Length: 2–3 pages (12pt, double-spaced); **AI Log:** brief list of prompts used; **Sources:** ≥ 2 non-AI sources

Overview

This assignment builds conceptual understanding with light mathematics. Use course resources for facts and reasoning. Generative AI may be used to brainstorm and clarify, *not* to obtain final numeric answers. Verify all claims and cite sources and adhere to course AI Policy.

Part A — Mars Escape Velocity

A1. Concept (all students)

In your own words, explain what *escape velocity* means and why it depends on a planet's mass and radius. Include a simple analogy.

A2. Qualitative reasoning (all students)

Would escape velocity on Mars be higher or lower than on Earth? Explain using mass/size comparisons; no equations required.

A3. Optional calculation

Use $v_e = \sqrt{2GM/R}$ and the data in §Data. *Check:* a reasonable value is on the order of $\sim 5\,\mathrm{km/s}$.

AI brainstorm (allowed): analogies for escape velocity; a 2–3 sentence, non-numeric explanation of mass/radius effects.

Part B — GPS Origins, Uses, Access

B1. Short research (all students)

Write a concise paragraph for each (cite sources): (a) origins of GPS; (b) two civilian uses; (c) when public access became common and why not earlier; (d) roughly how many satellites in the constellation and how many signals determine a 3D position; (e) a plain-language explanation of how GPS infers your position (time-of-flight idea).

AI brainstorm (allowed): a nontechnical 3-sentence explanation of how GPS determines location; an outline for the history paragraph (verify details with sources).

Part C — Time Dilation for GPS Clocks

Given: Satellites move at 13,900 km/h in orbits of radius 26,600 km in about two orbits per day.

C1. Concept (all students)

Explain why special relativity (SR) tends to make orbiting clocks run *slow* and general relativity (GR) tends to make higher-altitude clocks run *fast* relative to clocks on Earth's surface.

C2. Sense-check (all students)

Is the *net* relativistic effect expected to make GPS satellite clocks run fast or slow versus Earth? Why must GPS account for this?

C3. Optional estimate

SR (per day, ns): Find the fractional change in time, $\Delta t/t \approx v^2/(2c^2)$. Convert this to ns/day.
GR (per day, ns): Quote a reputable result for gravitational redshift between Earth's surface and the orbit radius; explain the sign.

AI brainstorm (allowed): Plain-English analogies for SR/GR clock effects; a one-paragraph GPS correction analogy (no numbers).

Part D — Fermi Estimation: Stars vs. Sand (Wrightsville Beach)

D1. Decompose

List the assumptions you need to estimate the number of grains of sand on Wrightsville Beach (beach dimensions, packing fraction, grain size; a figure for stars in the observable universe).

D2. Rough estimate

Compute a defensible order-of-magnitude (based on powers of ten) comparison using rounded arithmetic. State assumptions and give a one-sentence conclusion.

D3. Sensitivity

Identify the assumption that matters most. If changed by a factor of 10, does your conclusion change?

AI brainstorm (allowed): list of assumptions needed for a beach grain estimate; a clear structure for a Fermi write-up (you provide numbers).

Formatting & Integrity

- Clear title, 12pt, double-spaced; good grammar; figures labeled with captions.
- Equations (if used) typed and referenced in-text (e.g., Equation (1)).
- Cite all sources; include at least two non-AI sources; quote minimally.
- **AI Log:** at the end of your PDF, list prompts used, tool, date, and 1–2 lines on usefulness/limits.

Data

- $G = 6.674 \times 10^{-11}\ \mathrm{N\,m^2/kg^2}$, $c = 3.00 \times 10^8$ m/s
- Mars: $M \approx 6.42 \times 10^{23}$ kg, $R \approx 3.39 \times 10^6$ m
- GPS orbital radius (from Earth's center): $r \approx$ 26,600 km
- GPS speed: 13,900 km/h $\approx$ 3,860 m/s