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PHYSICS
Unit 3
Trial Examination

SOLUTIONS BOOK

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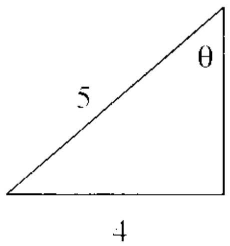
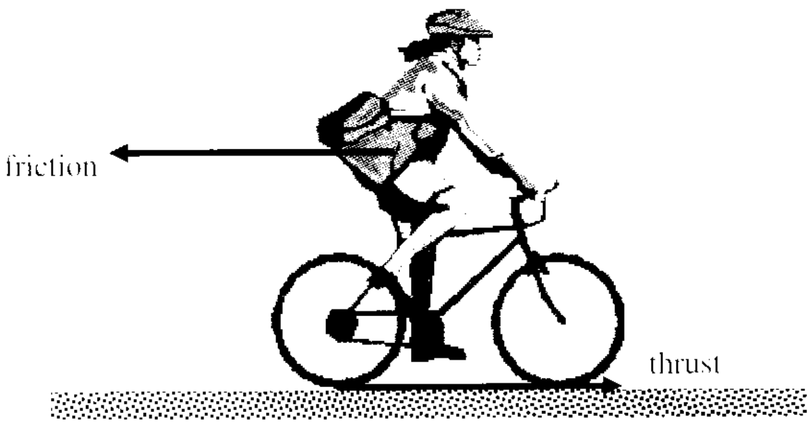
SEMESTER 1

AREA 1 – MOTION IN ONE AND TWO DIMENSIONS

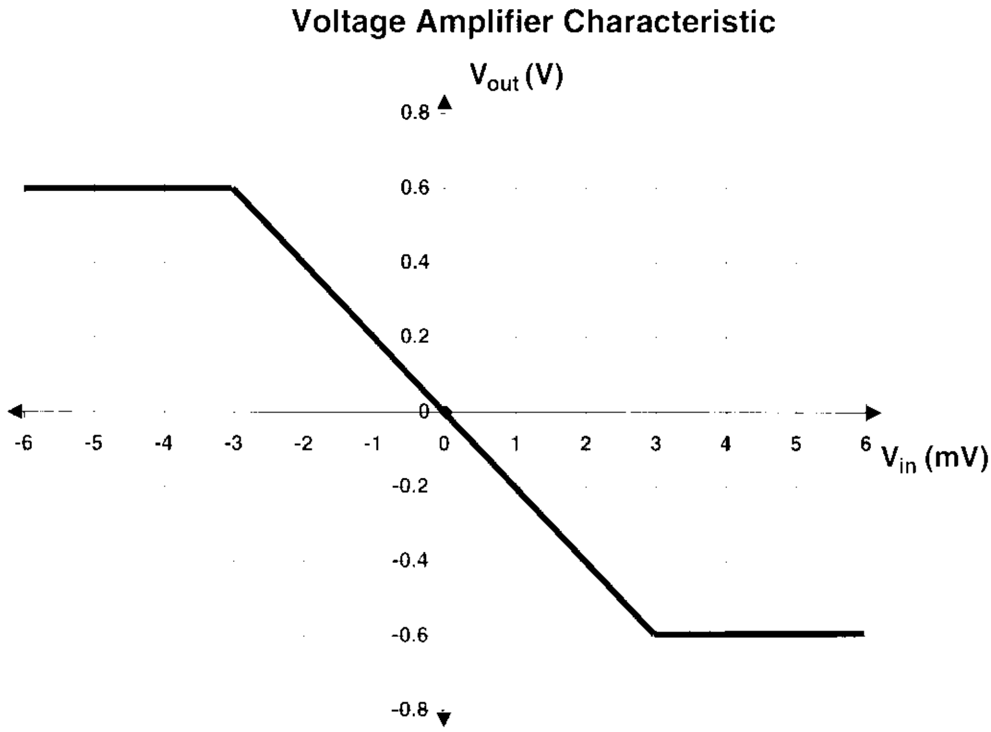
Q	Answer	Solution
1	**24 s**	time = distance ÷ speed = 120 ÷ 5 = 24 s
2	**233 °**	 $\sin\theta = \frac{4}{5}$ $\theta = \sin^{-1}\left(\frac{4}{5}\right)$ $\theta = 53.13°$ bearing = 180 + 53 = 233°
3	**$3\ m\ s^{-1}$**	bearing triangle above must be a 3 : 4 : 5 triad ∴ speed relative to river bottom is $3\ m\ s^{-1}$
4	**40 s**	time = distance ÷ speed = 120 ÷ 3 = 40 s *consequential answer:* 120 ÷ answer 3
5	**2.25 m**	Vertically: $u = 10 \sin 30° = 5\ m\ s^{-1}$, $v = 0\ m\ s^{-1}$ (at the top). $a = -10\ m\ s^{-2}$, $s = ?$ $v^2 = u^2 + 2as$ $0 = 5^2 - 20s$ $20s = 25$ $s = 1.25$ m height = 1.25 + 1.0 = 2.25 m
6	**1.0 s**	Vertically: $u = 5\ m\ s^{-1}$, $v = 0\ m\ s^{-1}$ (at the top), $a = -10\ m\ s^{-2}$, $t = ?$ $v = u + at$ $0 = 5 - 10t$ $10t = 5$ $t = 0.5$ s to the top ∴ total flight time = 1.0 s
7	**8.67 m**	Horizontally: $u = 10 \cos 30° = 8.67\ m\ s^{-1}$ $s = ut = 8.67 \times 1.0 = 8.67$ m
8	**E**	Once the car is in flight, the only forces acting on it are air resistance (negligible) and gravity downwards in direction E.

