STAV Publishing 2011

PHYSICS
Unit 3
Trial Examination

SOLUTIONS BOOK

Published by STAV Publishing. STAV House, 5 Munro Street, Coburg VIC 3058 Australia.
Phone: 61 + 3 9385 3999 • Fax: 61 + 3 9386 6722 • Email: stav@stav.vic.edu.au Website: http://www.sciencevictoria.com.au/stavpublishing

ABN 61 527 110 823

AREA 1 – MOTION IN ONE AND TWO DIMENSIONS

Q	Marks	Answer	Solution
1	**1**	**43 kmh^{-1}**	to convert from ms^{-1} to kmh^{-1} multiply by 3.6 $\therefore$ 12 ms^{-1} = 12 × 3.6 = 43.2 kmh^{-1}
2	**2**	**5400 J**	KE = ½ mv^2 = 0.5 × 75 × 12^2 = 5400 J
3	**2**	**900 $kgms^{-1}$**	p = mv = 75 × 12 = 900 $kgms^{-1}$
4	**2**	**360 N**	W = ΔKE = $F_{average}$ × distance 5400 = F_{av} × 15 → $\therefore$ F_{av} = 5400 ÷ 15 = 360 N OR u =12, v = 0, s = 15, a = ? $v^2 = u^2 + 2as$ → a = –4.8 ms^{-2} only magnitude needed $\therefore$ F_{av} = 75 × 4.8 = 360 N
5	**3**	Steve's momentum has been transferred to the Earth, so the total momentum of the Steve-Earth system has been conserved (OR remains constant). His KE has been transformed mainly into heat energy in the brakes and is therefore not conserved. Since KE is not conserved, this was an **inelastic** interaction.	
6	**3**	**5200 N**	Taking the car-trailer system: $F_{net} = F_{applied} - F_{opposing}$ Thrust is the $F_{applied}$, friction is the $F_{opposing}$ Friction on car = 50 × 2500/500 = 250 N Friction on trailer = 50 × 750/500 = 75 N $\therefore$ (2500 + 750) × 1.5 = thrust – (250 + 75) Thrust = 4875 + 325 = 5200 N
7	**3**	**1200 N**	Taking forces on the trailer: F_{net} = T – 75 750 × 1.5 = T – 75 T = 1125 + 75 = 1200 N OR Taking forces on the car: F_{net} = 5200 – (250 + T) 2500 × 1.5 = 5200 – (250 + T) T = 5200 – 3750 – 250 = 1200 N

Q	Marks	Answer	Solution
8	**2**	**4.4 s**	Vertically to the top: v = 0, a = –10, s = 24, t = ? $s = vt - \frac{1}{2} a t^2$ $24 = 0 - \frac{1}{2} \times -10 t^2 \rightarrow t = 2.19$ s (to the top) ∴ total time of flight = 2 × 2.19 = 4.38 s
9	**3**	**35 ms^{-1}**	For the horizontal motion: u = ?, s = 120, a = 0, t = 4.38 $s = ut + \frac{1}{2} a t^2$ $120 = u \times 4.38 \rightarrow u = 27.4$ ms^{-1} For the vertical motion: u = ?, s = 24, t = 2.19, a = –10 v = u + a t $0 = u - 10 \times 2.19 \rightarrow u = 21.9$ ms^{-1} Using pythag gives $U = \sqrt{(27.4^2 + 21.9^2)} = 35.1$ ms^{-1}
10	**2**	**39°**	Since we have the horizontal and vertical initial speeds: $\tan \theta = 21.9 \div 27.4 \rightarrow \theta = 38.6°$
11	**3 + 2**	**1.1×10^4 Nm^{-1}**	Loss of EPE = gain in KE $\frac{1}{2} k x^2 = \frac{1}{2} m v^2$ $\frac{1}{2} k \times 1^2 = \frac{1}{2} \times 12 \times 30^2$ $0.5 k = 5400 \rightarrow k = 10\ 800$ Nm^{-1} This is assuming all the EPE is transformed into the KE of the projectile (in reality it won't be, some will become the KE of the catapult arm).
12	**3**	**1.1 N**	$F_{net} = \frac{mv^2}{r} = 0.05 \times 4^2 \div 0.5 = 1.6$ N to the centre Weight force down = mg = 0.5 N At the top, F_{net} is down and is made up of Tension + W ∴ Tension = 1.6 – 0.5 = 1.1 N
13	**3**	**6 ms^{-1}**	Take the top position as 1.0 m higher than the bottom. At top, $KE = \frac{1}{2} m v^2 = 0.5 \times 0.05 \times 4^2 = 0.4$ J At top, GPE = mgh = 0.05 × 10 × 1 = 0.5 J Total at top = 0.4 + 0.5 = 0.9 J At bottom, GPE = 0 Total is still 0.9 J, so all 0.9 J is KE $0.9 = \frac{1}{2} \times 0.05 \times v^2 \rightarrow v = 6$ ms^{-1}

