pages of chapter 2, Fischer describes three dangers that we should avoid. What is one of these dangers? Why is it dangerous?

One of: shouldn't use natural expl. to deny God's existence
" conclude rational knowledge is proof for or against God
" consider any sci. expl. to be complete.
All define God in terms of our sci. understanding.

12) How does Fischer define hypothesis?

hyp is a tentative / untested expl.

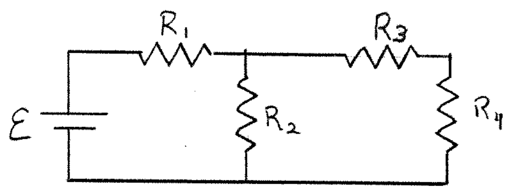
Part III - Problems.
Do all three. Worth 20 points each. Show and explain your work.

7. In the circuit shown, the battery can be considered to be ideal. It has an emf of 6.00 V. The values of the resistors are: $R_1 = 100\ \Omega$, $R_2 = 50.0\ \Omega$, $R_3 = 50.0\ \Omega$, and $R_4 = 75.0\ \Omega$.

a) What is the equivalent resistance of the combination of the 4 resistors?

b) How much current flows through R_1?

c) What is the power provided by the battery?



a) R_3 & R_4 in series so $R_{eq1} = 50\Omega + 75\Omega = 125.0\Omega$
this is in parallel with R_2 so,

$\frac{1}{R_{eq2}} = \frac{1}{50\Omega} + \frac{1}{125\Omega} \Rightarrow R_{eq2} = 35.7\Omega$

This in series with R_1, so $R_{eq} = 100\Omega + 35.7\Omega$
$= \boxed{135.7\Omega}$

b) i thru $R_1 = i_{batt} \Rightarrow i = \frac{\varepsilon}{R_{eq}} = \frac{6.00V}{135.7\Omega} = \boxed{0.0442A}$

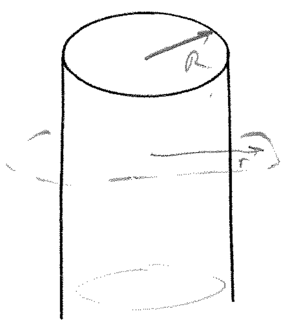
c) $P_{batt} = iV = (0.0442A)(6.00V) = \boxed{0.265W}$

8. A very long wire of radius R carries a current with a uniform (constant) current density $\vec{J}_0$. Starting from Ampere's law, derive an expression for the magnetic field B(r) where r is the radial distance from the center of the wire for the cases:

a) $r>R$

b) $r<R$.

[note: start from Ampere's law and show/explain intermediate steps leading to the answers. Simply writing down the answers will lead to zero credit.]



a) Amperes law is: $\oint \vec{B}\cdot d\vec{s} = \mu_0 i_{enc}$

Also $J = \frac{i}{A} = \frac{i}{\pi r^2}$

if $r > R$ $\quad i_{enc} = J_0 \pi R^2$

For a circular loop, from symmetry B is const, and $\vec{B} \parallel d\vec{s}$ so $\oint \vec{B}\cdot d\vec{s} = \oint B\,ds = B\oint ds = B2\pi r$

so $B\,2\pi r = \mu_0 J_0 \pi R^2$

$$B = \frac{\mu_0 J_0 R^2}{2r}$$

b) $r<R$ $\quad \oint \vec{B}\cdot d\vec{s} = B\,2\pi r$ as in a)

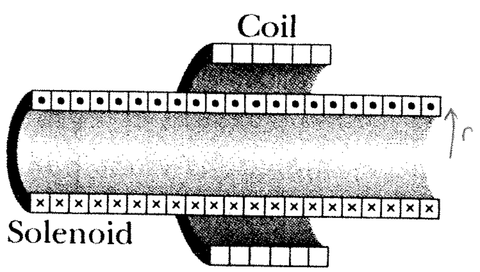
but $i_{enc} = J_0 \pi r^2$ so

$\oint \vec{B}\cdot d\vec{s} = \mu_0 i_{enc}$ yields

$B\,2\pi r = \mu_0 J_0 \pi r^2$

$$B = \frac{\mu_0 J_0 r}{2}$$

9. The diagram shows a cross section of two concentric cylindrical coils. The outer coil has has 120 turns of wire, has a radius of 1.8 cm, and has a resistance of 5.3 Ω. The inner coil (solenoid) contains 220 turns/cm and has a radius of 1.6 cm. If the current in the solenoid drops at a constant rate from 1.5 A to zero in a time interval of Δt = 25ms, what current is induced in the outer coil during Δt?