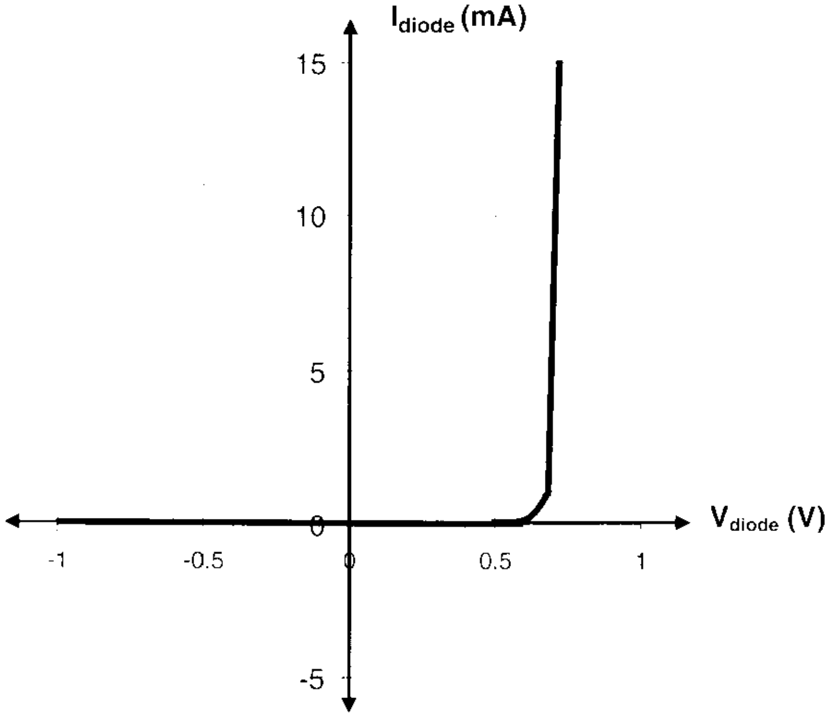
Q	Answer	Solution
9		
10	**400 N**	constant speed is reached when driving force = frictional forces after 80 m, frictional forces = 400 N = driving force
11	**4×10^4 J**	Work done = driving force × distance = 400 × 100 = 40,000 J *consequential answer:* answer 10 × 100
12	**2000 W**	Power = $\frac{\text{work}}{\text{time}}$ = 40,000 ÷ 20 = 2000 W *consequential answer:* answer 10 ÷ 20
13	**0.625 m s^{-2}**	at 60 m, frictional forces = 350 N, driving force = 400 N ∴ F_{net} = 400 − 350 = 50 N acceleration = F_{net} ÷ mass = 50 ÷ 80 = 0.625
14	**C**	The gravitational pull of the Earth continues to provide the centripetal force required to keep the wrench in circular motion around the Earth even though the wrench is no longer in contact with the astronaut.
15	**2.73×10^{-3} N kg^{-1}**	$g = \frac{GM_E}{r^2}$ $= (6.67 \times 10^{-11} \times 5.98 \times 10^{24}) \div (3.82 \times 10^8)^2 = 2.73 \times 10^{-3}$
16	**1.02×10^3**	$v = \sqrt{\frac{GM_E}{r}} = \sqrt{(6.67 \times 10^{-11} \times 5.98 \times 10^{24} \div (3.82 \times 10^8))} = 1021.8$
17	**11 m s^{-1}**	$p_i = m_{van} \times v_{van} + m_{car} \times v_{car} = 2200 \times 15 + 710 \times 0 = 33{,}000$ kg m s^{-1} conservation of momentum gives $p_f = p_i = (m_{van} + m_{car}) \times v_{van\,\&\,car}$ $33{,}000 = (2200 + 710) \times v \rightarrow v = 33{,}000 \div 2910 = 11.34$

