INSIGHT

Year 12 *Trial Exam Paper*

2013

PHYSICS

Written examination

Worked solutions
Section B – Detailed studies

This book contains:

- correct solutions with full working
- mark allocations
- explanatory notes
- tips and guidelines

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SECTION B

Detailed study 1 – Einstein's special relativity

Question 1

Answer is B

Worked solution

$$m = m_0\gamma$$
$$= \frac{6.64\times10^{-27}}{\sqrt{1-0.95^2}}$$
$$= 2.13\times10^{-26}\text{ kg}$$

Question 2

Answer is D

Worked solution

$$l = l_0\gamma$$
$$= \frac{2000}{\sqrt{1-0.99^2}}$$
$$= 282\text{ m}$$

Only the dimension in the direction of relativistic motion will contract.

Question 3

Answer is A

Worked solution

$$\Delta E_K = \Delta\gamma m_0 c^2$$
$$\Delta\gamma = \frac{1}{\sqrt{1-0.98^2}} - \frac{1}{\sqrt{1-0.90^2}}$$
$$= 2.731$$
$$\Delta E_K = 2.731\times7.0\times10^{12}\times9.0\times10^{16}$$
$$= 1.72\times10^{30}\text{ J}$$

Question 4

Answer is B

Worked solution

Observers on the ground measured 2 half-lives to have passed and so expected 2500 particles to arrive (10 000 ÷ 2 ÷ 2 = 2500). 625 particles indicates that 4 half-lives have passed from the frame of reference of the moving particles (10 000 ÷ 2 ÷ 2 ÷ 2 ÷ 2 = 625). Hence $\gamma = 2$.

Tip

- *Half-lives are a common way to compare elapsed time in different frames of reference. Brush up on your Unit 1 Physics if you need to.*

Question 5

Answer is D

Worked solution

The speed of light is constant for all observers so the velocities of the aliens are irrelevant. Both their lasers will reach Earth at the same time.

Question 6

Answer is C

Worked solution

Newton's laws apply to all inertial frames of reference. An inertial frame of reference is one that is not accelerating. A bus going around a corner is experiencing acceleration and so is not an inertial frame of reference.

Question 7

Answer is C

Worked solution

The faster one moves through space, the slower one moves through time. It does not matter whether it is Allan or Boris that is stationary, they are moving relative to each other fast enough for relativistic effects to be noticeable by both. As both are observed moving through space quite quickly, they will also be observed to be moving through time more slowly.

Question 8

Answer is A

Worked solution

Newton assumed that space and time would be absolute and the same for all observers. Einstein showed that only the speed of light is the same for all observers and that space and time will change to keep it so.

Question 9

Answer is B

Worked solution

Since the moving observer is travelling away from Alpha, the light takes longer to reach her. Although a stationary observer will see the two flashes as simultaneous events, for the moving observer the flash at Beta happens before the flash at Alpha.

Question 10

Answer is A

Worked solution

$$\gamma = \frac{l_0}{l} = \frac{1.00 \times 10^{16}}{2.50 \times 10^{15}} = 4$$

$$4 = \frac{1}{\sqrt{1 - x^2}}$$

$$x = 0.968$$

Question 11

Answer is C

Worked solution

$$E = \Delta mc^2$$

$$1.695 \times 10^{20} = \Delta m \times 9.0 \times 10^{16}$$

$$\Delta m = 1883 \text{ kg}$$

Detailed study 2 – Materials and their use in structures

Question 1

Answer is B

Worked solution

$$\sigma = \frac{F}{A}$$

$$6 \times 10^8 = \frac{F}{\pi \times 0.01^2}$$

$$F = 1.9 \times 10^5 \text{ N}$$

Question 2

Answer is D

Worked solution

From graph $\varepsilon = 6.0 \times 10^{-3}$

$$\varepsilon = \frac{\Delta l}{l}$$

$$6.0 \times 10^{-3} = \frac{\Delta l}{2.0}$$

$$\Delta l = 1.2 \times 10^{-2} \text{ m}$$

Tip

- *Always take careful note of the scales on graphs like Figure 1.*

Question 3

Answer is A

Worked solution

$$\text{Energy} = \text{area under graph} \times \text{volume of material}$$

$$= \frac{1}{2} \times 6.0 \times 10^{-3} \times 6.0 \times 10^8 \times \pi \times 0.01^2 \times 2.0$$

$$= 1.1 \times 10^3 \text{ J}$$

Question 4

Answer is C

Worked solution

$$E = \frac{\sigma}{\varepsilon}$$
$$= \frac{6\times10^{8}}{6\times10^{-3}}$$
$$= 1.0\times10^{11}\ \text{Pa}$$

Question 5

Answer is A

Worked solution

Strength is defined as the maximum stress before failure. Steel Y is the strongest.
Stiffness is the ratio of stress per strain and can be seen in the gradient. Steel Y is the stiffest.
Toughness is defined as the maximum energy absorbed before failure and can be seen in the area under the graph. Steel X is the toughest.

