Dawson College
203-SN3 Waves and Modern Physics
Sample Final Exam

This exam is divided into two parts:

Part I: Problems (*40 marks in total*) Solve all six problems. Show all of your work, clearly and in order, to receive full marks. If you use a formula not given on the formula sheet, a derivation must be shown.

Part II: Multiple Choice Questions (*2 marks each*) Answer all thirty questions. Circle the best response from the choices given. If your final selection is unclear you will not be given the marks. No marks will be awarded for diagrams, calculations, or reasoning.

Additional instructions:

1. The time allotted for this examination is three hours.
2. Answer directly on the question sheet. If you need extra room, you may use the back of
3. If a "bubble sheet" form is provided for the multiple choice questions, use a pencil to fill it in, and please fill all blanks at the top of the bubble sheet.
4. Use v_{sound} = 343 m/s.
5. When finished, return this entire package and the formula sheet to your instructor.

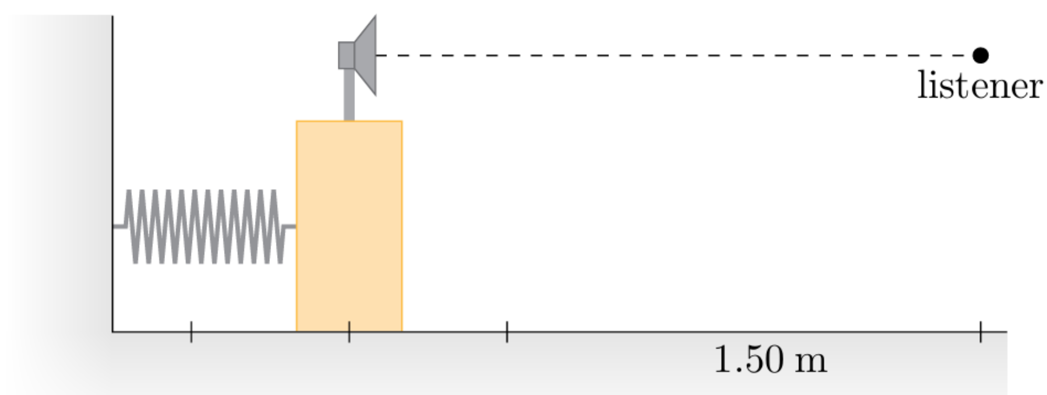
Good luck!

P1	P2	P3	P4	P5	P6	MC	Total /100

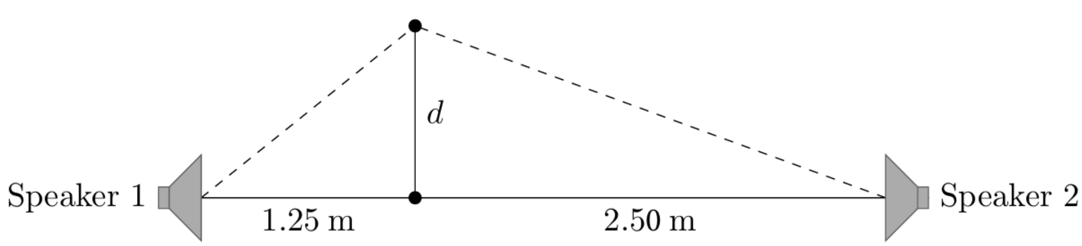
Part I: Problems (40 points in total)

1. (7 points) A transverse wave with amplitude 2.00 cm travels along a string under 50.0 N tension. Crest-to-crest distance is 70.0 cm and a fixed point oscillates 200 cycles in 12.0 s.
   (a) Find wave speed and max transverse speed of a point on the string.
   (b) Explain difference between the speeds found in part (a).
   (c) What is the mass per unit length of the string?
   (d) Find power transmitted.

2. (8 points) A block with a sound source oscillates horizontally with amplitude 50.0 cm and max speed 20.0 m/s. Spring constant is 600 N/m. (a) What is the mass of the block (including the sound source). (b) For 440 Hz source at rest, find lowest and highest frequencies heard by the listener. (c) Given geometry and 60.0 dB at closest approach to the listener, find minimum intensity heard.



3. (7 points) Two speakers emit equal-amplitude waves at 343 Hz. Listener initially stands 1.25 m from speaker 1 and 2.50 m from speaker 2.



