PHYS306 Homework#7

(Due on 12May2022)

Q#1:

Some outlaws escape in their getaway car, which goes $\frac{3}{4}c$, the police officer fires a bullet from the pursuit car, which only goes $\frac{1}{2}c$. The muzzle velocity of the bullet (relative to the gun) is $\frac{1}{3}c$. Does the bullet reach its target (a) according to Galileo , (b) according to Einstein.

Q#2:

A rocket ship leaves earth at a speed of A rocket ship leaves earth at a speed of $\frac{3}{5}c$. When a clock on the rocket says 1 hour has elapsed, the rocket ship send a light signal back to earth.

(a) According to earth clocks, when was the signal sent?
(b) According to earth clocks, how long after the rocket left did the signal arrive back on earth?
(c) According to the rocket observer, how long after the rocket left did the signal arrive back on earth?

Q#3:

Even A happens at point $(x_A = 5,\ y_A = 3,\ z_A = 0)$ and at time t_A given by $ct_A = 15$; event B occurs at $(10,8,0)$ and $ct_B = 5$ both in system *S*.

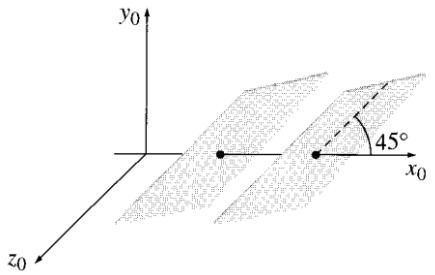
(i) What is the invariant interval between A and B?
(ii) Is there an inertial system in which they occur simultaneously? If so, find its velocity (magnitude and direction) relative to *S*.
(iii) Is there an inertial system in which they occur at the same point? If so, find its velocity relative to *S*.

Q#4:

(a) A particle of mass m whose total energy is twice its rest energy collides with an identical particle at rest. If they stick together, what is the mass of the resulting composite particle? What is its velocity?
(b) In a **pair annihilation** experiment, an electron of mass m with momentum pe hits the positron (same mass but opposite charge) at rest. They annihilate producing two photons. If one of the photon emerges at 60° to the incident electron direction, what is its energy? Why they couldn't produce one photon?

Q#5:

A parallel plate capacitor, at rest in S0 and tilted at a 45° angle to the x0 axis, carries charge densities $\pm\sigma$ on the two plates. System S is moving to the right at speed v relative to S0.



(a) Find E0, the field in S0.
(b) Find E, the field in S.

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(c) What angle do the plates make with the x-axis.
(d) Is the field perpendicular to the plates in S.

Q#6:

Two charges $\pm q$ are on parallel trajectories a distance d apart, moving with equal speed v in the opposite directions. We are interested in the force on +q due to –q at the instant they cross. Fill in the following table doing all the consistency checks:

	System A (Fig. 12.42)	System B ($+q$ at rest)	System C ($-q$ at rest)
E at $+q$ due to $-q$:			
B at $+q$ due to $-q$:			
F on $+q$ due to $-q$:			

Q#7:

(a) Show that $(\vec{E}.\vec{B})$ is relativistically invariant.
(b) Show that $(E^2 - c^2B^2)$ is relativistically invariant.
(c) Suppose that in one inertial system $\vec{B} = 0$ but $\vec{E} \neq 0$ (at some point P). Is it possible to find another system in which the electric field is zero at P.

Q#8:

An electromagnetic plane wave of angular frequency ω is travelling the x-direction through the vacuum. It is polarized in the y-direction, and the amplitude of the electric field is E_0.

(a) Write down the electric and magnetic fields, $\vec{E}(x, y, z, t)$ and $\vec{B}(x, y, z, t)$.
(b) This same wave is observed from an inertial system $\bar{S}$ moving in the x-direction with speed v relative to the original system S. Find the electric and magnetic fields in $\bar{S}$, and express them in terms of the $\bar{S}$ coordinates: $\vec{E}(\bar{x}, \bar{y}, \bar{z}, \bar{t})$ and $\vec{B}(\bar{x}, \bar{y}, \bar{z}, \bar{t})$.
(c) What is the frequency $\bar{\omega}$ of the wave in $\bar{S}$? What is the wavelength $\bar{\lambda}$ of the wave in $\bar{S}$? Determine the speed of the wave in $\bar{S}$.
(d) What is the ratio of the intensity in $\bar{S}$ to the intensity in S?
(e) What an electromagnetic wave would look like if you could run along beside it at the speed of light. What will be its amplitude, frequency and intensity of the wave, as v approaches c?

Q#9:

An ideal magnetic dipole moment $\vec{m}$ is located at the origin of an inertial system $\bar{S}$ that moves with speed v in the x-direction with respect to the inertial system S. In $\bar{S}$ the vector potential is:

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$$\bar{\mathbf{A}} = \frac{\mu_0}{4\pi} \frac{\bar{\mathbf{m}} \times \hat{\bar{\mathbf{r}}}}{\bar{r}^2}$$

And the electric potential $\bar{V}$ is zero.

(a) Find the scalar potential V in S.

(b) In the non-relativistic limit, show that the scalar potential in S is that of an ideal electric dipole of magnitude $\boldsymbol{p} = \frac{\boldsymbol{v}\times\boldsymbol{m}}{c^2}$ located at $\bar{O}$.

Q#10:

A stationary magnetic dipole, $\boldsymbol{m} = m\hat{\boldsymbol{z}}$ is situated above an infinite uniform surface current, as $\boldsymbol{K} = K\,\hat{\boldsymbol{x}}$ as shown in the figure.

a) Find the torque on the dipole.

b) Suppose that the surface current consists of a uniform surface charge σ, moving at velocity $\mathbf{v} = v\,\hat{\boldsymbol{x}}$, so that $\boldsymbol{K} = \sigma\mathbf{v}$, and the magnetic dipole consists of a uniform line charge λ, circulating at speed v around a square loop of side l, as shown, such that that $m = \lambda v l^2$. Examine the same configuration from the point of view of system $\bar{S}$, moving in the x-direction at speed v. In $\bar{S}$ the surface charge is at rest, so it generates no magnetic field. Show that in this frame the current loop carries an electric dipole moment and calculate the resulting torque.