**It's About Time**
**Colorado State Finals 2015**
**April 18, 2015**
**Time Limit: 30 Minutes**

**School Name** _____
**Team Number** _____
**Name (Print):** _____
**Name (Print):** _____

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This exam contains 7 pages (including this cover page) and 10 problems. Check to see if any pages are missing. Enter all requested information on the top of this page, and put your initials on the top of every page, in case the pages become separated.

You may only use your books, notes, or any calculator on this exam.

You are required to show your work on each problem on this exam.

- **Organize your work**, in a reasonably neat and coherent way, in the space provided. Work scattered all over the page without a clear ordering will receive very little credit.
- **Mysterious or unsupported answers will not receive full credit**. A correct answer, unsupported by calculations, explanation, or algebraic work will receive no credit; an incorrect answer supported by substantially correct calculations and explanations might still receive partial credit.
- If you need more space, use the back of the pages; clearly indicate when you have done this.

Do not write in the table to the right.

| Problem | Points | Score |
|---|---|---|
| 1 | 8 | |
| 2 | 2 | |
| 3 | 5 | |
| 4 | 5 | |
| 5 | 5 | |
| 6 | 5 | |
| 7 | 5 | |
| 8 | 5 | |
| 9 | 5 | |
| 10 | 5 | |
| Total: | 50 | |

1. (8 points) **Matching:** Fill in the correct clock type into the table below

Clock Types

• Cesium Fountain • Cesium Beam • Harrison Chronometer • Optical Lattice
• Pendulum Clock • Quartz Crystal • Sundial • Water Clock

| Year of Invention | Timing Uncertainty Uncertainty (24h) | Clock Type |
|---|---|---|
| ≈3500 BC | N/A | |
| ≈1600 BC | $> 30\,\text{min}$ | |
| 1656 AD | $10\,\text{s}$ | |
| 1759 AD | $350\,\text{ms}$ | |
| 1927 AD | $10\,\mu\text{s}$ | |
| 1952 AD | $1\,\text{ns}$ | |
| 1991 AD | $100\,\text{ps}$ | |
| 2014 AD | $10\,\text{ps}$ | |

2. (2 points) **Short Answer:** The quantity that measures the ratio between the rate an oscillator losses energy to the amount of energy it stores is called...

3. (5 points) **Short Answer:** Two events are separated by a positive *spacetime interval*, $\Delta s$, (note we are using the space-like convention) it is said that is interval is...

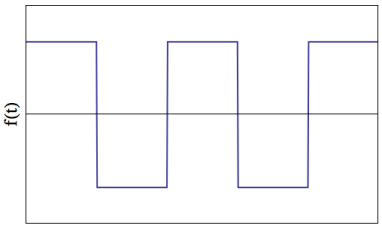
4. (5 points) **Short Answer:** A pendulum's period is constant and given by the equation

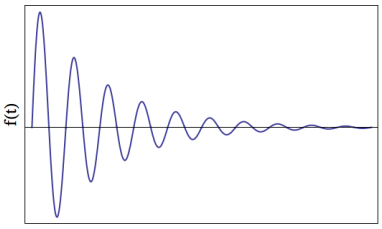
$$T = 2\pi\sqrt{\frac{L}{g}}$$

if the angle of deflection $\theta$ is...

5. (5 points) **Matching:** Match the time signal in blue, $f(t)$, with the spectrum or *Fourier transform*, $F(\omega)$.

| $f(t)$ | $F(\omega)$ |
|---|---|
| (1) | |
| (2) | |
| (3) | |
| (4) | |
| (5) | |

(1)



(2)
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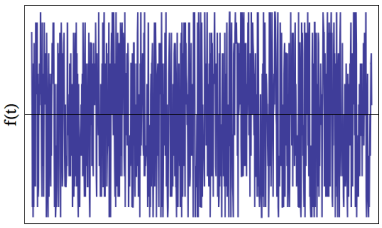


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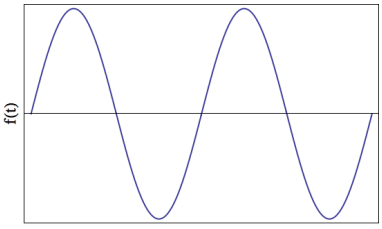


