Week 21

AP Physics 2

Homework bundle for this week

本周作业合集

exercises.lol

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14. Waves, Sound, and Physical Optics

Starter Quiz · 课前小测

AP Physics 2 Name: ____________________ Score: ______

1. A travelling wave carries:

   ☐ matter from place to place

   ☐ energy without moving matter along

   ☐ nothing at all

   ☐ only heat

2. A wave has frequency 50 Hz and wavelength 2 m. What is its speed, in $\frac{m}{s}$?

   ________________ m/s

3. Which type of wave can be polarised?

   ☐ longitudinal only

   ☐ transverse only

   ☐ both equally

   ☐ neither

4. In a vacuum, radio waves and X-rays travel at:

   ☐ radio is faster

   ☐ X-rays are faster

   ☐ the same speed, c

   ☐ it depends on brightness

5. A siren moves toward you. Compared with its true note, you hear a:

   ☐ lower pitch

   ☐ higher pitch

   ☐ the same pitch

   ☐ no sound

6. Two waves of amplitude 3 cm meet exactly in phase. What is the amplitude where they overlap, in cm?

   ________________ cm

7. Diffraction is the:

   ☐ bouncing of waves off a mirror

   ☐ spreading of waves through gaps and around edges

☐ speeding up of waves

☐ cancelling of two waves

8. Sound cannot be polarised because it is a longitudinal wave.

☐ True ☐ False

9. Electromagnetic waves can travel through empty space with no medium.

☐ True ☐ False

10. In the Doppler effect, the source's own frequency changes as it moves.

☐ True ☐ False

AP Physics 2

1. **energy without moving matter along**

   A wave transfers energy; the medium only vibrates in place.

2. **100 m/s**

   $v = f\lambda = 50 \times 2 = 100\ \frac{\mathrm{m}}{\mathrm{s}}$.

3. **transverse only**

   Only transverse waves vibrate in a plane, so only they can be polarised.

4. **the same speed, c**

   All EM waves travel at the speed of light c in a vacuum.

5. **higher pitch**

   Approaching bunches the waves, giving a higher observed frequency (higher pitch).

6. **6 cm**

   Constructive: $3 + 3 = 6$ cm.

7. **spreading of waves through gaps and around edges**

   Diffraction is the spreading of waves as they pass gaps or edges.

8. **True**

   Sound vibrates along its travel direction, so there is no cross-direction to filter.

9. **True**

   EM waves need no medium — that's how sunlight crosses space to Earth.

10. **False**

    The source's frequency is unchanged; only the observed frequency shifts.

AP PHYSICS 2 • EXERCISE SHEET

14.1 Properties of Wave Pulses and Waves

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS wave 波 • transverse 横波 • longitudinal 纵波 • amplitude 振幅 • wavelength 波长

Objective

Build the skills to answer exam questions on **properties of wave pulses and waves**.

You must be able to:

- describe a **wave 波** as a disturbance that transfers energy without transferring matter
- distinguish **transverse 横波** from **longitudinal 纵波** waves
- define amplitude and wavelength

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ What a wave carries

A wave transfers **energy** through a medium **without** transferring matter — the particles just vibrate about fixed positions.

■ Transverse vs longitudinal

- **Transverse** — vibration is perpendicular to the direction of travel (waves on a string, light).
- **Longitudinal** — vibration is along the direction of travel (sound).

■ Amplitude and wavelength

Amplitude is the maximum displacement from rest; **wavelength** is the distance between two matching points on the wave.

2 Practice

2.1 State what a wave transfers and what it does **not** transfer. [2]

2.2 Give one example each of a transverse and a longitudinal wave. [2]

2.3 Define the amplitude of a wave. [1]

3 Exam-style questions

3.1 A wave transfers [1]

- **A** matter only
- **B** energy without matter
- **C** both matter and energy equally
- **D** neither

3.2 Sound is an example of a [1]

- **A** transverse wave
- **B** longitudinal wave
- **C** electromagnetic wave
- **D** standing wave

3.3 A wave travels along a rope, with the rope moving up and down as the wave moves sideways.

(a) Name this type of wave. [1]

(b) State the direction of vibration relative to the direction of travel. [1]

(c) Name the quantity equal to the maximum displacement. [1]

Solutions

2.1 it transfers energy; it does not transfer matter.