Q	Marks	Answer	Solution
14	3	In a geostationary orbit, period T = 24 hours = (24 × 60 × 60) = 86 400 s Using Kepler's third law: $\frac{T^2}{r^3} = \frac{4\pi^2}{GM_E}$ → $r^3 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (86\,400)^2 \div (4\pi^2)$ ∴ r = 42 250 474 m or 42 250 km (which is approx 42 000 km)	
15	2	**3073 ms^{-1}**	$v = \sqrt{\frac{GM_E}{r}}$ $= \sqrt{(6.67 \times 10^{-11} \times 5.98 \times 10^{24} \div 42250474)} = 3073\ ms^{-1}$ OR v = 2πr / T $= 2\pi \times 42\,250\,474 \div 86\,400 = 3073\ ms^{-1}$

AREA 2 – ELECTRONICS AND PHOTONICS

Q	Marks	Answer	Solution
1	3	**A_1 = 0.4 A** **A_2 = 0.2 A** **A_3 = 0.2 A**	Calculation of single resistor as 10 Ω gives total resistance of the circuit of 15 Ω and gives $A_1 = 6 \div 15 = 0.4$ A and ∴ $A_2 = A_3 = 0.2$ A
2	3	**108 J**	$R_{total} = (10^{-1} + 10^{-1} + 10^{-1})^{-1} = 3.33\ \Omega$ Energy = Power × time = $V^2 / R \times t$ $E = 6^2 \div 3.33 \times 10 = 108$ J
3	2	**0**	The diode is reverse biased so no current flows.
4	2	**75 Ω**	4 V across R, so 8 V (out of 12) across the 100 & 50 combination. So, using ratio: 4 / 8 = R / 150 OR 4 / R = 8 / 150 → giving R = 75 Ω
5	5	The graph needs to show: 1. A negative sloping line with a gradient of 200 2. 2 flat sections adjoining the ends of the line. 3. V_{out} (V) on the y-axis and V_{in} (mV) on the x-axis 4. ΔV_{out} of ±10 V (typically –10 to 10 but other combinations ok) 5. ΔV_{in} of ±50 mV (typically –50 to 50 but other combinations ok)	

<table>
<tr><th>Q</th><th>Marks</th><th>Answer</th><th>Solution</th></tr>
<tr><td>6</td><td>4</td><td colspan="2">To calculate the amplitude of V_{out} rearrange the gain equation to give:
$\Delta V_{out} = \Delta V_{in} \times \text{gain} = 0.07 \times 200 = 14$ V above and below zero, but V_{out} will clip at 10 V above and below.
Graph must be
1. inverted 2. same frequency
3. clipped 4. clipping at ±10 V</td></tr>
<tr><td>7</td><td>1</td><td>900 Ω</td><td>Reading from the graph, go across to 8°C and up to the line, then across to the resistance value of 900 Ω.</td></tr>
<tr><td>8</td><td>2</td><td>4500 Ω</td><td>When point B is at 5 V, there is a 1 V drop across the 900 Ω thermistor. ∴ R has a 5 V drop across it and must be 5× the size of the thermistor or 4500 Ω.</td></tr>
<tr><td>9</td><td>1 + 2</td><td>B</td><td>A is always fixed at 6 V ∴ not A or alarm always off.
C is always fixed at 0 V ∴ not C or alarm always on.
B is the only point where the voltage changes.
OR
As the temperature drops, the resistance of the thermistor increases according to the graph, and it uses more voltage. ∴ the voltage at point B drops and activates the alarm.</td></tr>
<tr><td>10</td><td>1</td><td>B</td><td>Choice B gives a variation in amplitude over a higher frequency carrier wave. Choice C gives no variation in amplitude but rather a variation of frequency (this is in fact FM – frequency modulation). Choice A is a pure sine wave without a carrier wave.</td></tr>
<tr><td>11</td><td>1</td><td>A</td><td>Choice A shows a signal wave without a carrier wave. The carrier wave generally has a much higher frequency than the signal wave which is then overlaid (or modulated) on the carrier wave (as in choice B).</td></tr>
</table>