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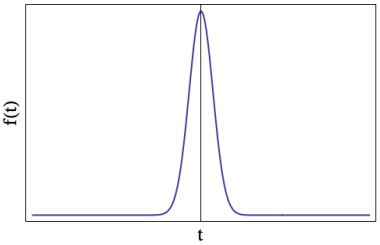
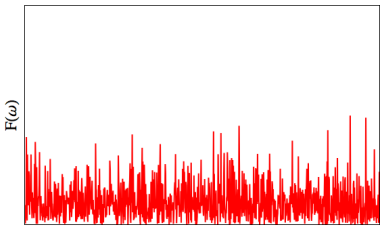
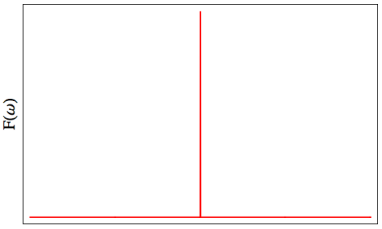



(a)



(b)
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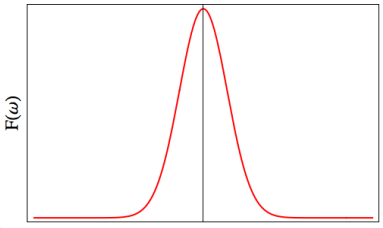


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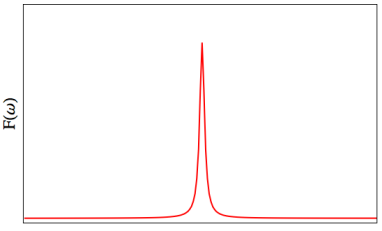


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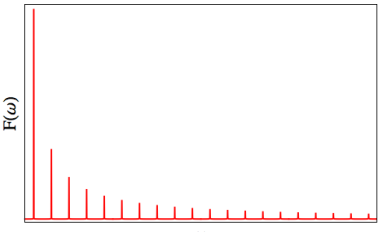


6. (5 points) **Calculation:**

   (a) (3 points) A time synchronization signal is sent between two clocks separated by a distance of 5500 km. Assuming the signal travels at the speed of light what is the amount of time you need to adjust to account for the delay?

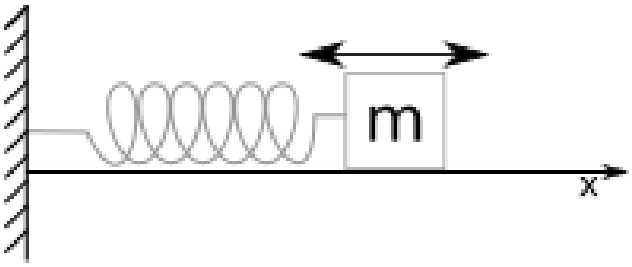
   (b) (2 points) What is the delay if the signal travels in an optical fiber with and index of refraction $n = 1.5$?

7. (5 points) **Calculation:** You are timing the period of a pendulum with a stopwatch. The primary source of uncertainty is human reaction time with an error of $\sigma = \pm 0.1\,\mathrm{s}$. Which measurement has lower uncertainty taking ten averages of a single period or measuring ten periods at once and dividing by ten?

8. (5 points) **Calculation:** You travel from earth to the center of the galaxy and back at the speed of light (without accelerating). An observer on earth waits 50 yrs for you to return. How long does the trip appear to you?

9. (5 points) **Calculation:** Matthew McConaughey is on a planet that is orbiting a black hole. Mr. McConaughey spends 1 hr on the surface of the planet and once he returns to his space station that is a long distance from the black hole he has found that 1 yr has passed. Assume the planet orbits at a radius of $r = 1.5 \times 10^8$ km and that the travel was instant. What was the mass of the black hole?

10. (5 points) **Calculation(Tiebreaker):** A massless spring with one end fixed and with a mass, $m$ attached to the free end (see figure). Assume the spring obeys *Hooke's Law* ($F = -kx$) and the surface the mass is resting on is frictionless.




(a) (3 points) Show that $x(t) = A\sin(\omega_0 t)$ is a solution for the equations of motion for the mass. Note that $\omega_0 = \sqrt{k/m}$.

(b) (2 points) What are the units of $\omega_0$?