S271

Specimen Exam Paper Answers

PART I *For each of Q1–Q11*: 3 marks

Q1 Correct response A. For v_x to be positive, dx/dt must be positive, i.e. the graph of Figure 1 must have a positive gradient.

Q2 Correct response B.

$$\begin{aligned}\Delta W &= \boldsymbol{F}\cdot\boldsymbol{s} = Fs\cos\theta\\ &= 1.0\times10^4\,\mathrm{N}\times10\,\mathrm{m}\times\cos 30^\circ\\ &= 8.7\times10^4\,\mathrm{J}.\end{aligned}$$

Q3 Correct response E.

$$\begin{aligned}\boldsymbol{l} &= \boldsymbol{r}\times\boldsymbol{p}\\ \text{units of } l &= \text{units of distance}\\ &\quad\times\text{units of linear momentum}\\ &= \mathrm{m}\times\mathrm{kg\,m\,s^{-1}}\\ &= \mathrm{kg\,m^2\,s^{-1}}.\end{aligned}$$

Q4 Correct response C.

$$\begin{aligned}\langle E_{\mathrm{trans}}\rangle &= \tfrac{3}{2}kT\\ &= \tfrac{3}{2}\times1.38\times10^{-23}\,\mathrm{J\,K^{-1}}\times300\,\mathrm{K}\\ &= 6.21\times10^{-21}\,\mathrm{J}.\end{aligned}$$

Q5 Correct response C.

C is the wrong statement: when the wave speed *decreases* at a boundary (e.g. when light travels from air to glass), the wave is refracted towards the normal. The other four statements are correct.

Q6 Correct response D.

The positive charge P will be attracted towards the negative charge N, so paths a, b and c cannot be correct. At the position shown, P will experience a force due to M (which will be directed along the line MP away from M), and a force due to N (which will be directed along the line PN towards N). These two forces are equal in magnitude so the resultant force on P will be 'horizontal' (in terms of Figure 2) and directed to the left. Hence P initially moves 'horizontally' and follows path d rather than path e.

Q7 Correct response A.

Force on the particle

$$\boldsymbol{F}_{\mathrm{m}} = q(\boldsymbol{v}\times\boldsymbol{B}).$$

So $\qquad F_{\mathrm{m}} = |q|vB\sin\theta = 0$

since $\boldsymbol{v}$ and $\boldsymbol{B}$ are co-linear (i.e. $\theta = 0$). There is no force on the particle, so neither its speed nor its direction of motion can change.

Q8 Correct response A.

$$E^2 = c^2p^2 + m^2c^4.$$

(*See equation list at the front of the paper.*)

Then $c^2p^2 = E^2 - m^2c^4 = (2mc^2)^2 - m^2c^4 = 3m^2c^4$, giving

$$p = \sqrt{3}\,mc.$$

[Alternatively, use

$$p = \frac{mv}{\sqrt{1-v^2/c^2}} \quad\text{and}\quad E = \frac{mc^2}{\sqrt{1-v^2/c^2}}$$

(*See equation list at the front of the paper.*)

In this case, $E = 2mc^2$, so $1/\sqrt{1-v^2/c^2} = 2$.

Hence $\qquad v = \frac{c}{2}\sqrt{3}$

and $\qquad |\boldsymbol{p}| = 2\times m\times\frac{c}{2}\sqrt{3} = mc\sqrt{3}.$]

Q9 Correct response B.

$$\begin{aligned}\tfrac{1}{2}m_e v_{\mathrm{max}}^2 &= hf - \phi\\ 1.9\times10^{-18}\,\mathrm{J} &= 6.63\times10^{-34}\,\mathrm{J\,s}\times4.0\times10^{15}\,\mathrm{s^{-1}} - \phi.\end{aligned}$$

Hence $\qquad \phi = 7.5\times10^{-19}\,\mathrm{J}$

Q10 Correct response A.

$$P \propto |\psi(x)|^2$$

$$\frac{P_2}{P_1} = \frac{\left|A\sin\left(\dfrac{D/4}{D}\right)\right|^2}{\left|A\sin\left(\dfrac{D/2}{D}\right)\right|^2} = \left|\frac{\sin(1/4)}{\sin(1/2)}\right|^2 = 0.27.$$

(*Remember your calculator must be in radian mode!*)

Q11 Correct response D.

In liquid ^{3}He at very low temperatures, two ^{3}He atoms can bind together forming a Cooper pair which behaves as a boson. The superfluidity of ^{3}He is associated with a Bose–Einstein condensation of these Cooper pairs into quantum states of low energy.

1.1 DT/W

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