Q	Answer	Solution
18	**37.4 m**	work done to overcome friction = loss of kinetic energy $F_{friction} \times s = \frac{1}{2} m v^2$ $5000 \times s = \frac{1}{2} \times 2910 \times 11.34^2$ $s = 187{,}106.6 \div 2910 = 37.4$ *consequential answer:* $0.291 \times$ answer 17 squared

AREA 2 – ELECTRONICS AND PHOTONICS

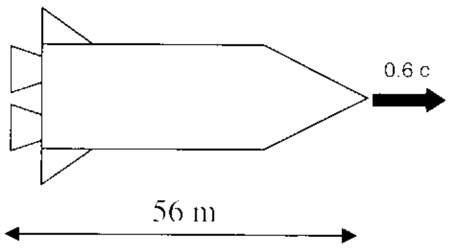
Q	Answer	Solution
1	**37 Ω**	$R_{parallel} = (30^{-1} + 40^{-1})^{-1} = 17.14$ $R_{total} = 17.14 + 20 = 37.14$
2	**5.5 V**	Using the voltage divider formula with $R_1 = 20\ \Omega$ and $R_2 = 17.14\ \Omega$ $V_{20} = 12 \times \left(\frac{17.14}{20 + 17.14} \right) = 5.54\ V$ *Consequential answer:* $205.68 \div$ answer 1 *Students are likely to use many different methods.*
3	**0.32 A**	I_{20} is the same as the current flowing through the whole circuit. $I = \frac{V}{R} = 12 \div 37.14 = 0.3231$ OR $V_{20} = 12 - 5.54 = 6.46\ V\ \therefore\ I_{20} = 6.46 \div 20 = 0.323$ *consequential answer:* $12 \div$ answer 1
4	**3 V**	Reading from the graph, 20 lux corresponds to a resistance of 600 Ω. $V_{out} = 9 \times \left(\frac{300}{300 + 600} \right) = 3$

Q	Answer	Solution
5		gain = $\frac{\Delta V_{out}}{\Delta V_{in}}$ → $\Delta V_{out} = \Delta V_{in} \times$ gain = 6 × 200 = 1200 mV or 1.2 V, equivalent to ± 0.6 V ∴ a sloping line is drawn on the graph from (−3, 0.6) to (0.3, −0.6) hence having a gradient of −200 (− for inverting, and 200 for the gain). Either side of the sloping line are two horizontal sections *(not necessary for full marks)*. 
6	**−0.6 V**	For any input voltage above 3 mV, the output voltage will remain at −0.6 V. 4 mV is beyond the linear operating range of the amplifier. *(No mention of cut-off or saturation is necessary for full marks.)*
7	**2.1 mV**	$V_{peak} = \sqrt{2} \times V_{rms} = \sqrt{2} \times 1.5 = 2.121$
8	**120 Hz**	input and output AC voltages will have the same frequency, just different peak values.