(a) What is the phase difference at the initial position of the listener? Does this correspond to a maximum constructive, maximum destructive, or other interference? (b) Walking perpendicular to the line connecting the two speakers, what would then they next experience? Maximum constructive or maximum destructive interference? Defend your answer. (c) Find distance d to first such interference found in part b.

4. (5 points) An electron with a speed of $2.135 \times 10^6 m/s$ collides with hydrogen atom (initially in ground state) exciting the atom to the highest possible energy level. The atom, then undergoes a transition with $\Delta n = 2$. What is the wavelength of the photon emitted in the transition? Assume hydrogen atom recoil is negligible and the electron transfers energy only to excite the atom. No relativistic effects are considered.

5. (7 points) Hydrogen Balmer visible lines: Given λ_Hα = 656.3 nm, λ_Hβ = 486.1 nm, λ_Hγ = 434.1 nm, λ_Hδ = 410.2 nm observed with a diffraction grating. (a) Second-order Hα is observed at 41.018°. What is the numbers of lines/mm of the grating? (b) Find the angular separation of Hγ and Hδ in first order (Keep at least 3 decimal places in your work). (c) How many complete orders on one side? (d) Are there any overlapping orders? If yes which ones?

6. (6 points) Plutonium-239 decays by α-emission with half-life 24120 years. Assume we have an 0.7939109 kg sample at t=0: (a) How many atoms are initially in the sample? (b) What is the initial activity of the sample in Bq? (c) How many years does it take for the activity to decrease to 0.100 Bq? (Use 1 year = 365.25 days.). (d) What is the total energy released between t = 0 and the time found in part (c)? (Use the masses: $m_{Pu} = 239.052157\ u, m_u = 235.043924\ u\ and\ m_\alpha = 4.002602\ u$).

Part II: Multiple Choice Questions (2 marks each)

1. A mass on an ideal spring vibrates with period T. If you double the mass, how must you change the force constant of the spring to achieve a period 2T?

(a) Decrease by factor of 4.

(b) Increase by factor of $\sqrt{2}$.

(c) Decrease by factor of $\sqrt{2}$.

(d) Decrease by factor of 2.

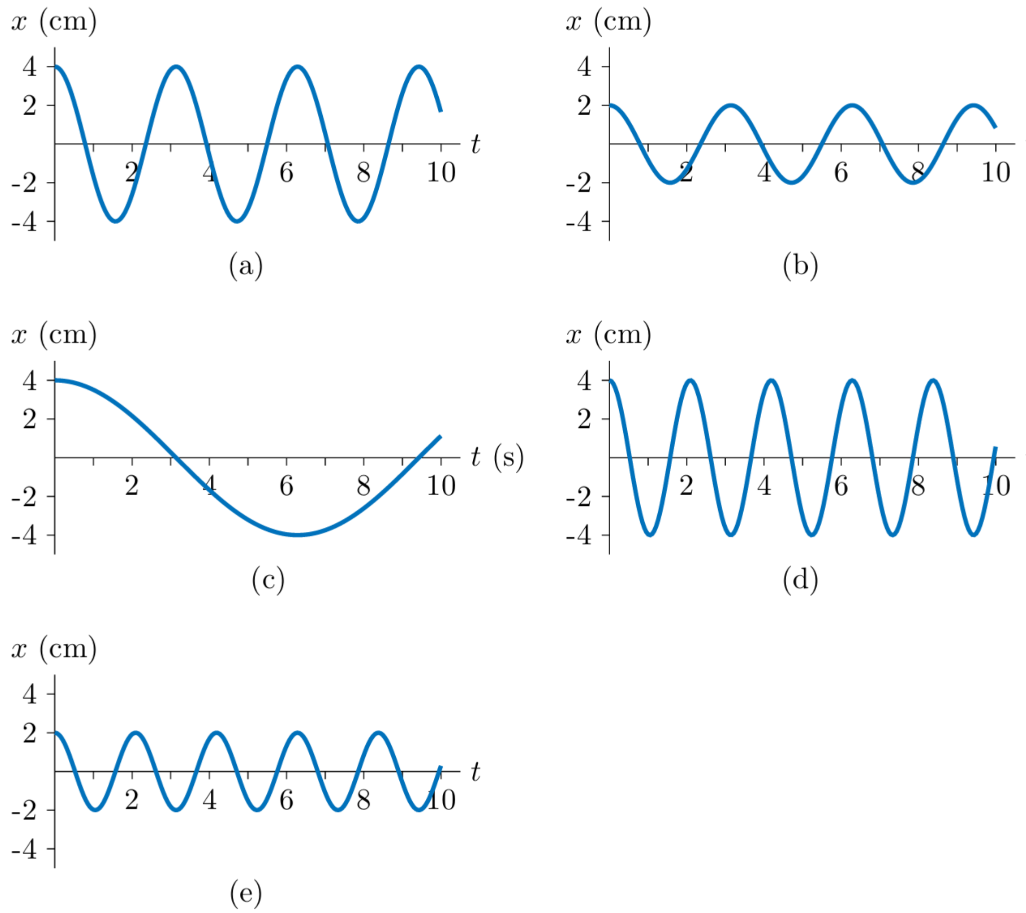
(e) Increase by factor of 2.

