Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work where requested in order to be considered for partial credit. In problems where you are requested to show your work, no credit will be given unless your work is shown.

Potentially useful formulas:

\[ F = G \frac{m_1 m_2}{r^2} \]
\[ F = k \frac{q_1 q_2}{r^2} \]
\[ F = ma \]

Distance = Speed \times Time
\[ v = \frac{\Delta x}{\Delta t} \]
\[ a = \frac{\Delta v}{\Delta t} \]

Momentum = \( p = mv \)

Length contraction (space is longer in proper frame): \( L' = \gamma L \)
Time dilation (time is shorter in proper frame): \( T = \gamma T' \)

\[ \gamma = \frac{1}{\sqrt{1 - (\frac{v}{c})^2}} \]

Wave properties: \( v = \lambda f \); \( f = \frac{1}{T} \) (T = period)

Constants: \( c = 300,000 \times 10^3 \text{ m/s} \); \( G = 6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2} \); \( k = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \)

Do not forget to put units in your results!

(6 pts) 1. Is it possible to prove, for certain, that a scientific theory is false?
   - (a) Yes, by means of a single confirmed experiment that contradicts the theory
   - (b) Yes, by taking a vote among all scientists who are experts concerning the theory
   - (c) Yes, by performing a large number of experiments and finding that the outcomes that dispute the theory outnumber the outcomes that support the theory
   - (d) No, because it is always possible that future experiments will agree with the theory
   - (e) No, because science can never be certain of anything

(12 pts) 2. Most meteoroids –rocks moving through outer space– have been moving for billions of years. What if anything keeps them moving and why?
   - (a) According to Newton’s law of gravity, the force of gravity keeps them moving
   - (b) According to current theories about the creation of the solar system, the rotation of the galaxy keeps them moving
   - (c) According to Newton’s law of gravity, nothing is needed to keep them moving
   - (d) According to the law of inertia, nothing is needed to keep them moving
   - (e) According to Newton’s law of motion, their own acceleration keeps them moving
3. Briefly describe all forces acting on a car accelerating in a straight line on a level asphalt road. What are the net forces in all directions?

**Horizontal Net Force:** \( F_H = F_{\text{motor}} - F_{\text{air}} - F_{\text{fr}} \)

**Vertical Net Force:** \( F_V = F_N - F_{\text{weight}} = 0 \)

- \( F_{\text{motor}} = \) Engine Driving Force
- \( F_{\text{fr}} = \) Friction of Tires with Asphalt
- \( F_{\text{air}} = \) Air Resistance
- \( F_{\text{weight}} = \) Weight of Car (Gravitational Attraction)
- \( F_N = \) Normal (Reaction Force to Weight), Applied by Road on Car, Such That the Car Does Not Move Up or Down.

4. Two small electrically charged objects are placed 8 cm apart, where they exert an electric force \( F \) on each other. How far apart must they be in order to exert an electric force \( F/4 \) on each other? Show your work.

   - (a) 2 cm  
   - (b) 4 cm  
   - (c) 10 cm  
   - (d) 16 cm  
   - (e) 32 cm

   **Square Dependence with Distance:** \( F = \frac{kq_1q_2}{d^2} \)

   \[ F = \frac{F}{4} \Rightarrow \frac{kq_1q_2}{d'^2} = \frac{1}{4} \frac{kq_1q_2}{d^2} \]

   \[ \Rightarrow d'^2 = 4d^2 \Rightarrow d' = 2d = 16 \text{ cm} \]

5. The radius of Jupiter is approximately 10 times larger than the Earth’s, and the mass of Jupiter is 300 times that of Earth. Show your work.

   - (a) (4 pts) What is the gravitational acceleration felt on the surface of Jupiter \( (g_{\text{Jupiter}}) \), in terms of the acceleration on Earth \( (g) \)?

     \[ g_J = \frac{GM_J}{R_J^2} = \frac{G \left( \frac{300 M_E}{10 R_E} \right)^2}{(10 R_E)^2} = \frac{300}{100} \times \frac{G M_E}{R_E^2} = 3 \times \frac{G M_E}{R_E^2} = 3g \]

     \[ g_J = 3g \]

     **The Acceleration is Only 3 Times Bigger!**

   - (b) (2 pts) How would your mass change on the surface of Jupiter?

     **My Mass Is the Same: No Change!**

     **What Changes Is the Weight.**

     **My Weight on the Surface of Jupiter is Three Times Bigger!**
6. Communications satellites must be in geosynchronous orbits. That is, they must remain above a fixed point on Earth’s surface, enabling sending and receiving antennas to be aimed at a fixed point overhead.