2.2 transverse: a wave on a string (or light); longitudinal: sound.

2.3 the maximum displacement of a particle from its rest position.

3.1 B.

3.2 B.

3.3 (a) a transverse wave. (b) perpendicular to the direction of travel. (c) the amplitude.

14.2 Periodic Waves

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS frequency 频率 • period 周期 • wavelength 波长 • wave equation 波速公式 • wave speed 波速

Objective

Build the skills to answer exam questions on **periodic waves**.

You must be able to:

- define **frequency 频率**, **period 周期**, and **wavelength 波长** of a periodic wave
- apply the **wave equation 波速公式** $v = f\lambda$
- relate the wave speed to the properties of the medium

1 Worked examples

Study these first. Each one shows the method for a question type used later.

Definitions

- **Frequency** f — cycles per second (Hz).
- **Period** $T = \dfrac{1}{f}$ — time for one cycle.
- **Wavelength** λ — length of one full wave.

The wave equation

$v = f\lambda$. The wave **speed** is set by the medium, so if f rises, λ falls to keep v fixed.

Example

$f = 50$ Hz and $\lambda = 2.0$ m give $v = 100\ \text{m s}^{-1}$.

2 Practice

2.1 A wave has frequency 20 Hz and wavelength 1.5 m. Find its speed. [2]

2.2 A wave has a period of 0.25 s. Find its frequency. [1]

2.3 State the wave equation. [1]

3 Exam-style questions

3.1 The wave equation is [1]

- **A** $v = f/\lambda$
- **B** $v = f\lambda$
- **C** $v = \lambda/f$
- **D** $f = v\lambda$

3.2 If the frequency of a wave doubles at constant speed, the wavelength [1]

- **A** doubles
- **B** halves
- **C** stays the same
- **D** quadruples

3.3 A sound wave travels at 340 m s^{-1} with a frequency of 170 Hz.

(a) Find the wavelength. [2]

(b) Find the period. [2]

Solutions

2.1 $v = f\lambda = 20 \times 1.5 = 30\ \mathrm{m\ s^{-1}}$.

2.2 $f = \dfrac{1}{T} = \dfrac{1}{0.25} = 4.0\ \mathrm{Hz}$.

2.3 $v = f\lambda$.

3.1 **B**.

3.2 **B**.

3.3 (a) $\lambda = \dfrac{v}{f} = \dfrac{340}{170} = 2.0\ \mathrm{m}$. (b) $T = \dfrac{1}{f} = \dfrac{1}{170} = 5.9 \times 10^{-3}\ \mathrm{s}$.

14.3 Boundary Behavior of Waves and Polarization

Name: ____________ Class: ________ Date: ________ **Total: 9 marks**

KEY WORDS polarization 偏振 • wave 波 • transverse 横波 • longitudinal 纵波

Objective

Build the skills to answer exam questions on **boundary behaviour of waves and polarization**.

You must be able to:

- describe **reflection**, **transmission**, and **inversion** of a wave at a boundary
- describe **polarization 偏振** and state which waves can be polarized
- explain why only transverse waves can be polarized

1 Worked examples

Study these first. Each one shows the method for a question type used later.

At a boundary

A wave reaching a boundary is partly **reflected** and partly **transmitted**. Reflecting off a **denser** medium (a fixed end) **inverts** the pulse; off a less dense medium (a free end) it does not.

Polarization

Polarization restricts the vibration to a single plane. Only **transverse** waves can be polarized, because their vibration is perpendicular to travel and so has a plane to restrict.