<table>
<tr><th>Q</th><th>Answer</th><th>Solution</th></tr>
<tr><td>9</td><td colspan="2">

Line follows the x-axis from the left until about 0.7 V where it curves upwards indicating that the diode starts conducting when this voltage is applied across it.</td></tr>
<tr><td>10</td><td>220 kΩ</td><td>voltage drop across $R_b = 6 - 0.7 = 5.3$ V
$R_b = V \div I = 5.3 \div (24.1 \times 10^{-6}) = 219.917\ \Omega = 220\ k\Omega$</td></tr>
<tr><td>11</td><td>2.9 V</td><td>$I_c = 100\ I_b = 100 \times 24.1 \times 10^{-6} = 0.00241$ A
$V_c = IR = 0.00241 \times 1200 = 2.892$</td></tr>
<tr><td>12</td><td>3.1 V</td><td>$V_{out} = 6 - V_c = 6 - 2.9 = 3.1$
consequential answer: 6 – answer 11</td></tr>
</table>

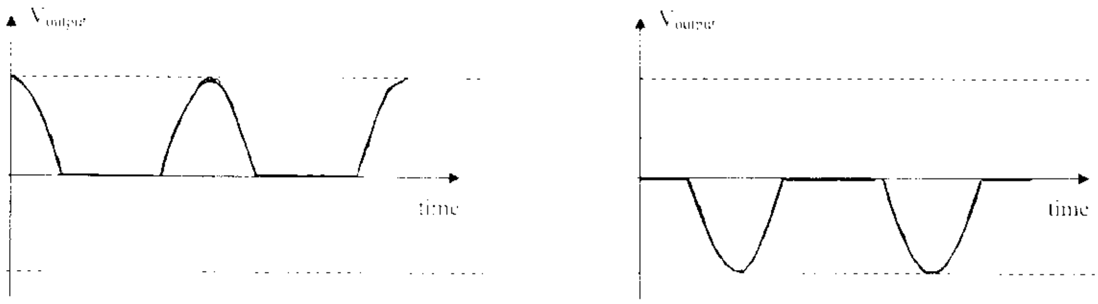
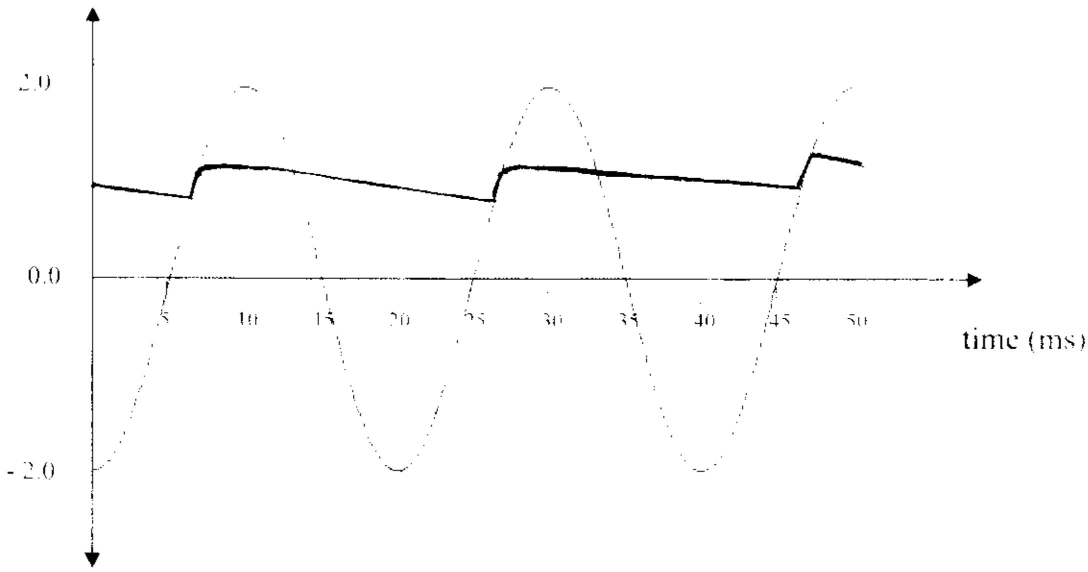
Detailed study 1 – Einstein's special relativity