(f) Increase by factor of 4.

(g) Keep k unchanged.

(h) Decrease by factor of 8.

2. Which graph represents SHM with amplitude 4 cm and angular frequency 2 rad/s?



3. Which statement is false?

(a) The speed of a wave and the speed of the vibrating particles that constitute the wave are different entities.

(b) For a transverse wave the particle motion is perpendicular to the direction of propagation of the wave.

(c) A wave in which the particle motion is parallel to the direction of propagation of the wave is called a longitudinal wave.

(d) Waves transport energy and matter from one region to another.

(e) Not all waves are mechanical waves.
(f) All mechanical waves require a medium to move in.

(g) Standing waves store energy.

(h) Particles in waves oscillate around an equilibrium position.

4. Four travelling waves are given; which two have the same wave speed?

$$\begin{aligned}
\text{I:}\quad & y(x,t) = (0.12\ \mathrm{m}) \cos\left[(3.0\ \mathrm{rad/m})x + (2.0\ \mathrm{rad/s})t\right] \\
\text{II:}\quad & y(x,t) = (0.15\ \mathrm{m}) \sin\left[(6.0\ \mathrm{rad/m})x - (3.0\ \mathrm{rad/s})t\right] \\
\text{III:}\quad & y(x,t) = (0.23\ \mathrm{m}) \cos\left[(3.0\ \mathrm{rad/m})x + (6.0\ \mathrm{rad/s})t\right] \\
\text{IV:}\quad & y(x,t) = (0.29\ \mathrm{m}) \sin\left[(1.5\ \mathrm{rad/m})x + (1.0\ \mathrm{rad/s})t\right]
\end{aligned}$$

(a) I and III

(b) I and II

(c) I and IV

(d) III and IV

(e) II and III

(f) II and IV

(g) All have same speed

(h) None

5. An open–open tube (0.46 m) supports a standing wave of 1114 Hz. Distance from center of the tube to nearest displacement antinode is closest to?

(a) 0.15 m

(b) 0.12 m

(c) 0.46 m

(d) 0.038 m

(e) Antinode is at the center

(f) 0.23 m

(g) 0.31 m

(h) 0.077 m

6. A 137 cm long wire that is fixed at both ends has a fundamental frequency of 87.5 Hz. The tension in the wire is then changed so that the fundamental frequency becomes 175.0 Hz. The ratio of the new fundamental wavelength to the old fundamental wavelength ($\frac{\lambda_{new}}{\lambda_{old}}$) is,

(a) $\sqrt{3}$

(b) $\sqrt{2}$

(c) 2

(d) $1/\sqrt{2}$

(e) 1/2

(f) 1

(g) 3

(h) 1/3

7. A Car is on a road parallel to a railroad track and right beside it. The car is traveling east at 30 m/s while a train traveling west at 50 m/s is approaching it. If the Car honks its horn at a frequency of 1.00 kHz. What is the wavelength of the sound perceived by person riding on the train?

(a) 0.235 m

(b) 0.275 m

(c) 0.294 m

(d) 0.400 m

(e) 0.344 m

(f) 0.365 m

(g) 0.313 m

(h) 0.290 m

8. Tripling distance from a point sound source changes intensity by what multiple?

(a) 3

(b) 1/3

(c) 1

(d) 9

(e) 1/9

(f) 1/6

(g) 1/27

(h) 1/18

9. At a distance of 2.00 m from a point source of a sound, the sound intensity level is 80.0 dB. At a distance of 4.00 m from the source, what is the sound intensity level ?