Why not sound

Sound is longitudinal — its vibration is along the direction of travel, so there is no plane to polarize.

2 Practice

2.1 State what happens to a wave pulse reflecting off a fixed (denser) end. [1]

2.2 State the two things that happen to a wave meeting a boundary between two media. [2]

2.3 State which type of wave can be polarized. [1]

3 Exam-style questions

3.1 A pulse reflecting from a fixed end is [1]

- **A** unchanged
- **B** inverted
- **C** absorbed completely
- **D** doubled in size

3.2 Only _________ waves can be polarized. [1]

- **A** longitudinal
- **B** transverse
- **C** sound
- **D** all

3.3 Light is passed through a polarizing filter.

(a) State what the filter does to the light. [1]

(b) Explain why sound cannot be polarized. [2]

Solutions

2.1 it is inverted (turned upside down).

2.2 part of it is reflected and part is transmitted.

2.3 transverse waves.

3.1 B.

3.2 B.

3.3 (a) it only lets through light vibrating in one plane (it polarizes the light). (b) sound is longitudinal, so its vibration is along the direction of travel and has no single plane to restrict.

14.4 Electromagnetic Waves

Name: ______________ Class: __________ Date: ____________ **Total: 9 marks**

KEY WORDS electromagnetic wave 电磁波 • speed of light 光速 • electromagnetic spectrum 电磁波谱 • wave 波 • frequency 频率

Objective

Build the skills to answer exam questions on **electromagnetic waves**.

You must be able to:

- describe an **electromagnetic wave 电磁波** as oscillating electric and magnetic fields
- state that all EM waves travel at the **speed of light 光速** c in a vacuum
- order the regions of the **electromagnetic spectrum 电磁波谱** by wavelength and frequency

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ What an EM wave is

An electromagnetic wave is oscillating electric and magnetic fields, at right angles to each other and to the direction of travel. It needs **no** medium.

■ Speed

Every EM wave travels at $c = 3.0 \times 10^8$ m s^{-1} in a vacuum.

■ The spectrum (increasing frequency)

radio → microwave → infrared → **visible** → ultraviolet → X-ray → gamma.

2 Practice

2.1 State the speed of all electromagnetic waves in a vacuum. [1]

2.2 State what oscillates in an electromagnetic wave. [1]

2.3 Order these by increasing frequency: X-rays, radio waves, visible light. [2]

3 Exam-style questions

3.1 All electromagnetic waves in a vacuum have the same [1]

- **A** frequency
- **B** wavelength
- **C** speed
- **D** amplitude

3.2 Which of these has the highest frequency? [1]

- **A** radio waves
- **B** infrared
- **C** visible light
- **D** gamma rays

3.3 A radio wave has a frequency of 1.0×10^8 Hz (take $c = 3.0 \times 10^8$ m s^{-1}).

(a) Find its wavelength. [2]

(b) State whether X-rays have a longer or shorter wavelength than this. [1]

Solutions

2.1 3.0×10^8 m s^{-1}.

2.2 electric and magnetic fields.

2.3 radio waves, then visible light, then X-rays.

3.1 **C**.

3.2 **D**.

3.3 (a) $\lambda = \dfrac{c}{f} = \dfrac{3.0 \times 10^8}{1.0 \times 10^8} = 3.0$ m. (b) shorter.

14.5 The Doppler Effect

Name: ____________ Class: ________ Date: __________ **Total: 8 marks**

KEY WORDS doppler effect 多普勒效应 • redshift 红移 • frequency 频率 • wave 波 • wavelength 波长

Objective

Build the skills to answer exam questions on **the Doppler effect**.

You must be able to:

- describe the **Doppler effect 多普勒效应** as a change in observed frequency due to relative motion
- explain why an approaching source is heard higher and a receding source lower
- give applications such as radar, sonar, and astronomical **redshift 红移**

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ The Doppler effect

When a source and observer move relative to each other, the **observed frequency changes**.

