Exam Papers Practice

Doppler Effect

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Course	HL IB Physics
Section	Wave Behaviour
Topic	Doppler Effect
Difficulty	Medium

To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

1

The correct answer is **C** because:

- The speed of sound is dependent on the medium it is travelling in, therefore the observed speed of sound is v
  - This eliminates options **B** and **D**
- The Doppler equation for a moving source and a stationary observer is:
  - $f' = f\left(\frac{v}{v \pm u_s}\right)$
- Because the train is moving **away** from the observer, the denominator becomes $(v + u_S)$:
  - $f' = f\left(\frac{v}{v + u_s}\right)$
- Substituting the value from the question gives:
  - $f' = f\left(\frac{v}{v + u_s}\right) = f\left(\frac{v}{v + \frac{v}{17}}\right)$
- Simplifying gives:
  - $f' = f\left(\frac{v}{\frac{18v}{17}}\right) = f\left(\frac{17v}{18v}\right)$
  - $f' = f\left(\frac{17}{18}\right) = \frac{17f}{18}$
- This is answer **C**

2

The correct answer is **A** because:

- List the known quantities:
  - Wavelength of hydrogen line, $\lambda = 400 \text{ nm} = 400 \times 10^{-9}$ m
  - Speed of galaxy away from the Earth, $v = 0.2c$
  - Speed of light = c

- The change in observed wavelength, $\Delta\lambda$ can be calculated by:
  - $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
  - $\Delta\lambda = \lambda \times \frac{v}{c} = (400 \times 10^{-9}) \times \frac{0.2c}{c} = (400 \times 10^{-9}) \times 0.2 = 80 \times 10^{-9}$ m
- Since the galaxy is moving **away** from Earth, $\Delta\lambda$ is positive:
  - Change in wavelength, $\lambda' = \lambda + \Delta\lambda = (400 \times 10^{-9}) + (80 \times 10^{-9}) = 480 \times 10^{-9}$ m = 480 nm

B is incorrect as 320 nm is the answer if $\lambda' = \lambda - \Delta\lambda$ is used

C is incorrect as 80 nm is the change in wavelength, $\Delta\lambda$, not the observed wavelength, λ'

D is incorrect as 2000 nm is the change in wavelength obtained if c and v in the equation have been inverted:

- $(400 \times 10^{-9}) \times \frac{c}{0.2c} = \frac{(400 \times 10^{-9})}{0.2} = 2000 \times 10^{-9}$ m

The whole question can be completed without converting λ into m, which makes the maths feel simpler!

3

The correct answer is **B** because:

- The Doppler equation for a moving source is $f' = f\left(\frac{v}{v \pm u_s}\right)$
- As the car is moving **towards** the observer, the denominator becomes $(v - u_s)$
- Substituting $0.2v$ for u_s gives:
  - $f' = f\left(\frac{v}{v - 0.2v}\right) = f\left(\frac{v}{0.8v}\right) = f\left(\frac{1}{0.8}\right) = 1.25f$

A is incorrect as $0.80f$ is found when is used rather than $\frac{f}{0.8}$

C is incorrect as 0.83f is found when + is used in the denominator instead of –

D is incorrect as 1.20f is found when v + u_s is used incorrectly as the numerator, and v as the denominator which is the equation for a moving observer

4

The correct answer is **D** because:

- The speed of a wave is not dependent on the motion of the source or the observer, therefore the observed wave speed is *v*
  - This eliminates options **A** and **C**
- The Doppler equation for a stationary source and a moving observer is $f' = f\left(\frac{v \pm u_o}{v}\right)$
- In this question the observer is moving **towards** the source, so the numerator is ($v + u_O$)
- This means *f'* will be larger than *f*
- Since $f \propto \frac{1}{\lambda}$, an increase in *f* means a decrease in *λ*
  - This means the observed wavelength is less than *λ*
  - Therefore the answer is **D**

5

The correct answer is **C** because:

- The equation for redshift for non-relativistic galaxies is $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
- Rearranging gives $\Delta\lambda = \frac{v\lambda}{c}$
- Substituting in the values from the question gives:
  - $\Delta\lambda = \frac{v\lambda}{c} = \frac{(3.00 \times 10^6) \times (530 \times 10^{-9})}{3.00 \times 10^8}$
- This can be simplified as the two examples of 3.00 cancel to 1, and the powers of 10 can be simplified:
  - $$\Delta\lambda = \frac{v\lambda}{c} = \frac{(1 \times 10^6) \times (530 \times 10^{-9})}{1 \times 10^8} = (1 \times 10^{-2}) \times (530 \times 10^{-9}) = 530 \times 10^{-11}$$

    = 5.3 nm

- Since the galaxy is moving **away**, wavelength will **increase**:
  - $\Delta\lambda = \lambda + \lambda' = 530 + 5.3 = 535.3$ nm
  - This is answer **C**

A is incorrect as $\Delta\lambda = \lambda - \lambda'$ has been used giving 530 – 5.3 = 534.7 nm

B is incorrect as 5.3 nm is $\Delta\lambda$ not λ'

D is incorrect as the indices have been evaluated incorrectly, giving $\Delta\lambda$ as 53 nm

Being able to simplify indices is a vital skill. Remember that divided indices subtract, and multiplied indices add their powers together.