Question 6

Answer is D

Worked solution

Apply rotational equilibrium with the top of pole A as a pivot point.

$$6.0\ \text{m}\times 20\,000\ \text{N} = 8.0\ \text{m}\times F_{\text{B}}$$
$$F_{\text{B}} = 15\,000\ \text{N}$$

Question 7

Answer is B

Worked solution

Applying rotational equilibrium again but taking the top of pole B as the pivot point.

$$2.0\ \text{m}\times 20\,000\ \text{N} = 4.0\ \text{m}\times F$$
$$F = 10\,000\ \text{N}$$

The balcony can balance with a force of 10 kN applied to its far end.

$$\frac{10\,000\ \text{N}}{700\ \text{N}} = 14.29$$

The balcony can support up to 14 people.

Question 8

Answer is D

Worked solution

$$\tan^{-1}\left(\frac{2}{2}\right) = 45°$$

The angle between the cable and the wall is 45°.

Use rotational equilibrium with the wall as a pivot point:

$$F_v \times 2.0 \text{ m} = 14000 \text{ N} \times 1.7 \text{ m}$$

$$F_v = 11900 \text{ N}$$

The vertical component of the tension force is 11 900 N.

$$\sin(45°) = \frac{11900}{T}$$

$$T = 16829 \text{ N}$$

Tip

- *Torque is the product of radius and force perpendicular to each other. For this reason, only the vertical component of tension was given by the rotational equilibrium expression.*

Question 9

Answer is B

Worked solution

The sum of all the horizontal forces acting on the veranda must equal zero.
Therefore, the force of the wall on the veranda must equal the horizontal component of tension in the cable F_h.

$F_h = F_B = 11\ 900$ N

Question 10

Answer is C

Worked solution

The concrete will try to sag under its own weight, placing the top section under compression and the bottom section under tension. Concrete is weak under tension and so steel is placed near the bottom.

Question 11

Answer is B

Worked solution

Concrete is strong under compression but weak under tension. Steel has high tensile strength so it is often used to reinforce concrete.

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Detailed study 3 – Further electronics

Question 1

Answer is A

Worked solution

$$\frac{240V_{\text{RMS}}}{12} = 20V_{\text{RMS}}$$

$$20 \times \sqrt{2} = 28\ V_{\text{peak}}$$

Question 2

Answer is C

Worked solution

Trace the path from high potential to low potential for both cycles of alternating current. C is the only example that works.

Tip

- *Have a standard full-wave bridge rectifier on your summary sheet to compare against.*

Question 3

Answer is D

Worked solution

The current passes through two diodes on its way through the bridge, dropping a total of 1.6 V, making the effective output 18.4 V.

Question 4

Answer is C

Worked solution

$$\tau = 0.025 \text{ s}$$
$$\tau = RC$$
$$0.025 = 1000 \times C$$
$$C = 2.5 \times 10^{-5}$$
$$= 25\ \mu\text{F}$$

Question 5

Answer is C

Worked solution

The 1000 Ω resistor is not involved in the charging cycle.

Question 6

Answer is A

Worked solution

A capacitor is considered fully charged or discharged after 5τ. $5 \times 0.025 = 0.125$ s

Question 7

Answer is D

Worked solution

Since the zener diode is limited to 2.0 W,

$$I_{\text{max}} = \frac{P}{V} = \frac{2.0}{6.5}$$
$$= 0.308 \text{ A}$$

For the resistor A,

$$R_{\text{A}} = \frac{V}{I} = \frac{4.5}{0.308}$$
$$= 14.6\ \Omega$$

Question 8

Answer is A

Worked solution

Voltage across the zener diode will not change and so voltage across the load will not change either. Since the resistance of the load doesn't change, the current through it does not change either. The extra current runs through the zener diode instead.

Question 9

Answer is D

Worked solution

The only component is a full-wave bridge rectifier, which will turn an AC signal into a pulsing DC signal.