■ Higher or lower

- **Approaching** — waves bunch up → shorter wavelength → **higher** frequency (higher pitch).
- **Receding** — waves stretch out → **lower** frequency.

■ Applications

Speed-camera radar, sonar, and the **redshift** of distant galaxies (showing the Universe is expanding).

2 Practice

2.1 State what the Doppler effect is. [1]

2.2 State whether an approaching siren sounds higher or lower in pitch. [1]

2.3 Give one application of the Doppler effect. [1]

3 Exam-style questions

3.1 As a sound source moves toward you, the frequency you hear is [1]

- **A** higher
- **B** lower
- **C** unchanged
- **D** zero

3.2 The redshift of distant galaxies shows that they are [1]

- **A** approaching us
- **B** receding from us
- **C** stationary
- **D** exploding

3.3 A car sounding its horn drives past a stationary listener.

(a) Describe the change in pitch the listener hears as the car approaches and then recedes. [2]

(b) Name the effect responsible. [1]

Solutions

2.1 the change in the frequency observed when a source and observer move relative to each other.

2.2 higher.

2.3 radar speed guns, sonar, or astronomical redshift (any one).

3.1 **A**.

3.2 **B**.

3.3 (a) the pitch is higher while the car approaches, then drops to a lower pitch as it recedes. (b) the Doppler effect.

AP PHYSICS 2 • EXERCISE SHEET

14.6 Wave Interference and Standing Waves

Name: ______________ Class: _________ Date: ____________ **Total: 8 marks**

KEY WORDS standing wave 驻波 • destructive 相消 • constructive 相长 • nodes 波节 • principle of superposition 叠

Objective

Build the skills to answer exam questions on **wave interference and standing waves**.

You must be able to:

- apply the **principle of superposition 叠加原理** to combine overlapping waves
- distinguish **constructive 相长** from **destructive 相消** interference
- describe **standing waves 驻波** with nodes and antinodes

1 Worked examples

Study these first. Each one shows the method for a question type used later.

> ■ **Superposition**
>
> Where waves overlap, their displacements **add**.
>
> ■ **Constructive and destructive**
>
> - **In phase** → crests meet crests → **constructive** (larger amplitude).
> - **Out of phase** → crest meets trough → **destructive** (cancellation).
>
> ■ **Standing waves**
>
> Two waves travelling in opposite directions form a standing wave with fixed **nodes** (no motion) and **antinodes** (maximum motion) — as on a guitar string or in a pipe.

2 Practice

2.1 State the principle of superposition. [1]

2.2 State the condition for two waves to interfere destructively. [1]

2.3 Define a node on a standing wave. [1]

3 Exam-style questions

3.1 Two waves meeting in phase interfere [1]

- **A** destructively
- **B** constructively
- **C** not at all
- **D** randomly

3.2 A point of zero displacement on a standing wave is a [1]

- **A** antinode
- **B** node
- **C** crest
- **D** trough

3.3 Two identical waves overlap.

(a) State the result when they meet in phase. [1]

(b) State the result when they meet exactly out of phase. [1]

(c) Name the general principle used. [1]

Solutions

2.1 where waves overlap, the total displacement is the sum of the individual displacements.

2.2 they must be exactly out of phase (crest meets trough).

2.3 a point on a standing wave that stays at rest (zero displacement).

3.1 B.

3.2 B.

3.3 (a) a larger wave (constructive interference). (b) they cancel (destructive interference). (c) the principle of superposition.

14.7 Diffraction

Name: ____________ Class: ________ Date: __________ **Total: 8 marks**

KEY WORDS diffraction 衍射 • wave 波 • wavelength 波长

Objective

Build the skills to answer exam questions on **diffraction**.

You must be able to:

- describe **diffraction 衍射** as the spreading of waves around obstacles and through gaps
- relate the amount of diffraction to the ratio of wavelength to gap size
- connect diffraction to the wave nature of light

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Diffraction

Waves **spread out** as they pass an obstacle's edge or go through a gap.