$$i = \frac{\mathcal{E}_{ind}}{R}$$

$$+ \left|\mathcal{E}_{ind}\right| = \frac{d\, N \Phi_B}{dt}$$

$$\Phi_B = B A_{sol} = \mu_0 n_{sol}\, i\, \pi r^2$$

$$i = \frac{\mathcal{E}}{R} = \frac{1}{R} \mu_0 n_{sol} \pi r^2 N_{coil} \frac{\Delta i}{\Delta t}$$

$$i = \frac{1}{5.3\,\Omega}\left(1.26\times10^{-6}\,\frac{H}{m}\right)\frac{220}{0.01\,m}\,\pi(0.016\,m)^2\, 120\left(\frac{1.5A}{25\times10^{-3}s}\right)$$

$$= 0.0303\ A$$

PHYSICS 203 **EXAM #2** NAME KEY

18 November 2011

General Instructions: For each problem your solution must be readable and your logic followable. Put a box around any numerical answers.

Constants: $\mu_0 = 1.26 \times 10^{-6}$ H/m $e = 1.60 \times 10^{-19}$ C $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$c = 3.00 \times 10^{8}$ m/s $n_{water} = 1.33$ $n_{air} = 1.00$ $n_{diamond} = 2.42$
Prefixes: $c = 10^{-2}$ $m = 10^{-3}$ $\mu = 10^{-6}$ $n = 10^{-9}$

PART I - SHORT ANSWER QUESTIONS.

Do the 4 short questions/problems. Worth 7 points each.

1. A parallel plate capacitor is part of an AC circuit. The capacitor has circular plates of radius R separated by d . If the voltage across the plates is given by:

$$V(t) = V_o \sin(\omega t)$$

What is the time dependent magnetic field that is produced at the edge of the capacitor (i.e. at r = R)?

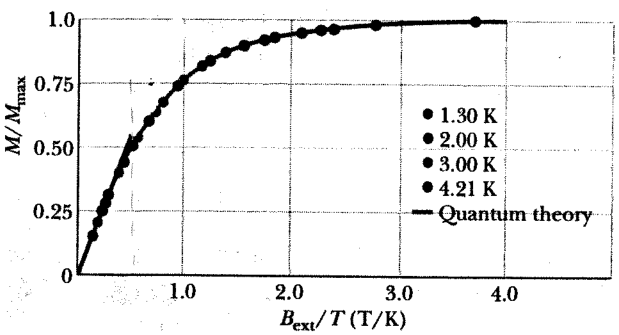
$$\oint \vec{B}\cdot d\vec{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 I_{enc} \;(\to 0)$$

by symmetry $B\cdot 2\pi R = \mu_0 \varepsilon_0 \frac{d\,EA}{dt} = \mu_0\varepsilon_0 \frac{d}{dt}\left(\frac{V}{d}\right)\pi R^2 = \mu_0 \varepsilon_0 \frac{\pi R^2}{d}\frac{dV}{dt}$

$$B\, 2\pi R = \mu_0 \varepsilon_0 \frac{\pi R^2}{d}\frac{d}{dt} V_o \sin\omega t = \ldots$$

$$\boxed{B = \mu_0 \varepsilon_0 \frac{R}{2d} V_o\, \omega \cos\omega t}$$

2. The graph below shows the magnetization curve for a particular paramagnetic material. If the magnetization were measured as a function of magnetic field strength at a temperature of 5.00 K, at what value of B_{ext} would the material stop obeying Curie's law? Explain how you found this answer.