(a) 74.0 dB

(b) 77.0 dB

(c) 60.0 dB

(d) 20.0 dB

(e) 40.0 dB

(f) 68.0 dB

(g) 86.0 dB

(h) 70.0 dB

10. Rank electromagnetic waves longest to shortest wavelength:

(a) radio, infrared, microwaves, UV, visible, X-rays, gamma

(b) radio, microwaves, visible, X-rays, infrared, UV, gamma

(c) radio, infrared, X-rays, microwaves, UV, visible, gamma

(d) radio, UV, X-rays, microwaves, infrared, visible, gamma

(e) radio, microwaves, infrared, visible, UV, X-rays, gamma

(f) gamma, X-rays, UV, visible, infrared, microwaves, radio

(g) infrared, radio, microwaves, visible, UV, X-rays, gamma

(h) radio, microwaves, infrared, UV, visible, gamma, X-rays

11. In the simple energy-balance view, Earth warms when the net radiative forcing is positive. Which change most directly produces a positive forcing?

(a) Decrease in planetary albedo from 0.30 to 0.28

(b) Increase in aerosol loading that reflects sunlight

(c) Reduction of greenhouse gas concentrations

(d) Decrease in solar constant from 1361 to 1358 W/m^2

(e) Expansion of sea-ice extent

(f) Increase in CO_2 from 278 ppm to 420 ppm

(g) Strengthening trade winds enhancing upwelling

(h) Deep-ocean heat uptake increasing

12. In the multi-layer greenhouse model, why does surface temperature rise rapidly as total atmospheric absorption $\varepsilon \to 1$?

(a) Because incoming solar flux Q increases without bound

(b) Because σ decreases as temperature rises

(c) Because the logarithm in $T_s \propto [\ln(1/(1-\varepsilon))]^{1/4}$ grows large

(d) Because Kirchhoff's law fails at high ε

(e) Because convection ceases at high ε

(f) Because clouds become perfectly transparent

(g) Because emissivity of the surface drops to zero

(h) Because Wien's law shifts peak to visible

13. Double-slit: increasing slit separation d causes what change on screen?

(a) Minima and maxima stay put

(b) Maxima stay put

(c) Minima stay put

(d) Minima get closer

(e) Maxima get further apart

(f) Fringes disappear

(g) Central maximum narrows

(h) Pattern rotates

14. In a double-slit experiment the central bright fringe is at $\theta=0°$and the next bright is at $\theta=15°$. If I_0 is central intensity, intensity of next bright is?

(a) $I_0 \cos 15°$

(b) I_0

(c) $I_0 \cos^2 15°$

(d) $I_0/\sqrt{2}$

(e) $I_0/2$

(f) $2I_0$

(g) $0.5\ I_0 \cos^2 15°$

(h) Depends on slit width

15. A grating has 450 lines/mm. Highest order containing entire visible (400–700 nm)?

(a) m=2

(b) m=3

(c) m=4

(d) m=5

(e) m=6

(f) m=1

(g) No complete order

(h) m=7

16. If radar dish diameter is doubled (small-angle), resolving power becomes…

(a) 1/4 of original

(b) 1/2 of original

(c) Double

(d) Quadruple

(e) Unchanged unless focal length changes

(f) Eight times

(g) $\sqrt{2}$ times

(h) $1/\sqrt{2}$ times

17. A Laser pulse of 25 ms duration has an energy of 1.2 J at 463 nm wavelength. How many photons are emitted per pulse?

(a) 3.4×10^{19}

(b) 1.1×10^{17}

(c) 2.2×10^{17}

(d) 6.9×10^{19}

(e) 2.8×10^{18}

(f) 1.2×10^{20}

(g) 4.5×10^{18}

(h) 9.0×10^{16}

18. Photoelectric effect: If intensity increases (frequency fixed above threshold), what happens to ejection rate and max kinetic energy of photo electrons?