Question 10

Answer is A

Worked solution

The capacitor will smooth the signal but not as much as option D.
The time constant $\tau = 600 \times 50 \times 10^{-6} = 0.03 \text{ s}$ is not sufficient to fully smooth the signal.

Question 11

Answer is A

Worked solution

The zener diode stops the wave rising above 6.5 V and instead levels it out, as shown in graph A.

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Detailed study 4 – Synchrotron and its applications

Question 1

Answer is C

Worked solution

Light from a synchrotron spans a wide range of energies and therefore a wide range of wavelengths, making it useful in a wide range of applications.

Tip

- *Other reasons why synchrotron light is beneficial are:*
  - *it is much brighter (more intense) than other sources*
  - *it is a very focused beam (high degree of collimation)*
  - *the light is polarised.*

Question 2

Answer is C

Worked solution

$$\Delta E_{\text{k}} = \frac{1}{2} \times m_{\text{e}} \times v^2 = q \times V$$

$$v = \sqrt{\frac{2 \times q \times V}{m_{\text{e}}}}$$

$$= 2.3 \times 10^{-7}\ \text{m s}^{-1}$$

Question 3

Answer is A

Worked solution

The electron will be forced up the page by the right-hand slap rule. Its radius can be found as follows:

$$r = \frac{mv}{eB}$$

$$= \frac{9.1 \times 10^{-31} \times 2.0 \times 10^{6}}{1.6 \times 10^{-19} \times 2.3 \times 10^{-5}}$$

$$= 0.49\ \text{m}$$

Therefore the electron will curve in arc with a radius of 0.49 m and be detected by A.

Question 4

Answer is D

Worked solution

$$
\begin{aligned}
F &= q \times v \times B \\
&= 1.6 \times 10^{-19} \times 2.0 \times 10^{6} \times 2.3 \times 10^{-5} \\
&= -7.36 \times 10^{-18}
\end{aligned}
$$

Question 5

Answer is A

Worked solution

The acceleration of a charged particle produces electromagnetic radiation. When the electrons change direction, they are accelerating and producing synchrotron radiation.

Question 6

Answer is C

Worked solution

Light from a wiggler is increased in intensity by a factor of two times the number of magnetic poles. The smaller wiggler increases light by a factor of 12 while the larger wiggler increases the intensity by a factor of 36, three times more than the smaller one.

Question 7

Answer is D

Worked solution

The undulator uses weaker magnets than a wiggler, which means the beam of light is more collimated and can reinforce at particular wavelengths.

Question 8

Answer is D

Worked solution

Compton scattering is the result of inelastic collisions between X-rays and atoms. This loss of energy is seen as an increase in wavelength.

Question 9

Answer is B

Worked solution

$$\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$$

$$\theta_1 = \sin^{-1}\left(\frac{1\times 0.378}{2\times 0.612}\right) = 18.0°$$

$$\theta_2 = \sin^{-1}\left(\frac{2\times 0.378}{2\times 0.612}\right) = 38.1°$$

$$\theta_3 = \sin^{-1}\left(\frac{3\times 0.378}{2\times 0.612}\right) = 67.9°$$

Question 10

Answer is C

Worked solution

52.1° could be a first-, second- or third-order peak. Another peak will confirm a value of *d*.

$$2d\sin(52.1°) = n\times 0.378 \text{ nm}$$

$$d = n\times 0.240 \text{ nm}$$

If 52.1° is a first-order peak, d = 0.240 nm

$$\theta_2 = \sin^{-1}\left(\frac{2\times 0.378}{2\times 0.612}\right) = \text{ undefined and so no second-order peak is possible}$$

If 52.1° is a second-order peak, d = 0.480 nm

$$\theta_1 = \sin^{-1}\left(\frac{1\times 0.378}{2\times 0.480}\right) = 23.2°$$

A peak at θ = 23.2° would confirm that d = 0.480 nm

Question 11

Answer is A

Worked solution

Higher-energy X-rays mean a smaller wavelength. A smaller value of λ means a smaller value of θ as a result of the expression $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$.

Detailed study 5 – Photonics

Question 1

Answer is D

Worked solution

When a source of electromagnetic radiation emits waves of the same frequency and in phase, it is said to be a coherent source. Lasers are an example of a coherent light source.