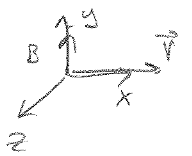


Curie's law is the linear relation → works up to $\sim \frac{B_{ext}}{T} = 0.5 \frac{T}{K}$

so $B_{ext} = \left(0.5\frac{T}{K}\right)(5.00\,K) = \boxed{2.5\,T}$

3. A plane electromagnetic wave travels in the + x direction. The x and z components of the magnetic field are zero, and the y component is given by: $B_y = (1.5\text{ nT}) \cos[(\pi \times 10^{15}\text{ s}^{-1})(t-x/c)]$.
a) What is the amplitude of the electric field?
b) At a time when the magnetic field points in the –y direction, in what direction does the electric field point?

a) $E_m = B_m c = 1.5\times10^{-9}\text{T} \cdot 3.00\times10^{8}\frac{\text{m}}{\text{s}} = \boxed{0.45\frac{\text{V}}{\text{m}}}$

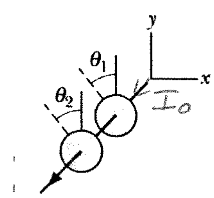


b) $\vec{E}\times\vec{B}$ points in +x dir, so via the RHR, $\vec{E}$ is in the **+z dir** when $\vec{B}$ is in −y dir.

4. Unpolarized light is sent into a pair of polarizing sheets as shown. If $\theta_1 = 30^0$ and $\theta_2 = 50^0$ (from +y dir) how much of the original intensity of the light emerges from the second polarizer?

1st pol takes unpol light to $I = \frac{1}{2}I_0$

2nd pol: $I = (\frac{1}{2}I_0)\cos^2(50^0 - 30^0) = \boxed{0.442\, I_0}$



<u>Part II – Shorter Questions:</u> Do any <u>six of the nine</u> questions based on presentations and your readings from Fischer's book. Be very clear which ones you are omitting or the first 8 with any markings at all will be graded. Worth 2 points each.

1) Maxwell thought of molecules as 'manufactured' items. Why?

For Maxwell, molecules could never change in time, so could not evolve. They must have been created.

2) In the presentation on making sense of Genesis 1, several things to keep in mind were given. What are two of them? 2 of:

- Western/modern concept of time is different
- similarities to Egyptian creation story
- language differences
- ⋮

3) Radioactive dating of rocks gives what sort of age estimate for what are thought to be some oldest rocks on Earth? Within a factor of 10, what is that age? Are the different techniques in agreement with each other?

~ 3×10^9 years

yes

4) The presentation on miracles talked about two different types of miracles recorded in the Bible. What were these two types?

timing & physical

5) What is scientism?

The idea that scientific methods / results are the only source of truth.

6) Fischer warns against making a distinction between the natural and supernatural. What are two of the reasons he gives for this? 2 of:

- Bible doesn't
- hard to have a clear definition
- too easy to limit God to supernatural

7) Fischer states that we do not necessarily need to interpret Genesis 1 and 2 as saying that the creation events took place during 24 hour days. What argument does he use to support his understanding?

The Hebrew word for day (yome) can mean a longer period than 24 hours.

8) Fischer cites a number of pieces of scientific evidence for an old age for the Earth. What are two of them (not including radioactive decay).

Any 2 of:

- salt content of ocean / rate of change of salt content
- motion of Moon w.r.t. Earth
- energy from Sun
- spectral distrib. of light from stars

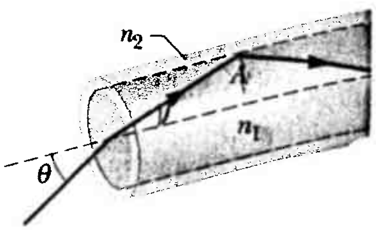
9) What are two of the weaknesses of biological evolutionary theory cited by Fischer?

2 of:

- claim that ev. is a fact
- small fraction of time span available for study
- fossil record imperf.
- evidence of abrupt changes
- assumption that fossil sim ⇒ descent
- cultural evidence at odds
- lack of calc.

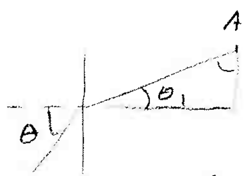
Part III - Problems.
Do all three. Worth 20 points each. Show and explain your work.

1. A glass (index of refraction of 1.65) cylinder is used as a 'light pipe.' A ray of light enters the flat end and undergoes total internal reflection at the point labeled A on the diagram. The entire rod is immersed in water (n_{water} = 1.33).
a) Assuming the entire rod is surrounded by water, what is the maximum angle θ for which the light will be totally internally reflected at A?
b) Suppose the rod is in air instead of being in water. Would the maximum angle θ in this case be greater than, less than, or equal to the answer in part a)? Explain.



a) At "A" if θ_A is the critical angle:

$$\theta_{crit} = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\frac{1.33}{1.65} = 53.7^\circ$$



so $\theta_1 = 90^\circ - 53.7^\circ = 36.3^\circ$

so applying Snell's law:

$$1.33 \sin\theta = 1.65 \sin 36.3^\circ$$

$$\sin\theta = 0.734 \qquad \boxed{\theta = 47.3^\circ}$$

If $\theta < 47.3^\circ$, θ_1 is less than 36.3°, & at A, angle is $> 53.7^\circ$

b) If in air, $\theta_{crit} = \sin^{-1}\frac{1.00}{1.65} = 37.3^\circ$ so $\theta_1 = 52.7^\circ$

$$1.00 \sin\theta = 1.65 \sin 52.7^\circ = 1.31$$

Can't have $\sin\theta > 1$!

