Physics 205 Test 1

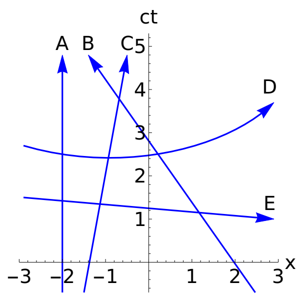
I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Name ______________________ Signature ______________________

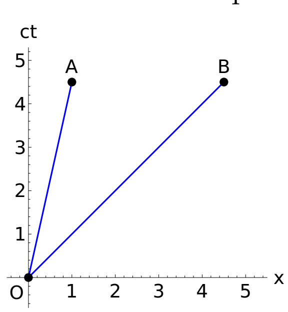
Questions (7 for 7 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. Since the laws of physics are the same in every inertial reference frame, if you perform identical experiments in two different inertial frames, should you get exactly the same results? Explain.

2. The spacetime diagram here shows the worldlines of various objects. Are any of them incorrect? Explain.



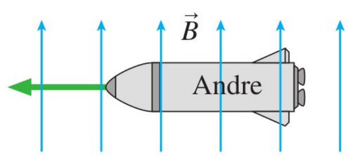
3. Consider the spacetime diagram below. Let the spacetime interval between events O and A be Δs_{OA} and the spacetime interval between O and B be Δs_{OB}. Which of these two spacetime intervals is larger? Or are they equal? Or you don't have enough information? Explain your answer.



4. What are the properties of Newtonian Time?

5. We started the semester studying Galilean relativity and the 'Trouble with Galileo'. What trouble did Galilean relativity have when we applied it to electromagnetism?

6. Andre is flying his spaceship to the left through the laboratory magnetic field of the figure below. (a) Does Andre see a magnetic field? If so, in which direction does it point? (b) Does Andre see an electric field? If so, in which direction does it point? Explain your answers.



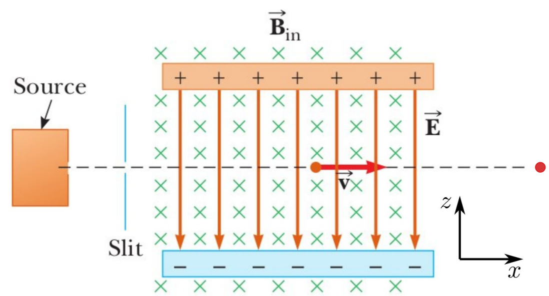
7. Suppose an observer in the Other frame measures two events to be at the same place, but at different times. Can an observer in the Home frame possibly measure them to be at the same location? Explain.

Problems (4). Clearly show all reasoning for full credit. Use a separate sheet to show your work.

1. 10 pts. Suppose you send out a light flash at $t = 3.5$ s as registered on your clock and you receive a return reflection showing a picture of Einstein at a time $t = 12$ s. (a) At what time t_h did the light flash hit the picture? (b) How far away is the picture?

2. 10 pts. Suppose we have a train a length $L = 100\ m$ long and place the origin $x' = 0$ in the train frame at the rear end. We then use a track signal light to define the origin $x = 0$ in the track frame. Suppose the train's rear end/origin passes this light at $t = t' = 0$ as the train moves in the $+x$ direction at a constant speed $v = 20\ m/s$. At a time $t = 10\ s$ later, the engineer turns on the train's headlight. Assume the Galilean transformations are true. (a) Where does this event occur in the train frame? (b) Where does this event occur in the track frame? Explain.

3. 14 pts. A velocity selector consists of electric and magnetic fields described by the expressions $\vec{E} = -E\hat{k}$ and $\vec{B} = B\hat{j}$ with $B = 20.0\ mT$. It is designed to only allow particles with a chosen speed to pass through the device without being deflected. What are the directions of the forces? Starting from Newton's Second Law ($\vec{F}_{net} = \sum \vec{F}_i = m\vec{a}$) what is the electric field such that an electron with velocity $\vec{v} = 1.62 \times 10^7\ m/s\ \hat{i}$ is undeflected? What is the value of the electric field?



4. 17 pts. At $t = 0$ a spaceship passes by the Earth. This is event A. At $t = 45\ s$ it passes by Mars (event B) which is a distance 30 $light\!-\!sec$ or $9.0 \times 10^9\ m$ away. These times are measured with synchronized clocks on Earth and Mars. The spaceship moved at a constant velocity during its journey. You can ignore the effects of gravity and treat the Earth and Mars as if they are stationary in the inertial frame of the solar system. What is the spacetime interval between the two events? How is the time interval measured traveling on the spaceship related to the spacetime interval? What is the time interval measured on the spaceship?

DO NOT WRITE BELOW THIS LINE.

Physics 205 Equations

$$v = \frac{dx}{dt} \quad x = \frac{1}{2}at^2 + v_0 t + x_0 \quad v = at + v_0 \quad a_g = -g$$

$$\vec{F}_{net} = \sum \vec{F}_i = m\vec{a} = \frac{d\vec{p}}{dt} \quad \vec{F}_{Earth} = -mg\hat{j} \quad a_c = \frac{v^2}{r}$$

$$KE = \frac{1}{2}mv^2 \quad KE_0 + PE_0 = KE_1 + PE_1 \quad PE_{Earth} = mgh \quad PE_V = qV$$

$$\vec{p}_i = \vec{p}_f \quad \vec{p} = m\vec{v}$$

$$\vec{F}_C = k_e \frac{q_1 q_2}{r^2}\hat{r} \quad \vec{E} \equiv \frac{\vec{F}}{q_0} \quad d\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I d\vec{s} \times \hat{r}}{r^2} = \frac{\mu_0}{4\pi}\frac{q d\vec{v} \times \hat{r}}{r^2} \qquad \vec{F}_B = q\vec{v} \times \vec{B} \qquad |\vec{F}_B| = |qvB\sin\theta|$$

$$\vec{E}_B = \vec{E}_A + \vec{v}_{BA} \times \vec{B}_A \quad \vec{B}_B = \vec{B}_A - \mu_0\epsilon_0\vec{v}_{BA} \times \vec{E}_A$$