■ How much

Diffraction is greatest when the gap is **about the same size** as the wavelength. A gap much wider than λ gives little spreading.

■ Evidence for waves

Light diffracts through very narrow slits, which is direct evidence that light behaves as a wave.

2 Practice

2.1 State what diffraction is. [1]

2.2 State when diffraction through a gap is greatest. [1]

2.3 State what the diffraction of light shows about its nature. [1]

3 Exam-style questions

3.1 Diffraction is the _________ of waves around obstacles. [1]

- **A** speeding up
- **B** spreading
- **C** reflection
- **D** absorption

3.2 Diffraction through a gap is greatest when the gap size is [1]

- **A** much larger than the wavelength
- **B** about equal to the wavelength
- **C** zero
- **D** infinite

3.3 Water waves pass through a gap in a barrier.

(a) Describe what happens to the waves as they pass through. [1]

(b) State how to make them spread out more (for the same waves). [2]

Solutions

2.1 the spreading of waves around obstacles and through gaps.

2.2 when the gap is about the same size as the wavelength.

2.3 that light behaves as a wave.

3.1 B.

3.2 B.

3.3 (a) they spread out into the region beyond the gap. (b) make the gap narrower (closer to the wavelength).

14.8 Double-Slit Interference and Diffraction Gratings

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS diffraction grating 衍射光栅 • young's double-slit 杨氏双缝 • wave 波 • wavelength 波长 • diffraction 衍射

Objective

Build the skills to answer exam questions on **double-slit interference and diffraction gratings**.

You must be able to:

- describe **Young's double-slit 杨氏双缝** experiment as evidence for the wave nature of light
- apply $d \sin\theta = m\lambda$ to locate bright fringes (maxima)
- explain how a **diffraction grating 衍射光栅** produces sharp, widely spaced maxima

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Young's double slit

Light passing through two close slits produces bright and dark **fringes** — clear evidence of wave interference.

■ Fringe condition

$d \sin\theta = m\lambda$, where d is the slit spacing and $m = 0, 1, 2, \ldots$ labels the bright fringes.

■ Diffraction grating

A grating has many slits, so it gives very **sharp, widely spaced** maxima — ideal for measuring wavelength.

2 Practice

2.1 State what the double-slit experiment demonstrates about light. [1]

2.2 Write the condition for bright fringes in a double-slit pattern. [1]

2.3 Light of wavelength 600 nm falls on slits 0.20 mm apart. Find the angle to the first bright fringe ($m = 1$). [2]

3 Exam-style questions

3.1 In a double-slit experiment, bright fringes occur when $d \sin \theta$ equals [1]

- **A** $m\lambda$
- **B** $(m + \frac{1}{2})\lambda$
- **C** λ/m
- **D** $2m\lambda$

3.2 Compared with a double slit, a diffraction grating gives maxima that are [1]

- **A** blurrier
- **B** sharper and more widely spaced
- **C** closer together
- **D** absent

3.3 A grating has 300 lines per millimetre and is lit by light of wavelength 500 nm.

(a) Find the slit spacing d. [2]

(b) Find the angle to the first-order maximum. [2]

Solutions

2.1 that light behaves as a wave (it interferes).

2.2 $d \sin\theta = m\lambda$.

2.3 $\sin\theta = \dfrac{m\lambda}{d} = \dfrac{600 \times 10^{-9}}{0.20 \times 10^{-3}} = 3.0 \times 10^{-3} \Rightarrow \theta = 0.17°$.