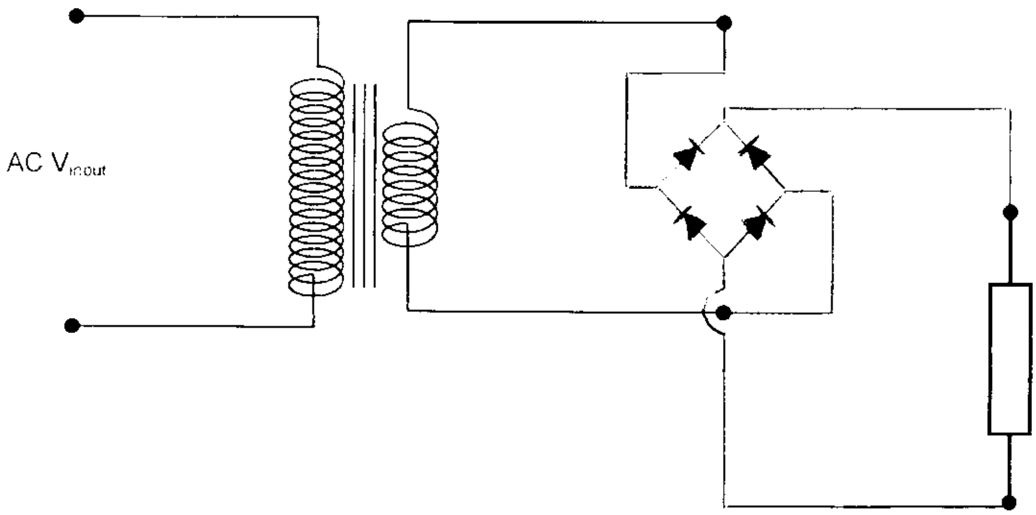
Q	Answer	Solution
1	Maxwell proposed that light was electromagnetic waves that travelled through a medium called the aether (or ether).	
2	The purpose was to measure the speed of the Earth relative to the aether. The outcome was that the experiment failed to measure any movement. The motion of the Earth through the aether was undetectable.	
3	In this instance "proper" refers to the measurement taken by an observer who is at rest relative to the object being observed.	
4	**1.25**	$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{(0.6c)^2}{c^2}}} = \frac{1}{\sqrt{1-0.6^2}} = 1.25$
5	**56 m**	$l = \frac{l_o}{\gamma} = 70 \div 1.25 = 56$ *consequential answer:* 70 ÷ answer 4
6	The spacecraft will be length contracted to 56 m (consequential on Q5). The other dimensions (width and height) will remain the same. 	
7	**91.1 % c**	$t_o = 10.0$ & $t = 24.3$ → $\gamma = t \div t_o = 24.3 \div 10 = 2.43$ $v = c\sqrt{1-\frac{1}{\gamma^2}} = c\sqrt{1-\frac{1}{2.43^2}} = c \times 0.911$ or 91.1 % c
8	The relative velocities of distant stars and galaxies to the observer on Earth causes the light (travelling at a fixed value of c in all frames of reference) to undergo frequency shifts. This means that objects receding from the Earth undergo red shift (longer wavelengths) and those coming towards the Earth are blue shifted (shorter wavelengths) The fact that most objects are receding from the Earth (red shifted) gives credence to the concept of the expanding Universe and the big bang theory.	
9	**1.15×10^{-13} J**	total mass–energy = $\frac{1}{2} m_o v^2 + m_o c^2$ $= \frac{1}{2} \times 9.1 \times 10^{-31} \times (0.9 \times 3 \times 10^8)^2 + 9.1 \times 10^{-31} \times (3 \times 10^8)^2$ $= 3.31695 \times 10^{-14} + 8.19 \times 10^{-14} = 1.15 \times 10^{-13}$