6

The correct answer is **C** because:

- The frequency of light from the galaxy has decreased, therefore the galaxy is moving away from the Earth
  - This eliminates answers A and B
- The equation for redshift for non-relativistic galaxies is $\frac{\Delta f}{f} = \frac{v}{c}$
- $\Delta f = f - f'$ when a galaxy is receding, therefore $\frac{(f - f')}{f} = \frac{v}{c}$
- This rearranges to $\frac{(f - f')}{f}c = v$
  - This is answer **C**

7

The correct answer is **A** because:

- The Doppler equation for wavelength as a source is moving is $\lambda' = \lambda\left(1 \pm \frac{u_s}{v}\right)$
- Because the source is moving **towards** the observer the operator in brackets becomes '**–**':
  - $\lambda' = \lambda\left(1 - \frac{u_s}{v}\right)$

- Substituting in the value $0.15v$ for u_s from the question gives:
  - $\lambda' = \lambda\left(1 - \frac{0.15v}{v}\right) = \lambda(1 - 0.15) = 0.85\lambda$
  - This is answer **A**

B is incorrect as 1.15λ has used $\lambda' = \lambda\left(1 + \frac{u_s}{v}\right)$ with + as the operator rather than –

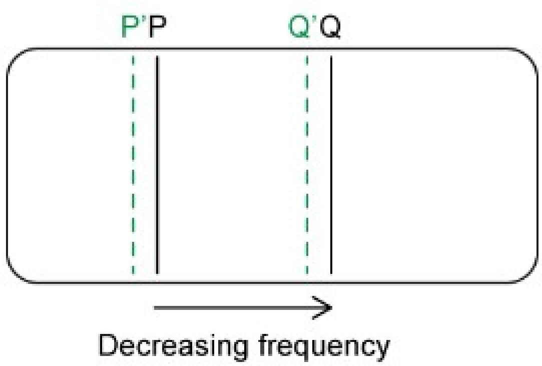
C is incorrect as rather than using the equation, 0.15 has just been used as the multiplier for λ

D is incorrect as 0.66λ has been found by using $\lambda' = \lambda\left(1 + \frac{v}{u_s}\right)$. This evaluates to $\lambda' = \lambda\left(1 + \frac{v}{0.15v}\right) = 7.67\lambda$

8

The correct answer is **D** because:

- In the Doppler effect, the spectral lines will all be shifted in the same direction
  - This eliminates answer **B**
- An observer moving towards the source will cause the frequency to increase
  - This means the spectral lines will be shifted to the left
  - This eliminates answer **A**
- At such low speeds the change in frequency will be small, and approximately the same shift will be observed for each spectral line
  - This eliminates answer **C** as the shift is too extreme for line Q
- Therefore, the correct answer is **D**



9

The correct answer is **B** because:

- Redshift led to the idea that the space between galaxies is expanding, not the galaxies themselves
    - This eliminates answer **A**
- Redshift shows that most of the galaxies in the universe are moving away from a single point:
    - This eliminates answer **C**
- Whilst redshift does cause a change in frequency, it doesn't cause a change in speed of electromagnetic waves
    - This eliminates answer **D**
- It is correct that a greater redshift indicates a greater speed of recession
    - Therefore, the correct answer is **B**

Take extra care in questions that may appear simple that small changes to words haven't changed the whole meaning of the sentence! On first glance a number of these statements might appear correct.

10

The correct answer is **B** because:

- The Doppler equation for a moving observer and a stationary source is $f' = f\left(\frac{v \pm u_o}{v}\right)$
- Since the car is, sensibly, driving **away** from the T. rex the numerator becomes ($v - u_o$)
  - $f' = f\left(\frac{v - u_o}{v}\right)$
- Substituting in the values from the question:
  - $f' = f\left(\frac{v - u_o}{v}\right) = 170 \times \left(\frac{340 - 10}{340}\right) = 170 \times \left(\frac{330}{340}\right)$
- This can be rearranged to give:
  - $f' = \frac{170}{340} \times 330 = \frac{1}{2} \times 330 = 165$ Hz
  - This is answer **B**

A is incorrect as the operator + has been used rather than –

C is incorrect as 100 m s^{-1} has been used for the speed rather than 10

D is incorrect as 100 m s^{-1} has been used for the speed rather than 10 AND the operator + has been used rather than –

In many films where a T. rex chases a car, both dinosaur and car are moving. Luckily, you do not have to worry about relative motion when both source and observer are moving!