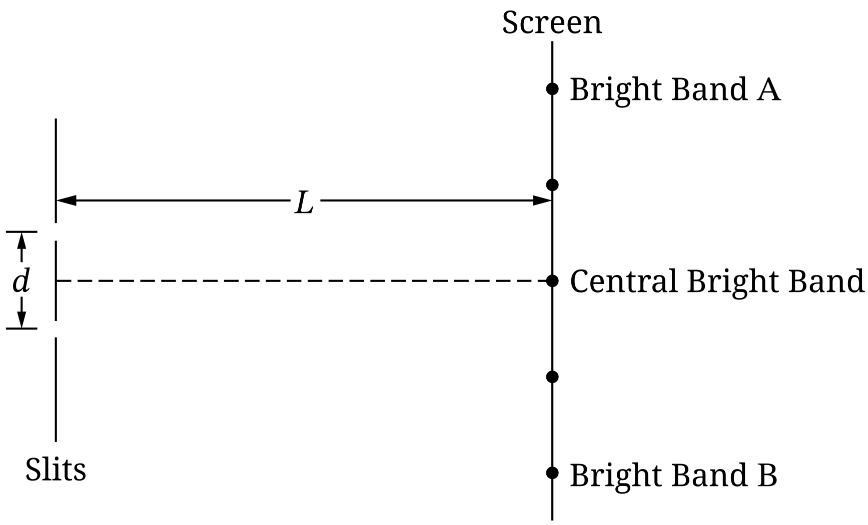
3.1 **A**.

3.2 **B**.

3.3 (a) $d = \dfrac{1}{300 \times 10^{3}\ \mathrm{m}^{-1}} = 3.33 \times 10^{-6}$ m. (b) $\sin\theta = \dfrac{\lambda}{d} = \dfrac{500 \times 10^{-9}}{3.33 \times 10^{-6}} = 0.15 \Rightarrow \theta = 8.6°$.

Question 4

4. Two narrow slits are a distance d apart. A screen is a distance L from the midpoint of the slits, where $L \gg d$. When a laser emits monochromatic light toward the slits, a pattern of narrow bright and dark bands is observed on the screen. The centers of bright bands A and B are indicated. Three additional bright bands, including the central bright band, are observed on the screen between bands A and B, as shown.



Note: Figure not drawn to scale.

A student claims that the distance between the center of Band A and the center of the central bright band is smaller when using a laser that emits violet light than when using a laser that emits red light.

A. **Indicate** whether the student's claim is correct or incorrect. Without manipulating equations, **justify** your answer by referencing the difference in path length traveled by the light from each slit to the center of Band A.

B. **Derive** an expression for the distance between the centers of bands A and B when light of frequency f is emitted toward the slits. Express your answer in terms of d, L, f, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

C. **Indicate** whether the expression you derived in part B is or is not consistent with your answer from part A. Briefly **justify** your answer.

STOP

END OF EXAM

Begin your response to **QUESTION 1** on this page.

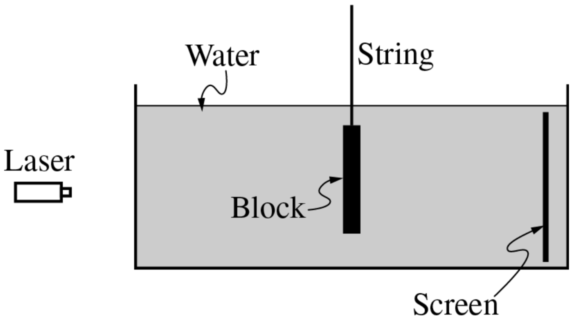
PHYSICS 2

SECTION II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points, suggested time 20 minutes)

Students are investigating electromagnetic wave phenomena in transparent media. They use a string to support a stationary thin, rectangular block of mass m_b, volume V_b, and density ρ_b. The block has two narrow slits in its center and is submerged in a glass tank containing water with density ρ_w, as shown above.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 1** on this page.