Tip

- *The waves do not need to have matching amplitudes to be coherent.*

Question 2

Answer is A

Worked solution

$$E = \frac{hc}{\lambda}$$
$$= \frac{6.63\times10^{-34}\times3.00\times10^{8}}{589\times10^{-9}}$$
$$= 3.37\times10^{-19}\text{ J}$$

Tip

- *Remember to add '$\times 10^{-9}$' when working with nm to convert to m.*

Question 3

Answer is C

Worked solution

An electron that loses 2.1 eV indicates an LED with a band gap of 2.1 eV.

$$E = \frac{hc}{\lambda}$$

$$\begin{aligned}\lambda &= \frac{hc}{E} \\ &= \frac{4.14\times10^{-15}\times3.0\times10^{8}}{2.1} \\ &= 5.9\times10^{-7}\text{ m} \\ &= 590\text{ nm}\end{aligned}$$

Tip

- *Note that the voltage drop of an LED expressed in volts matches the band gap expressed in eV. Recall that volts are defined as joules per coulomb whereas electron-volts are a measure of energy on the scale of individual electrons.*

Question 4

Answer is B

Worked solution

Each parallel path takes the full 4.5 V. 2.1 V drops across the LED and so 2.4 V drops across the resistor. Calculate the current through each resistor and add them to find the current through the LED.

$$\begin{aligned}I &= \frac{V}{R} \\ &= \frac{2.4}{330} \\ &= 0.00727\text{ A} \\ 0.00727\times2 &= 0.0145\text{ A} \\ &= 15\text{ mA}\end{aligned}$$

Tip

- *Examiners have commented that students often forget to include the voltage drop across diodes.*

Question 5

Answer is C

Worked solution

Photons reflect inside a chamber in which they can collide with excited electrons and prompt them to emit photons of the same wavelength and phase, hence amplifying the light.

Question 6

Answer is D

Worked solution

For total internal reflection to occur easily (as desired in an optical fibre) the critical angle must be as large as possible. From Snell's law we get the expression:

$$i_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

The largest values for i_c occur when n_2 is only slightly larger than n_1, i.e. as $\frac{n_2}{n_1}$ approaches 1.

Therefore, optical fibres are constructed with cladding of a slightly lower refractive index than the core.

Question 7

Answer is A

Worked solution

$$i_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$$= \sin^{-1}\left(\frac{1.28}{1.36}\right)$$

$$= 70°$$

Tip

- *The inverse sin can only be applied to numbers between 0 and 1 in this case. If your calculator is giving you a 'domain error' or similar, you may have your n_1 and n_2 values mixed up, making a fraction larger than 1.*

Question 8

Answer is D

Worked solution

$$\begin{aligned}\text{NA} &= n_{\text{ext}}\sqrt{n_1^2 - n_2^2}\\ &= 1.00 \times \sqrt{1.36^2 - 1.28^2}\\ &= 0.46\end{aligned}$$

Tip

- *The square root of a negative number has no (real) solution so if your calculator gives you a 'domain error' or similar, your n_1 and n_2 values may be mixed up, giving a negative number inside the square root.*

Question 9

Answer is B

Worked solution

$$\begin{aligned}\text{NA} &= n_{\text{ext}} \sin\theta_1\\ 0.46 &= 1.33 \sin\theta_1\\ \theta_1 &= \sin^{-1}\left(\frac{0.46}{1.33}\right)\\ \theta_1 &= 20.2^\circ\end{aligned}$$

Question 10

Answer is D

Worked solution

$$\Delta P = -10\log_{10}\frac{P_{\text{in}}}{P_{\text{out}}}$$

$$-12 = -10\log_{10}\frac{5\times10^{-3}}{P_{\text{out}}}$$

$$1.2 = \log_{10}\frac{5\times10^{-3}}{P_{\text{out}}}$$

$$10^{1.2} = \frac{5\times10^{-3}}{P_{\text{out}}}$$

$$P_{\text{out}} = 5\times10^{-3}\times10^{-1.2}$$

$$= 3.15\times10^{-4}$$

$$= 0.32\text{ mW}$$

Tip

- *Remember that a loss of 12 dB means ΔP = –12 dB*

Question 11

Answer is C

Worked solution

Single-mode fibre carries one mode and so suffers no modal dispersion. Graded-index fibre has varying refractive indices in its core to slow down lower order modes. Step-index fibre allows lower-order modes to travel faster than higher-order modes, which results in significant modal dispersion and limits its usefulness in high-speed data transfer.

Detailed study 6 – Sound

Question 1

Answer is C

Worked solution

Sound is a longitudinal wave, which means vibrations occur in the direction the wave is travelling.