Galilean Transformation
$x' = x - vt$ $y' = y$ $z' = z$ $t' = t$ $v'_x = v_x - v_O$ $v'_y = v_y$ $v'_z = v_z$

Coordinate Time	Proper Time	Spacetime Interval
Time between two events in an inertial frame measured with synchronized clocks	Time between two events measured by the same clock at both events.	Time between two events measured by the same, inertial clock at both events.
Δt	Δs_{AB}, $\Delta\tau_{AB}$	Δs
Frame dependent	Frame independent	Frame independent

$$\Delta s^2 = \Delta t^2 - \Delta d^2 = \Delta s'^2 \quad \text{or} \quad \Delta s^2 = c^2\Delta t^2 - \Delta d^2 = \Delta s'^2$$

$$\Delta s_{AB} = \int_{t_A}^{t_B} \sqrt{1 - \frac{v^2}{c^2}}\, c\,dt \quad \text{or} \quad \Delta\tau_{AB} = \int_{t_A}^{t_B} \sqrt{1 - v^2}\, dt$$

$$\Delta s_{AB} = \sqrt{1 - v^2/c^2}\, c\Delta t \quad \text{or} \quad \Delta\tau_{AB} = \sqrt{1 - v^2}\,\Delta t$$

$$\frac{d}{dx}(f(u)) = \frac{df}{du}\frac{du}{dx} \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int \frac{1}{x}dx = \ln x \quad \vec{A}\cdot\vec{B} = AB\cos\theta \quad |\vec{A}\times\vec{B}| = |AB\sin\theta|$$

$$\frac{d}{dx}(x^n) = nx^{n-1} \quad \frac{de^x}{dx} = e^x \quad \frac{d}{dx}(\ln x) = \frac{1}{x} \quad \frac{d}{dx}(\cos ax) = -a\sin ax \quad \frac{d}{dx}(\sin ax) = a\cos ax$$

$$\langle x\rangle = \frac{1}{N}\sum_i x_i \quad \sigma = \sqrt{\frac{\sum_i (x_i - \langle x\rangle)^2}{N-1}} \quad A = 4\pi r^2 \quad V = Ah \quad V = \frac{4}{3}\pi r^3$$

$$\frac{df(x)}{dx} = \lim_{\Delta x\to 0}\frac{f(x+\Delta x) - f(x)}{\Delta x} \qquad \int_a^b f(x)dx = \lim_{\Delta x\to 0}\sum_{n=1}^{N} f(x)\Delta x$$

$$\int \frac{1}{x}dx = \ln x \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int e^{ax}dx = \frac{e^{ax}}{a} \quad \int \frac{1}{\sqrt{x^2+a^2}}dx = \ln\left[x + \sqrt{x^2+a^2}\right]$$

$$\int \frac{x}{\sqrt{x^2+a^2}}dx = \sqrt{x^2+a^2} \quad \int \frac{x^2}{\sqrt{x^2+a^2}}dx = \frac{1}{2}x\sqrt{x^2+a^2} - \frac{1}{2}a^2\ln\left[x+\sqrt{x^2+a^2}\right]$$

$$\int \sqrt{1-ax^2}dx = \frac{x}{2}\sqrt{1-ax^2} + \frac{\arcsin(\sqrt{a}x)}{2\sqrt{a}} \quad \int \frac{x^3}{\sqrt{x^2+a^2}}dx = \frac{1}{3}(-2a^2+x^2)\sqrt{x^2+a^2}$$

Physics 205 Constants and Conversions

Avogadro's number (N_A)	6.022×10^{23}	Speed of light (c)	$3 \times 10^8\ m/s$
k_B	$1.38 \times 10^{-23}\ J/K$	proton/neutron mass	$1.67 \times 10^{-27}\ kg$
1 u	$1.67 \times 10^{-27}\ kg$	g	$9.8\ m/s^2$
Gravitation constant	$6.67 \times 10^{-11}\ N - m^2/kg^2$	Earth's radius	$6.37 \times 10^6\ m$
Coulomb constant (k_e)	$8.99 \times 10^9 \frac{N-m^2}{C^2}$	Electron mass	$9.11 \times 10^{-31}\ kg$
Elementary charge (e)	$1.60 \times 10^{-19}\ C$	Proton/Neutron mass	$1.67 \times 10^{-27}\ kg$
Permittivity constant (ϵ_0)	$8.85 \times 10^{-12} \frac{kg^2}{N-m^2}$	1.0 eV	$1.6 \times 10^{-19}\ J$
1 MeV	$10^6\ eV$	atomic mass unit (u)	$1.66 \times 10^{-27}\ kg$
Planck's constant (h)	$6.63 \times 10^{-34}\ Js$	Planck's constant (h)	$4.14 \times 10^{-15}\ eVs$
Permeability constant (μ_0)	$1.26 \times 10^{-6}\ Tm/A$	Rydberg constant (R_H)	$1.097 \times 10^7\ m^{-1}$
Becquerel (Bq)	$1\ decay/s$	Curie (Ci)	$3.7 \times 10^{10}\ Bq$