(a) (3 pts) What is the communications satellite's orbital period (the time for one complete orbit around Earth)?

**ONE DAY, OR 24 HOURS.**

**THE SAME TIME IT TAKES FOR A FIXED POINT ON THE SURFACE TO GIVE ONE COMPLETE TURN.**

(b) (3 pts) The geosynchronous satellite orbits at approximately 22,000 miles above the surface of the Earth. If this satellite was moved to an orbit at 20,000 miles above the surface, would its period increase or decrease? Explain.

**LOWER ORBITAL RADIUS MEANS THAT THE SATELLITE HAS TO HAVE A LARGER SPEED (SINCE THE GRAVITATIONAL FORCE IS BIGGER).**

7. Sam is on Earth and Alice passes him on a spaceship at a speed of 0.6c.

(a) (10 pts) Suppose that they are born at the same time, and that Sam observes himself to live 30 years. As Sam dies, how old will he observe Alice to be? Show your work.

\[
\gamma = \frac{1}{\sqrt{1 - (\frac{v}{c})^2}} = \frac{1}{\sqrt{1 - (0.6)^2}} = \frac{1}{\sqrt{1-0.36}} = \frac{1}{\sqrt{0.64}} = \frac{1}{0.8} = 0.8 = \frac{10}{8} = \frac{5}{4} = 1.25
\]

**TIME DILATION:**

\[
T' = \gamma T
\]

**TIME ON EARTH (SAM)**

\[
T = \frac{30}{5/4} = \frac{4 \times 30}{5} = \frac{120}{5} = 24 \text{ years}
\]

**PAPER TIME ON ALICE SHIP**

**ALICE IS YOUNGER BECAUSE 1 SECOND ON EARTH TAKES 1.25 SECONDS ON HER SHIP.**

(b) (10 pts) Alice’s spaceship was 100 meters long standing on the launch platform on Earth. When it passes by at 0.6c, how long will it appear to Sam? Show your work.

**SPACE CONTRACTION:**

\[
L' = \gamma L
\]

**MEASURED ON REFERENCE FRAME AT REST ALICE, OR WHEN SHIP WAS STOPPED**

\[
L = \frac{L'}{\gamma} = \frac{100}{5/4} = \frac{4 \times 100}{5} = \frac{400}{5} = 80 \text{ m}
\]

**MEASURED BY SAM ON EARTH AS IT PASSES BY**

**THE SHIP APPEARS SHORTER TO SAM AS IT ZIPS BY.**

(c) (10 pts) Sam and Alice each carry a standard kilogram. Sam will observe that:

(a) Alice’s has a mass of 1 kg, but Sam’s is more massive than 1 kg
(b) Alice’s has a mass of 1 kg, but Sam’s is less massive than 1 kg
(c) Both have a mass of 1 kg
(d) Alice’s is more massive than 1 kg and Sam’s has a mass of 1 kg
(e) Alice’s is less massive than 1 kg and Sam’s has a mass of 1 kg

**AS OBJECTS APPROACH C, THEIR MASSES AS MEASURED BY AN OUTSIDE OBSERVER INCREASE WITH \( \gamma \).**

36 pts
8. Which of the following is transported by all traveling waves?
   (a) particles
   (b) energy
   (c) light
   (d) matter
   (e) both energy and matter

9. A wave completes one vibration as it moves a distance of 2 meters at a speed of 20 meters per second. What is the frequency of the wave? [1 Hz = 1/second].
   (a) 10 Hz
   (b) 20 Hz
   (c) 2 Hz
   (d) 40 Hz
   (e) 5 Hz

10. What is the period of a wave, if 20 crests pass an observer in 4 seconds?
    (a) 80 s
    (b) 5 s
    (c) 4 s
    (d) 0.2 s
    (e) 0.05 s

11. If two electrons are near each other and are moving past each other, the electromagnetic forces they exert on each other will be:
    (a) zero
    (b) magnetic but not electric
    (c) electric but not magnetic
    (d) both electric and magnetic

12. You are inside a smooth-flying jet plane speeding up along a straight line in the middle of the Atlantic Ocean. Can you detect this acceleration without directly or indirectly making use of anything outside of your own reference frame? If so, how could you observe this, and if not, why not?
    (a) No, because the principle of relativity
    (b) No, because of the principle of constancy of light speed
    (c) Yes, for example if you dropped a coin you would find that it lands to the rear of the drop point
    (d) Yes, for example if you dropped a coin you would find that it lands to the front of the drop point
    (e) No, because jet planes move far too slowly for such an effect to actually be observed