Question 2

Answer is B

Worked solution

$$\begin{aligned}\text{Intensity} &= \frac{\text{power (W)}}{\text{area (m}^2\text{)}}\\ &= \frac{100}{4\pi r^2}\\ &= \frac{100}{4\times\pi\times 5^2}\\ &= 0.32\ \text{W m}^{-2}\end{aligned}$$

Tip

- *Sound energy spreads as if it were covering the surface of a sphere with the origin at the centre. Remember the formula for the surface area of a sphere and don't confuse it with other measurement formulae.*

Question 3

Answer is C

Worked solution

$$\frac{I_1}{I_2}=\left(\frac{r_2}{r_1}\right)^2$$

$I_2=\frac{I_1}{4}$ By doubling the distance, the intensity has been reduced by a factor of 4.

$\Delta L=10\log_{10}\left(\frac{1}{4}\right)$ This calculates the change in decibels for a sound intensity $\frac{1}{4}$ of the original.

$=-6.0$ dB

$105-6=99$ dB

Tip

- *The formula to calculate decibel level from intensity level, $L(dB)=10\log_{10}\left(\frac{I}{I_0}\right)$, can also be used to calculate the change in decibel levels. In this case 'I_0' was the original intensity and 'I' was the new intensity.*

Question 4

Answer is A

Worked solution

A 50 dB sound (vertical axis) played at 100 Hz (horizontal axis) corresponds to a point on the graph just below the 40 phon curve. This shows that Helen hears the sound as being slightly less than 40 dB.

Tip

- *Remember that the values on the vertical axis are those that would be objectively measured by a machine. The points that make up a phon curve are all heard at the same volume by a human ear.*

Question 5

Answer is D

Worked solution

Human ears are most sensitive to frequencies matching human speech, from 1000 to 5000 Hz. Our ears respond less well to very high or very low frequencies.

Question 6

Answer is B

Worked solution

$$v = f\lambda$$

$$340 = 262 \times \lambda$$

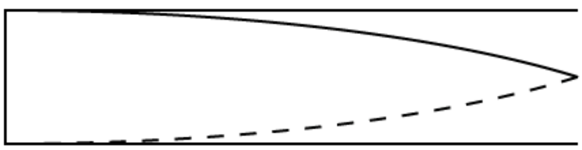
$$\lambda = \frac{340}{262} = 1.3 \text{ m}$$

For the fundamental frequency of a closed tube: $\lambda = 4L$

$$\lambda = \frac{1.3}{4} = 0.33 \text{ m}$$

Tip

- *Open and closed ends reflect sound waves differently and this has implications for the length of the standing waves that form resonant frequencies. Make sure you understand (and possible have copies on your summary sheet) diagrams like this:*



Question 7

Answer is C

Worked solution

For a tube closed at one end: $f_n = \dfrac{nv}{4L}$, $n = 1, 3, 5...$

When v = 340 m s^{-1} and L = 0.9 m,

$$f_3 = \frac{3 \times 340}{4 \times 0.9} = 283 \text{ Hz}$$

$$f_5 = \frac{5 \times 340}{4 \times 0.9} = 472 \text{ Hz}$$

Tip

- *Even-numbered harmonics (f_2, f_4, etc.) do not exist in a closed tube.*

Question 8

Answer is C

Worked solution

High fidelity requires linear response curves. Mic Z has a linear section in the low-frequency range making it best for accurately recording low-frequency sounds like the ‘thud’. The same applies with the other microphones.

Tip

- *Remember that fidelity means linear response, not maximum gain.*

Question 9

Answer is B

Worked solution

The diaphragm in an electret-condenser microphone has a permanent electric charge. As it moves back and forth near a metal plate, the capacitance of that plate is altered, creating an electrical signal.

Tip

- *All microphones operate by capturing sound vibrations with a diaphragm and somehow converting the motion of that diaphragm into an electrical signal.*

Question 10

Answer is A

Worked solution

According to the relationship diffraction $\propto \frac{\lambda}{w}$, longer wavelengths diffract more than shorter ones. This means that Brian heard longer wavelengths (bass tones) more than shorter wavelengths (treble tones) as the longer wavelengths bend around the wall.

Tip

- *Remember that a large wavelength means a low frequency and vice versa.*

Question 11

Answer is D

Worked solution

When a compression is formed at the front of the cone, a rarefaction is formed at the back. If these two waves are allowed to meet, they will destructively interfere and mute the sound. A baffle stops the out-of-phase waves from meeting and cancelling each other out.

Tip

- *Even better than a baffle is an enclosure, sometimes called an infinite baffle. Most speakers are sold in an enclosure of some sort.*

END OF DETAILED STUDIES SOLUTIONS BOOK