(a) Same; same

(b) Greater; same

(c) Same; greater

(d) Greater; greater

(e) No ejection

(f) Lower; same

(g) Greater; lower

(h) Same; lower

19. Blackbody at T has peak at λ. At 2T, peak is…

(a) 16λ

(b) 8λ

(c) λ

(d) $\lambda/16$

(e) 2λ

(f) $\lambda/4$

(g) 4λ

(h) $\lambda/2$

20. Hydrogen emission at 434.0 nm corresponds to transition to n=2 from which n?

(a) n=3

(b) n=4

(c) n=8

(d) n=6

(e) n=1

(f) n=7

(g) n=5

(h) n=9

21. Doubling a planet's radius with same temperature changes total infrared power emitted by…

(a) No change

(b) Factor 2

(c) Factor 4π

(d) Factor 8

(e) Factor 1/2

(f) Factor $\sqrt{2}$

(g) Factor 4

(h) Depends on albedo

22. Earth's equilibrium temperature (no greenhouse): Which parameter decreases T_{eq}, if increased?

(a) Solar constant I

(b) Planetary albedo A

(c) Stefan–Boltzmann σ

(d) Emissivity ε

(e) Planet radius

(f) Atmospheric absorption ε

(g) Day length

(h) Axial tilt

23. In the one-layer greenhouse model, if ε=0.71 and T_{eq}= 254.6 K, the surface temperature T_s is approximately…

(a) 254.6 K

(b) 260 K

(c) 270 K

(d) 284 K

(e) 300 K

(f) 238.9 K

(g) 214 K

(h) 294 K

24. If Earth's albedo rises from 0.30 to 0.31 (everything else fixed), the change in equilibrium temperature is…

(a) Increase ~1 K

(b) Decrease ~1 K

(c) Increase ~10 K

(d) No change

(e) Decrease ~0.3 K

(f) Increase ~0.3 K

(g) Decrease ~6 K

(h) Increase ~6 K

25. Unpolarized light is passed through three successive Polaroid filters, each with its transmission axis at 45.0° to the preceding filter. What percentage of light gets through?

A) 100%
B) 0%
C) 50.0%
D) 85.3%
E) 25.0%
F) 33.3%
G) 20.0%
H) 12.5%

26. A rod is placed between a hot object and a cold object. The rod has length ℓ, cross sectional area A and thermal conductivity k. The temperature difference between the two objects is shown by ΔT. Which of the following changes leaves the rate of conductive heat transfer unchanged?

(a) Double k, halve A

(b) Double A, double ℓ

(c) Double ΔT, halve ℓ

(d) Halve k, double ΔT

(e) Halve ℓ, halve ΔT

(f) Double k and ℓ

(g) Halve A and k

(h) Double A and halve ℓ

27. A filament radiates 60 W from area 3.14×10^{-3} m^2 at 20°C ambient. Approximate filament temperature (°C)?

(a) ~300 °C

(b) ~800 °C

(c) ~1200 °C

(d) ~1750 °C

(e) ~2000 °C

(f) ~100 °C

(g) ~500 °C

(h) ~2500 °C

28. If CO_2 rises from 278 ppm to 834 ppm, the radiative force, is approximately...

(a) 2.20 W/m^2

(b) 3.50 W/m^2

(c) 5.88 W/m^2

(d) 1.00 W/m^2

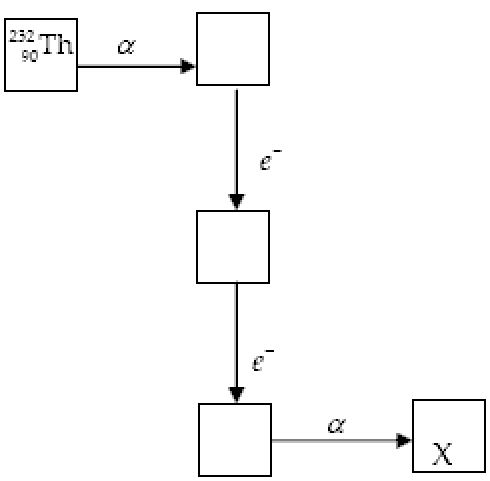
(e) 0.55 W/m^2

(f) 7.00 W/m^2

(g) 4.40 W/m^2

(h) 2.70 W/m^2

29. The chart below shows part of the radioactive series beginning with the isotope $^{232}_{90}Th$. The isotope marked with an X is



(a) $^{222}_{88}Ra$.
(b) $^{224}_{88}Ra$.
(c) $^{228}_{89}Ac$.
(d) $^{224}_{90}Th$.
(e) $^{228}_{90}Th$.

