Year 12 Physics	TEST # 6 – Standard Model	2022

NAME: SOLUTIONS

Total Marks: 35 *Time Allowed: 45 minutes*

(Formula sheet and scientific calculator permitted)

Question 1 **(3 marks)**

Calculate in joules the energy lost when a top quark decays to a charm quark.

$\Delta m = (173{\cdot}07 - 1{\cdot}275)\ GeV/c^2$ ✓

$\therefore \Delta E = \Delta m\, c^2$

$= (173{\cdot}07 - 1{\cdot}275)\ GeV$ ✓

$= 171{\cdot}795 \times 10^9 \times 1{\cdot}6 \times 10^{-19}\ J$

$\approx \underline{2{\cdot}75 \times 10^{-8}\ J}$ ✓

3

Question 2 **(4 marks)**

State Y (yes) or N (no) to indicate which of the four fundamental forces affect(s) anti-neutrinos:

Force	YES/NO
Electromagnetism	N ✓
Gravity	Y ✓
Weak nuclear	Y ✓
Strong nuclear	N ✓

4

7

Question 3 **(7 marks)**

The meson $u\bar{s}$ is called a *kaon* (or K^+) particle. This particle decays according to the following partially complete equation:

$$K^+ \rightarrow 2\pi^+ + \ldots\ldots$$

where π^+ (pion positive) is the meson $u\bar{d}$.

(a) Determine the charge and baryon number of the missing particle. [2]

Charge : $+1 \rightarrow +2 + ?$

$\therefore$ Charge $= \underline{-1}$ ✓

2

Baryon no : $(\frac{1}{3}) + (-\frac{1}{3}) \rightarrow 2 \times (\frac{1}{3} + (-\frac{1}{3})) + ?$

$0 \rightarrow 0 + ?$

$\therefore$ Baryon no. $= \underline{0}$ ✓

(b) Complete the table below to classify the kaon positive particle. Answer Y (yes) or N (no) in each case: [4]

Category	YES/NO
Baryon	N ✓
Hadron	Y ✓
Fermion	N ✓
Boson	Y ✓

4

(c) Write down the quark code for the antiparticle (K^-) of the kaon particle. [1]

$\bar{u}s$ ✓

1

7

Question 4 **(5 marks)**

The *Compton wavelength* λ of a particle is given by $\lambda = \frac{h}{mc}$ and the *Compton frequency* f is given by $f = \frac{mc^2}{h}$, where h is Planck's constant and c is the speed of light.

If gravitons have mass, it is believed that their Compton wavelength is at least 1.60 light-years.

Use the above information to determine

(a) the maximum mass of a graviton in kg, [3]

$$\lambda = \frac{h}{mc}$$

$$1 \cdot 6 \times 9 \cdot 46 \times 10^{15} = \frac{6 \cdot 63 \times 10^{-34}}{m \times 3 \times 10^{8}}$$ ✓✓

$$\therefore m \simeq \underline{1 \cdot 46 \times 10^{-58} \text{ kg}}$$ ✓

3

(b) the maximum Compton frequency of a graviton in Hz. [2]

$$f = \frac{mc^2}{h}$$

$$= \frac{1 \cdot 46 \times 10^{-58} \times (3 \times 10^{8})^2}{6 \cdot 63 \times 10^{-34}}$$ ✓

$$\simeq \underline{1 \cdot 98 \times 10^{-8} \text{ Hz}}$$ ✓

2

5

Question 5 **(4 marks)**

Show that the following equation obeys lepton number conservation for all the appropriate lepton number types:

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu \, .$$

L_e $LHS = 0$ ✓

$RHS = 1 + (-1) + 0 = 0 = LHS$ ✓

L_μ $LHS = 1$ ✓

$RHS = 0 + 0 + 1 = 1 = LHS$ ✓

4

Question 6 **(4 marks)**

With reference to dark energy and dark matter, explain why the Big Crunch theory of the universe's fate is now thought unlikely.

- Dark energy and dark matter have been theorized to explain the unexpectedly high acceleration of the universe's expansion. ✓
- Most (about 95%) of the universe's energy + matter is dark, and the majority of that is dark energy. ✓
- Hence the universe's KE exceeds its PE and so the universe will continue to expand indefinitely. ✓
- Hence the Big Crunch, which predicts that the expansion of the universe will slow down + eventually reverse (if PE > KE) will not occur. ✓

4

8

Question 7 **(8 marks)**

(a) Explain the observed phenomenon of red shift, using the current scientific thinking that space itself is expanding. [3]

Red shift is the observed increase in wavelength (i.e. shift towards the red end of the visible spectrum) of visible light coming from distant galaxies. ✓

Since space is expanding, successive wavefronts will be further apart than normal ✓, hence moving the light towards the red end of the spectrum. ✓

3

(b) Use Hubble's Law to determine the recessional speed of the galaxy GN-z11, which was discovered in the Ursa Major constellation in 2015 at a distance of 9.80 billion parsecs. Use H_o = 67.4 km s^{-1} MPc^{-1} and give your answer in terms of c, the speed of light. [3]

$$v = H_o d$$
$$= 67.4 \times 9.8 \times 10^3 \text{ km s}^{-1} ✓$$
$$= 660\,520 \text{ km s}^{-1} ✓$$
$$= \frac{6.60520 \times 10^8 \text{ m s}^{-1}}{3 \times 10^8 \text{ m s}^{-1}} c$$
$$\approx \underline{2.20c} ✓$$

3

(c) Does your answer in part (b) conflict with Einstein's universal speed limit? (Hint: refer to part (a).) [2]

NO. ✓ The galaxy itself is not moving at this speed. It is the stretching of space in the region of the galaxy that is occurring at that speed. ✓

- End of Questions -

2

8