This means any θ (0 → 90°) will result in $\theta_1 < 52.7^\circ$

so at A, $\theta > \theta_{crit}$.

so $\boxed{\theta \text{ is greater}}$

2. A concave mirror has the absolute value of its focal length given by |f| = 36 cm. An object is placed +24 cm away.

4 pts each

a) Is the focal length positive or negative?
b) How far from the mirror is the image located?
c) What is the magnification of the image?
d) Is the image upright or inverted? How do you know?
e) Is the image real or virtual? How do you know?

a) Since concave **f is positive** so $f = +36\,cm$.

b) $\frac{1}{i} + \frac{1}{p} = \frac{1}{f}$ so $\frac{1}{i} = \frac{1}{36\,cm} - \frac{1}{24\,cm}$

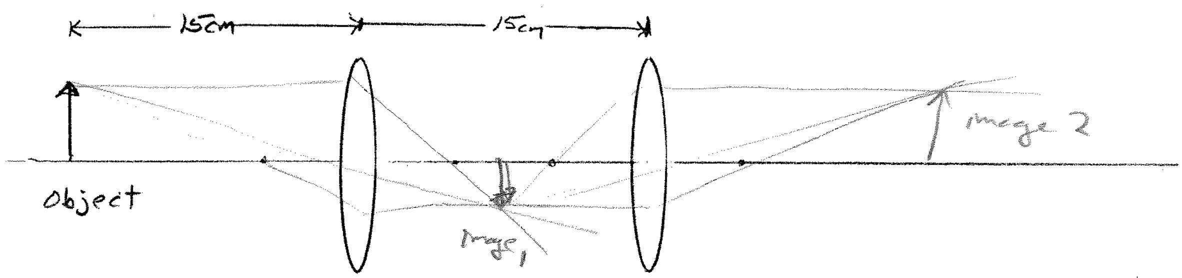
$i = -72\,cm$ Image is 72 cm from the mirror on other side than object.

c) $m = \frac{-i}{p} = \frac{-(-72\,cm)}{24\,cm} = \boxed{+3.0}$

d) **upright** since $m > 0$

e) **virtual** since $i < 0$

3. Two lenses, each of focal length 5.00 cm, are placed 15.0 cm apart. An object is placed 15.0 cm to the left of the combination.
a) Where is the image located that is produced by the first lens?
b) Using the image produced by first lens as the object for the second lens, find the final image location.
b) Compared to the original object, is the final image upright or inverted? Explain.
c) Compared to the original object, what is the magnification of the final image?



a) $\frac{1}{i_1} + \frac{1}{p_1} = \frac{1}{f_1} \Rightarrow \frac{1}{i_1} = \frac{1}{5.00\text{cm}} - \frac{1}{15.0\text{cm}}$ $\quad i_1 = \boxed{7.5 \text{ cm to right of 1st lens}}$

b) for 2nd lens $\quad p = 15.0\text{cm} - 7.5\text{cm} = 7.5\text{cm}$

$\frac{1}{i_2} = \frac{1}{f_2} - \frac{1}{p_2} = \frac{1}{5.0\text{cm}} - \frac{1}{7.5\text{cm}}$ $\quad \boxed{i_2 = 15\text{cm to the right of 2nd lens}}$

c) Upright, as seen in ray tracing

(or $m_1 = -\frac{i_1}{p_1} = -\frac{7.5\text{cm}}{15.0\text{cm}} = -0.50$ 1st image is inverted

$m_2 = -\frac{i_2}{p_2} = -\frac{15\text{cm}}{7.5\text{cm}} = -2.00$ 2nd image is inverted from 1st image.

d) $M_{tot} = m_1 \cdot m_2 = (-0.500)(-2.00) = \boxed{+1.00}$