Detailed study 1 – Einstein's special relativity

Q	Marks	Answer	Solution
1	**2**	**C**	1 minute is t_0 and 10 minutes is t → $\gamma = t / t_0$ $\gamma = 10 \div 1 = 10$ → $v = c\,(1 - 1/10^2)^{1/2} = 0.995c$
2	**2**	**B**	$\gamma = (1 - 0.8^2)^{-1/2} = 1.67$
3	**2**	**B**	Choice A indicates a speed greater than c which is impossible. The speed of light is constant in all frames of reference so choice C is wrong. Speed doesn't reduce due to relativistic effects so choice D is wrong. For relative motion near the speed of light, Pythagoras theorem cannot be used and "Einstein velocity addition" must be used instead (which is beyond our course) ∴ B.
4	**2**	**D**	Since the brass rod is travelling along with James, nothing changes. These effects only occur when a moving object is observed by a stationary observer.
5	**2**	**D**	$E = m\,c^2 = 1 \times 10^{-3} \times (3 \times 10^8)^2 = 9 \times 10^{13} \approx 10^{14}$ J
6	**2**	**A**	The protons will appear heavier as they accelerate. D could be considered but does not relate to the information in the question.
7	**2**	**D**	$\gamma = (1 - 0.995^2)^{-1/2} = 10$ $m = m_0 \times \gamma = 1.67 \times 10^{-27} \times 10 = 1.67 \times 10^{-26}$ kg
8	**2**	**A**	$\gamma = (1 - 0.2^2)^{-1/2} = 1.02$ and $E_k = (\gamma - 1)\,m_0\,c^2$ $= 0.02 \times 5000 \times (3 \times 10^8)^2 = 9 \times 10^{18}$ J OR At 0.2c, relativistic effects can be ignored, $E_k = ½\,mv^2$ $= 0.5 \times 5000 \times (0.2 \times 3 \times 10^8)^2 = 9 \times 10^{18}$ J
9	**2**	**A**	The torches turn on simultaneously for James inside the carriage, but not for John outside on the platform. John sees the torch coming towards him turn on first, i.e. Stuart's at the back of the carriage.
10	**2**	**A**	This is an example of time dilation. $\gamma = (1 - 0.9^2)^{-1/2} = 2.294$ $t = t_0 \times \gamma$ → $t_0 = 25 \div 2.294 = 10.9$ s
11	**2**	**B**	This is an example of length contraction $L = L_0 \div \gamma = 10 \div 2.294 = 4.36$ m
12	**2**	**B**	In a Newtonian system, there is no change in mass, so the horizontal line on the graph at 1 is correct.

Detailed study 2 – Materials and their use in structures

Q	Marks	Answer	Solution
1	**2**	**B**	All components in an arch are in compression. This allows the use of stone or concrete to be used as these materials are strong under compression.
2	**2**	**B**	All components in an arch are in compression. This allows the use of stone or concrete to be used as these materials are strong under compression.
3	**2**	**B**	The gradient of the graph when under tension (tensile section) gives the Young's modulus. Young's modulus = $\frac{4\times10^{7}}{5\times10^{-4}}$ = 8×10^{10} Nm^{-2}
4	**2**	**D**	Under both tension and compression the graph exhibits no plastic deformation before failure indicating the material is brittle in both tension and compression.
5	**2**	**C**	Stress in compressive section = $\frac{\text{force}}{\text{area}}$ $\therefore$ force = stress × area = $8 \times 10^{7} \times 2 = 1.6 \times 10^{8}$ N Mass = force ÷ g = $1.6 \times 10^{8} \div 10 = 1.6 \times 10^{7}$ kg
6	**2**	**A**	Energy per unit volume = area under stress-strain graph = ½ base × height (in compressive section) = $\frac{1}{2} \times 15 \times 10^{-4} \times 8 \times 10^{7} = 6.0 \times 10^{4}$ Jm^{-3}
7	**2**	**A**	Energy = energy per unit volume × volume Energy = $6.0 \times 10^{4} \times 18 \times 2 = 2.16 \times 10^{6}$ J
8	**2**	**D**	Young's modulus = gradient = $8 \times 10^{7} \div (15 \times 10^{-4}) = 5.33 \times 10^{10}$ $Y = \frac{\sigma}{\varepsilon} = \frac{F \times l_0}{A \times \Delta l} \rightarrow \Delta l = \frac{F \times l}{A \times Y}$ = $100\,000 \times 18 \div (2 \times 5.33 \times 10^{10}) = 1.69 \times 10^{-5}$ m
9	**2**	**B**	The strongest material has the highest stress before failure $\therefore$ material B.
10	**2**	**C**	The toughest material absorbs the most energy before failure i.e. the largest area under its stress vs strain graph $\therefore$ material C.

Q	Marks	Answer	Solution
11	2	C	T_3 supports the 2 kg light therefore it is supporting a 20 N weight. The tension therefore must be 20 N.
12	2	D	All the components are in tension so they can all be replaced by a rod. Rods can be equally good under tension or compression.

Detailed study 3 – Further electronics

Q	Marks	Answer	Solution
1	2	D	W is a diode which does the rectification.
2	2	D	Y is a zener diode and resistor which is the voltage regulator.
3	2	A	Z is the load resistor.
4	2	A	The voltage follows the turns ratio of 24 : 1 so 240 V steps down to 10 V.
5	2	A	$P = V I = 240 \times 0.02 = 4.8$ W max (all values are RMS)
6	2	B	Using the same power on the secondary side, 4.8 W $I = P / V = 4.8 \div 10 = 0.48$ A or 480 mA
7	2	C	AB is after rectification by the single diode, but before smoothing $\therefore$ C.
8	2	B	CD is after rectification and after smoothing $\therefore$ B.
9	2	A	EF is after rectification, smoothing and regulation to a constant voltage $\therefore$ A.
10	2	B	A zener diode works when reverse biased. The reverse bias section is where the graph is negative and the voltage is where the graph goes vertical, i.e. 6 V. $I = V / R = 6 \div 2400 = 2.5$ mA
11	2	C	R_1 has 6 V across it too. $I = V / R = 6 \div 240 = 25$ mA
12	2	B	$V_{ripple} = V_{max} - V_{min}$ $V_{ripple} = 50 \text{ mV} - 30 \text{ mV} = 20 \text{ mV}$