30. Light of unknown monochromatic wavelength are shown on a cathode of a photoelectric device having the work function of 1.00 eV. The stopping potential for the released photoelectrons are measured to be1.00 volt. The wavelength (in nm) of these unknown photons is closest,

a) 310
b) 476
c) 650
d) 402
e) 562
f) 620
g) 598
h) 300

Solutions part 1:

Question 1:

given:

$A = 2.00\text{cm}$, $T = 50.0\text{N}$, $\lambda = 70.0\text{cm}$, $f = \frac{200}{12.0} = 16.\dot{6}\text{ Hz}$

a) $V_{wave} = \lambda f = (70.0)(16.\dot{6}) = 1167\text{cm/s} = \boxed{11.7\text{ m/s}}$

$V_{trans,max} = A\omega = A(2\pi f) = (2.00)(2\pi)(16.\dot{6}) = 209.4\frac{\text{cm}}{\text{s}} = \boxed{2.09\text{ m/s}}$

b) V_{wave} is the speed of the disturbance or the crests of the wave and it depends only on the medium - not the wave.

$V_{trans,max}$ is the maximum speed of the medium over any cycle and it depends on the wave, not the medium.

Note: if the question asked about velocity then it would be important to add that the direction of V_{wave} and $V_{trans,max}$ are perpendicular to each other.

c) $v_{wave} = \lambda f$ and $v_{wave} = \sqrt{\frac{T}{\mu}}$ (for a string)

$$\therefore \quad \mu = \frac{T}{\lambda^2 f^2} = \frac{50.0\,N}{(0.70\,m)^2 (16.\dot{6}\,s^{-1})^2} = \boxed{0.367\,\frac{kg}{m}}$$

since $N = \frac{kg\,m}{s^2}$ we need to convert λ to m

d) $P = \frac{1}{2}\mu v_{wave} \omega^2 A^2 = \frac{1}{2}\mu v_{wave} (2\pi f)^2 A^2$

don't use v_{trans} here!

$$P = \frac{1}{2}\left(0.3673\,\frac{kg}{m}\right)\left(11.67\,\frac{m}{s}\right) 4\pi^2 (16.\dot{6}\,s^{-1})^2 (0.020\,m)^2$$

$$= \boxed{9.40\,W}$$

$1\,W = 1\,J/s = 1\,\frac{kg\,m^2}{s^3}$

Question 2:

The lowest freq will occur when the speaker is moving away at max. speed:

$$f_{lowest} = 440\text{Hz}\left(\frac{343}{343+20}\right) = \boxed{416\text{ Hz}}$$

a) $V_{max} = A\omega$ and $\omega = \sqrt{\frac{k}{m}}$

$\therefore V_{max}^2 = \frac{A^2 k}{m}$

or $m = \frac{A^2 k}{V_{max}^2} = \frac{(0.50\text{m})^2(600\text{ N/m})}{(20\text{ m/s})^2} = \boxed{0.375\text{ kg}}$

check units: $\frac{m^2 \cdot N/m}{m^2/s^2} = \frac{(kg\,m/s^2)/m}{/s^2} = kg$ ✓

b) The highest frequency will occur when speaker is moving towards the listener with max. speed:

$$f_{Highest} = 440\text{Hz}\left(\frac{343}{343-20}\right) = \boxed{467\text{ Hz}}$$

The lowest freq will occur when the speaker is moving away at max. speed:

$$f_{lowest} = 440\text{Hz}\left(\frac{343}{343+20}\right) = \boxed{416\text{ Hz}}$$

c) at $r = 1.50\,m$ from the listener:

$$\beta = 60\,dB = 10 \log\left(\frac{I_{1.5m}}{1\times10^{-12}}\right)$$

$$\therefore I_{1.5m} = \left[\log^{-1}\left(\frac{60}{10}\right)\right](1\times10^{-12}) = 1\times10^{-6}\ W/m^2$$

$\therefore$ at $r = 2.50m$ $(1.5m + 2A)$

$$\frac{I_{1.5m}}{I_{2.5m}} = \frac{(2.5m)^2}{(1.5m)^2}$$

$$\therefore I_{2.5m} = \left(1\times10^{-6}\,W/m^2\right)\left(\frac{1.5^2}{2.5^2}\right) = 0.36\times10^{-6}\,W/m^2$$

$$\therefore \beta_{2.5m} = 10 \log\left(\frac{0.36\times10^{-6}}{1\times10^{-12}}\right) = \boxed{55.6\,dB}$$