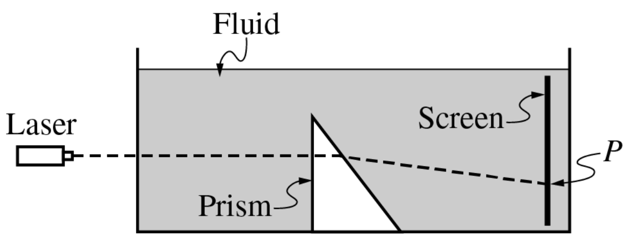
(a)

i. On the dot below, which represents the block, draw and label the forces that are exerted on the block. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

ii. Derive an expression for the force exerted on the block by the string in terms of the given quantities and physical constants, as appropriate.

GO ON TO THE NEXT PAGE.

(b) A monochromatic laser beam is incident perpendicular to the wall of the tank. The beam passes through the slits in the block. An interference pattern is formed on the screen inside the tank. The water is then replaced with a clear fluid with a greater index of refraction than that of water. In a coherent, paragraph-length response, describe how the greater index of refraction of the new fluid affects the interference pattern. Explain your reasoning in terms of speed, frequency, and wavelength of the light.



(c) The block is replaced by a triangular prism, as shown above. The path of the beam is indicated by the dotted line, and the beam reaches the screen at point P. The fluid is then removed from the tank, and the prism is surrounded by air. Predict whether the beam will reach the side of the tank above point P, at point P, or below point P when the prism is surrounded by air. Support your answer using physics principles.

GO ON TO THE NEXT PAGE.

14.9 Thin-Film Interference

Name: ______________ Class: __________ Date: ____________ **Total: 9 marks**

KEY WORDS thin film 薄膜 • thin-film interference 薄膜干涉 • phase change 相位变化 • wave 波 • wavelength 波长

Objective

Build the skills to answer exam questions on **thin-film interference**.

You must be able to:

- explain **thin-film interference 薄膜干涉** as interference between light reflected from two surfaces
- account for the **phase change 相位变化** on reflection from a denser medium
- relate film thickness to constructive or destructive interference

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Thin-film interference

Light reflects from **both** the top and bottom surfaces of a thin film; the two reflected waves overlap and interfere.

■ Phase change on reflection

Reflection from a **denser** medium flips the wave by half a wavelength (a phase change of π).

■ Colours

The film **thickness** decides which wavelengths interfere constructively, giving the shifting colours of soap bubbles, oil films, and lens coatings.

2 Practice

2.1 State what causes the colours seen on a soap bubble. [2]

2.2 State what happens to the phase of light reflecting off a denser medium. [1]

2.3 Give one everyday example of thin-film interference. [1]

3 Exam-style questions

3.1 Thin-film interference is between light reflected from [1]

- **A** one surface only
- **B** the top and bottom surfaces of the film
- **C** two separate films
- **D** a plane mirror

3.2 Light reflecting off a denser medium undergoes a phase change of [1]

- **A** zero
- **B** a quarter wavelength
- **C** half a wavelength
- **D** a full wavelength

3.3 A soap film shows bands of colour that change as it drains and thins.

(a) Explain why different colours appear at different thicknesses. [2]

(b) Name the effect responsible. [1]

Solutions

2.1 light reflecting from the top and bottom surfaces of the film interferes; the thickness sets which colours interfere constructively.

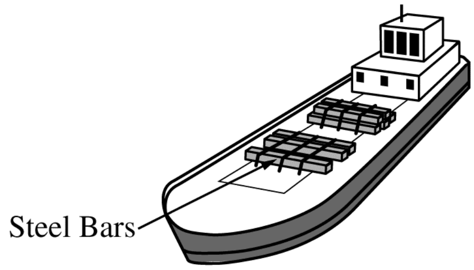
2.2 it changes by half a wavelength (a phase change of π).

2.3 oil films on water, or anti-reflection coatings on lenses (any one).

3.1 **B**.

3.2 **C**.

3.3 (a) at each thickness a different wavelength interferes constructively, so a different colour is seen. (b) thin-film interference.



4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number *N* of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \mathrm{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

STOP

END OF EXAM