Midterm, Oct 29th, 2018

Name_____

Allowed: Formula sheet, calculator

Time allowed: 1 hour 50 mins

PART 1 (worth 50% of marks). Answer all questions **1 - 8** in the spaces provided, **then** use your scratch card: One scratch = **4** points; two scratches = **2** point; three scratches = **1** point
PART 2 (worth 50% of marks). Answer all questions **9 - 11** in the exam booklet provided.

PART 1 – Answer all questions

Qu 1-3) In the earth's reference frame a tree is at the origin and a post is at $x = 30$ km, and lightning strikes both tree and post at $t = 10\ \mu$s . These strikes are observed by a rocket travelling along the +*x* direction at 0.5*c*.

1) What are the spacetime coordinates for the lightning striking the **tree** in the rocket's frame?

A. $(x'_{tree}, t'_{tree}) = (-2.8 \text{ km}, 31\ \mu\text{s})$ **B.** $(x'_{tree}, t'_{tree}) = (-2.6 \text{ km}, 22\ \mu\text{s})$ **C.** $(x'_{tree}, t'_{tree}) = (-1.7 \text{ km}, 12\ \mu\text{s})$
D. $(x'_{tree}, t'_{tree}) = (-2.4 \text{ km}, 40\ \mu\text{s})$ **E.** $(x'_{tree}, t'_{tree}) = (-1.5 \text{ km}, 50\ \mu\text{s})$

2) What are the spacetime coordinates for the lightning striking the **post** in the rocket's frame?

A. $(x'_{post}, t'_{post}) = (33 \text{ km}, -46\ \mu\text{s})$ **B.** $(x'_{post}, t'_{post}) = (30 \text{ km}, -22\ \mu\text{s})$ **C.** $(x'_{post}, t'_{post}) = (29 \text{ km}, 0\ \mu\text{s})$
D. $(x'_{post}, t'_{post}) = (28 \text{ km}, 20\ \mu\text{s})$ **E.** $(x'_{post}, t'_{post}) = (29 \text{ km}, 40\ \mu\text{s})$

3) According to observers in the frame of the rocket, which of these events occurred first, and by how much?

A. tree strike occurs before post strike by 10 μs **B.** post strike occurs before tree strike by 44 μs
C. post strike occurs before tree strike by 31 μs **D.** tree strike occurs before post strike by 20 μs
E. post strike occurs before tree strike by 58 μs

4) An asteroid is heading towards Earth from the star Proxima Centauri with a speed relative to Earth of 0.3*c*. To an observer travelling away from Earth towards Proxima Centauri at speed 0.4*c* what speed does the asteroid have in their frame?

A. 0.96*c* **B.** 0.92*c* **C.** 0.85*c* **D.** 0.75*c* **E.** 0.63*c*

5) A particle of mass *m* is moving along the *x*-axis with velocity +*v* and collides *perfectly inelastically* with a particle of mass *m*/2 moving along the *x*-axis with velocity –*v*. By using appropriate conservation laws, what is the mass of the final particle, m_f?

A. $m_f = \frac{3m}{2}\sqrt{1-v^2/c^2}$ **B.** $m_f = \frac{m}{2}\frac{\sqrt{18-v^2/c^2}}{\sqrt{2-v^2/c^2}}$ **C.** $m_f = \frac{3m}{2}\frac{\sqrt{2-v^2/c^2}}{\sqrt{2-v^2/c^2}}$ **D.** $m_f = \frac{m}{2}\frac{\sqrt{9-v^2/c^2}}{\sqrt{1-v^2/c^2}}$ **E.** $m_f = \frac{m}{2}\frac{\sqrt{1-2v^2/c^2}}{\sqrt{1-v^2/c^2}}$

Qu's 6 & 7) Light of wavelength 446 nm is incident on a metal electrode in a demonstration of the photoelectric effect. An opposing electrical potential difference is established between this electrode and another electrode. The current of photoelectrons is stopped when the potential difference is 1.1 V.

6) What is the work function of the metal?

A. 1.5 eV **B.** 1.7 eV **C.** 1.9 eV **D.** 2.1 eV **E.** 2.4 eV

7) Using a reasonably-accurate value for the answer from the previous question, which of the following gives an approximate criterion for light that will eject electrons from this metal?

A. $\lambda \le 590$ nm **B.** $\lambda \le 670$ nm **C.** $\lambda \le 740$ nm **D.** $\lambda \le 520$ nm **E.** $\lambda \le 440$ nm

8) An electron travelling in a large region of space with speed $v << c$ is represented by the wave function $\Psi(x,t) = A\,\mathrm{Exp}\left[i\left(5.34\times10^{9}x - 1.65\times10^{15}t\right)\right]$. What is *v*?

A. 6.2×10^5 m/s **B.** 6.0×10^5 m/s **C.** 5.7×10^5 m/s **D.** 5.5×10^5 m/s **E.** 5.3×10^5 m/s

PART II – Answer all questions

9) According to Bob on Earth it is 30 ly to Planet X. Anna has just passed Earth heading towards Planet X, moving at constant speed *v* in a spaceship. When Anna passes Planet X she is 30 years older than when she passed Earth. Showing your working, find speed *v*.

10. a) Write down the mathematical expression for the *spectral energy density* emitted from a blackbody.
b) Sketch this expression, clearly showing how the shape of the sketched function connects with mathematical aspects of the expression.
c) What simplified mathematical expression of frequency does the spectral energy density approach at very low frequencies?
d) What is the total electromagnetic energy with frequency between 5×10^{14} Hz and 5.05×10^{14} Hz within a $1\ \mathrm{m}^3$ volume inside a 6000 K blackbody cavity?

11. a) Determine whether or not the wave function $y(x,t)=x^2+v^2t^2$ satisfies the 1-dimensional *classical wave equation* for non-dissipative waves travelling at speed *v*: $v^2\dfrac{\partial^2 y(x,t)}{\partial x^2}=\dfrac{\partial^2 y(x,t)}{\partial t^2}$. Show your working.

b) Determine whether or not the wave function $\Psi(x,t)=A\cos(kx-\omega t)$ satisfies the 1-dimensional *Schrödinger equation* for a free particle of mass *m*. Show your working.