Question 3:

given: $f = 343\,Hz$
assume: $V_{sound} = 343\,m/s$
$\Big\}\ \therefore\ \lambda = \frac{v}{f} = 1.00\,m$

and $\Delta\phi_{sources} = 0$

a) $\Delta\phi = \frac{2\pi}{\lambda}\Delta r + \Delta\phi_{sources}$

$\Delta r = 1.25\,m$

$= \frac{2\pi}{1.00}(2.50 - 1.25) + 0$

$= 2.50\pi + 0 = 2.50\pi$

get max. const. int. when $\Delta\phi = 0, 2\pi, 4\pi \ldots$
get complete dest. int when $\Delta\phi = \pi, 3\pi, \ldots$

$\therefore$ The sound waves are neither max. const. nor max. dest. int. but are instead in between.

b) to get destructive interference, need $\Delta\phi = \pi, 3\pi, 5\pi, 7\pi \ldots$ ($\Delta r = \frac{1}{2}\lambda, \frac{3}{2}\lambda \ldots$)

and for const. int. $\Delta\phi = 0, 2\pi, 4\pi \ldots$ ($\Delta r = 0, \lambda, 2\lambda \ldots$)

and since $\Delta r = 1.25\lambda$ from part a), the next possible value of Δr corresponds to

$$\Delta r = \lambda \longrightarrow \text{constructive}$$

$$\text{or } \Delta r = 1.5\lambda \longrightarrow \text{destructive}$$

to figure out which one it is, imagine what happens as $d \to \infty$:

As $d \to \infty$ $\Delta r \to 0$ $\therefore$ Δr decreases as the listener walks

So, as the listener walks, they would next experience **constructive interference.**

c) Now find d that corresponds to $\Delta r = \lambda = 1.00\text{m}$

$$\Delta r = \lambda \,(1.00\text{m}) = \sqrt{2.50^2 + d^2} - \sqrt{1.25^2 + d^2} = 1.00\text{m}$$

now, we solve for d.

First we rearrange:

$$1.00 + \sqrt{1.25^2 + d^2} = \sqrt{2.50^2 + d^2}$$

then we square both sides:

$$1.00^2 + \left(\sqrt{1.25^2 + d^2}\right)^2 + 2(1)\sqrt{1.25^2 + d^2} = \left(\sqrt{2.50^2 + d^2}\right)^2$$

$$1.00^2 + 1.25^2 + d^2 + 2\sqrt{1.25^2 + d^2} = 2.50^2 + d^2$$

Finally, we collect, rearrange and solve:

$$2.5625 + 2\sqrt{1.25^2 + d^2} = 6.25$$

$$1.25^2 + d^2 = (1.84375)^2$$

$$\boxed{d = 1.36\text{ m}}$$

Question 4:

Using $K.E. = \frac{1}{2}mv^2$ you can calculate the kinetic energy if the incoming electron:

$$K.E. = \frac{1}{2(9.11\ \times 9{,}11 \times 10^{-31})(2.135 \times 10^{6})} = 2.07627 \times .10^{-18} J = 12.960\ eV$$

From $E_n = \frac{-13.606\ eV}{n^2}$, you can easily find that this energy is enough to excite the H atom (highest possible) to the level n = 4. Then $\Delta n = 2\ transition\ would\ be\ from\ E_4 to\ E_2$.

$$\Delta E = E_4 - E_2 = 2.551\ eV$$

Now you can easily calculate the wavelength of the emitted photon by this transition:

$\lambda = \frac{hc}{\Delta E} = \frac{1240.0\ eV\ nm}{2.551\ eV} = 486\ nm\ (in\ visible\ range)$.

Question 5:

a) $d \sin\theta = m\lambda$ for a diffraction grating

$\therefore\ d = \frac{(2)\ 656.3\ nm}{\sin 41.018°} = 2000.0\ nm$

$\therefore\ N = \frac{1}{d} = 500{,}000\ lines/m = \boxed{500\ lines/mm}$

b) for H_γ: $d \sin\theta = m\lambda$ ($d \to 2000 \times 10^{-9}\ m$, $m \to 1$, $\lambda \to 434.1$)

$\therefore\ \theta_{1\gamma} = \sin^{-1}\left(\frac{(1)(434.1)}{2000}\right) = 12.5358°$

and for H_δ: $\theta_{1\delta} = \sin^{-1}\left(\frac{(1)\ 410.2}{2000}\right) = 11.8353°$

$\therefore\ \Delta\theta = 12.536° - 11.835° = \boxed{0.700°}$

c) For complete orders use highest λ : $H_\alpha = 656.3\,nm$

$\therefore \quad d \sin 90° = m_{max} \lambda_{max}$

$\therefore \quad m_{max} = \frac{d}{\lambda_{max}} = \frac{2000\,nm}{656.3} = 3.047$

$\therefore$ **3 complete orders are visible**

d) 1st order : $\theta_{min} = \sin^{-1}\left(\frac{(1)656.3}{2000}\right) = 11.83°$

$\theta_{max} = \sin^{-1}\left(\frac{(1)410.2}{2000}\right) = 19.16°$ — no overlap

2nd order : $\theta_{min,2} = 24.21°$

$\theta_{max,2} = 41.02°$ — These overlap

3rd order : $\theta_{min,3} = 37.97°$

$\theta_{max,3} = 79.88°$ — These overlap.