Detailed study 2 – Investigating materials and their use in structures

Q	Answer	Solution
1	C	Justification is in Q2 below
2		Instability is caused by a high centre of mass (or centre of gravity) and a narrow base. Object C has an equally high c.o.m. as objects A & D, but object C has a narrower base.
3		Brittle materials fail just after their elastic limit. ∴ B. Toughest material has the largest area under its graph. ∴ A. **Material**: Most brittle / Toughest **Graph**: B / A
4		The ductility of material A is indicated on the graph by elastic and plastic regions.
5		Any 2 of the following: 1. Stainless steel has a high tensile strength in order to withstand high forces. 2. Stainless steel resists rusting and so maintains its strength when exposed to the elements (i.e. rain). 3. Stainless steel wire provides good tension for small mass which is important for aircraft.
6	**1.8×10^4 N**	$T = mg = 1.8 \times 10^3 \times 10 = 1.8 \times 10^4$
7		$\sigma = \frac{F}{A} = T \div \frac{\pi d^2}{4} = (1.8 \times 10^4) \div (\pi \times (7.0 \times 10^{-3})^2 \div 4)$ $= (1.8 \times 10^4) \div (3.848 \times 10^{-5}) = 4.677 \times 10^8 = 4.7 \times 10^8$ N m^{-2} (correct to 2 sig figs)
8	**6.6 mm**	$\Delta L = \frac{\sigma L}{Y}$ $= 4.7 \times 10^8 \times 2.8 \div (2 \times 10^{11})$ $= 0.00658$ m $= 0.00658 \times 1000$ mm $= 6.58$ mm
9		The bracing wires and spreaders help to stiffen the thin mast and stop it from moving under the force of the wind on the sail.
10	**1.87 m**	The plank will tip when it exerts no force on the LH trestle. Take torques about the RH trestle & let the distance of the man from the RH trestle when it starts to tip be x: $(20 \times 10) \times 0.5 = (75 \times 10) \times x$ $100 = 750x$ → $x = 100 \div 750 = 0.133$ m from the RH trestle ∴ distance from the end of the plank $= 2 - 0.133 = 1.87$ m

Detailed study 3 – Further electronics

Q	Answer	Solution
1	A single diode will produce a half-wave rectified signal. Half-wave signal can be drawn with either polarity. 	
2	1 kΩ	$\tau = RC \rightarrow R = \tau \div C$ $= 100 \times 10^{-3} \div (100 \times 10^{-6}) = 1000\ \Omega = 1\ k\Omega$
3	the size of the ripple voltage can be calculated by: $V_{ripple} = \dfrac{V_{max}T}{RC}$ $= 2 \times 20 \times 10^{-3} \div (1000 \times 100 \times 10^{-6}) = 0.4$ V OR since $\tau = 100$ ms and the period of the signal = 20 ms, there will be only a small ripple voltage and this can be drawn on the graph. Remember that the diode will take out about 0.7 V, lowering the graph significantly. 	

Q	Answer	Solution
4	20 V	$V_{load} = I \cdot R_{load} = 2 \times 10 = 20$
5	100 turns	$\frac{N_S}{N_P} = \frac{V_S}{V_P}$ → $N_S = 20 \times 1200 \div 240 = 100$ *consequential answer:* answer 4 × 5
6	40 W	$P_{input} = P_{output} = V_S \times I_S = 20 \times 2 = 40$ W *consequential answer:* answer 4 × 2
7	0.17 A	$\frac{I_P}{I_S} = \frac{N_S}{N_P} = \frac{V_S}{V_P}$ → $I_P = 100 \times 2 \div 1200 = 0.17$ OR $I_P = 20 \times 2 \div 240 = 0.17$ *consequential answer:* answer 5 ÷ 600 OR answer 4 ÷ 120
8		Full-wave rectification is achieved by using a 4-diode bridge.  Note that the diodes in the bridge must be oriented correctly for the circuit to work.
9		Add a capacitor between the bridge rectifier and the load resistor in parallel with the load resistor. (Can be shown on the diagram).
10	120 mV	The peak value of the signal covers 1.2 cm $V_{peak} = 1.2$ cm × 100 mV cm^{-1} = 120 mV
11	16 ms	The period of the signal covers 1.6 cm T = 1.6 cm × 10 ms cm^{-1} = 16 ms