4th order : $\theta_{min,4} = 55.12°$

$\theta_{max,4} \rightarrow$ does not exist.

$\therefore$ **There are 2 overlapping orders : $n = 2$ and 3 as well as $n = 3$ and 4.**

Question 6:

from given data in question

a) $m_{Pu} = 239.052157\,u$

$= 3.969554 \times 10^{-25}\ kg/Pu$

$\therefore N_0 = \dfrac{0.793909\ kg}{3.969554 \times 10^{-25}\ kg/Pu}$

$= \boxed{2.00000 \times 10^{24}\ Pu}$

From Formula Sheet:

$B = [Zm_H + Nm_n - m_{atom}]c^2$

$\frac{dN}{dt} = -\frac{1}{\tau}N,\ N = N_0 e^{-t/\tau},\ N = N_0(\frac{1}{2})^{t/t_{1/2}}$

$r = \frac{1}{\tau} = \frac{\ln 2}{t_{1/2}}$

$\frac{dR}{dt} = -\frac{1}{\tau}R,\ R = R_0 e^{-t/\tau},\ R = R_0(\frac{1}{2})^{t/t_{1/2}}$

$R = -\frac{dN}{dt} = rN,\ \ R_0 = rN_0$

Constants

u = 1.660 539×10^{-27} kg = 931.494 MeV/c^2
m_p = 1.673×10^{-27} kg = 1.007 276 u
m_n = 1.675×10^{-27} kg = 1.008 665 u
m_e = 9.11×10^{-31} kg = 0.000 549 u
m_H = 1.007 825 u

1Ci = 3.7×10^{10} Bq = 3.7×10^{10} decay/s

b) $R_0 = rN_0$

where $r = \dfrac{\ln 2}{t_{1/2}}$

$\therefore r = \dfrac{\ln 2}{24120\,yrs\left(\frac{365.25\,d}{yr}\right)\left(\frac{24\,h}{d}\right)\left(\frac{3600\,s}{h}\right)}$

$= 0.9106347 \times 10^{-12}$

$\therefore R_0 = 1.82127 \times 10^{12}\ decays/s = \boxed{1.82127 \times 10^{12}\ Bq}$

c) $R = R_o \left(\frac{1}{2}\right)^{t/t_{1/2}}$

$\therefore\ 0.100 = 1.821\times10^{12} \left(\frac{1}{2}\right)^{t/24120}$

$\therefore\ 44.05 = \frac{t}{24120\text{yrs}}$

or $t = \boxed{1.06\times10^{6}\text{ years}}$

d) Energy per decay $= \left[m_{Pu} - m_{U} - m_{\alpha}\right]c^2$

$= \left[239.052157u - 235.043924u - 4.002602u\right]c^2$

$= \left[0.005635u\right]c^2 = 0.005635u\left(931.494\ \text{MeV}/c^2\right)c^2$

$= 5.24897\ \text{MeV/decay}$

$= \left(5.24897\times10^{6}\text{eV}\right)\left(1.602\times10^{-19}\text{J}\right)$

$= 0.8409\times10^{-12}\ \text{J/decay}$

Think: Since the vast majority of the nuclei would have decayed after a million years we can say that $N_{decayed} = N_o$

$\therefore$ Total $E = \left(2.000\times10^{24}\text{ decays}\right)\left(0.8409\times10^{-12}\ \text{J/decay}\right)$

$= \boxed{1.682\times10^{12}\text{ J}}$

Answers Part 2 (MCQs):

1. D
2. A
3. D
4. C
5. H
6. F
7. G
8. E
9. A
10. E
11. F
12. C
13. D
14. B
15. B
16. C
17. E
18. B
19. H
20. G
21. G
22. B
23. D
24. B
25. H
26. E
27. D
28. C
29. B
30. F