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PHYSICS
Unit 3
Trial Examination

SOLUTIONS BOOK

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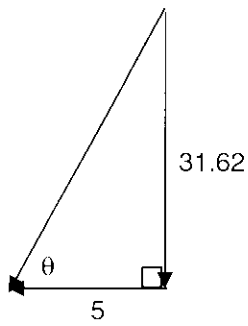
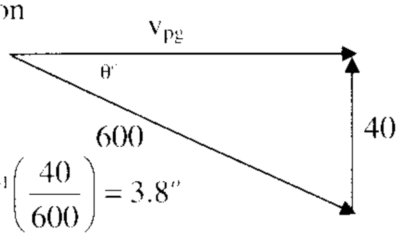
SEMESTER 1

Physics Unit 3 2005 Solutions

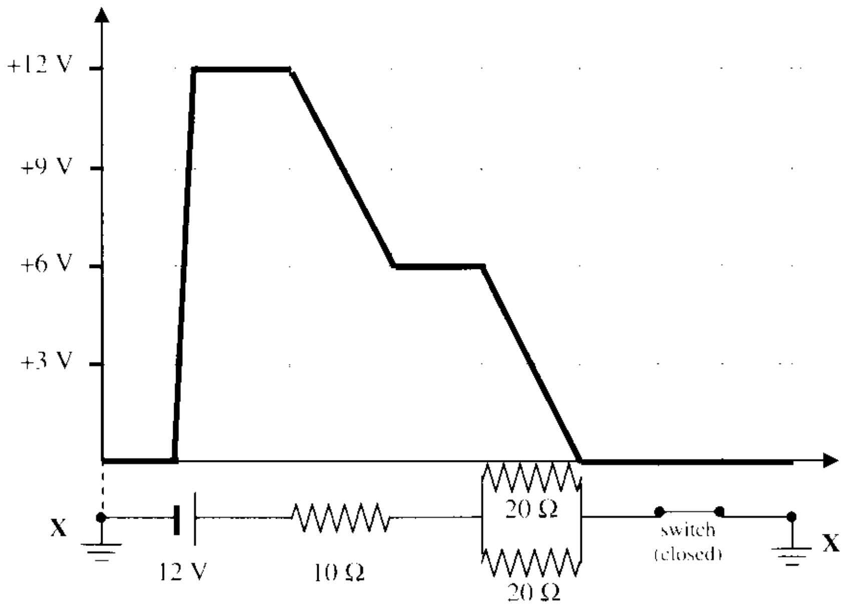
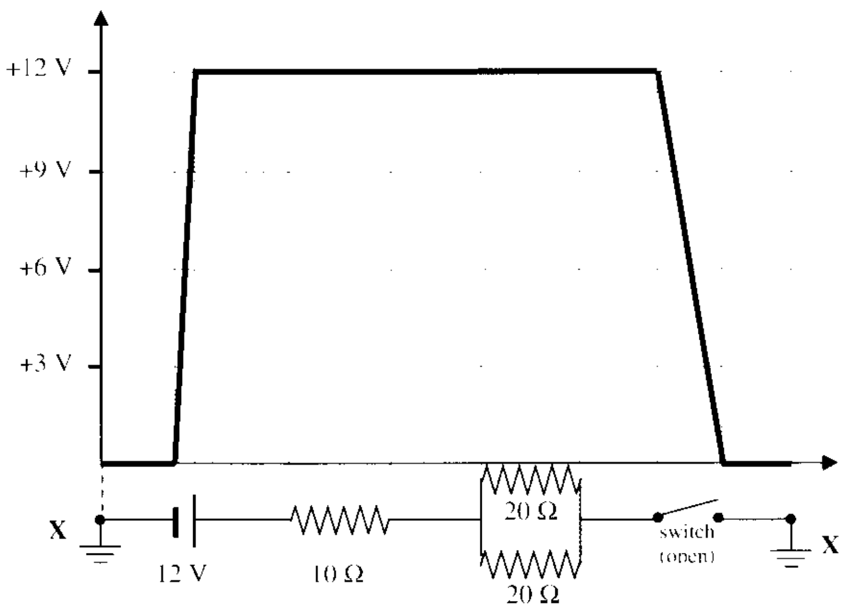
Area of study 1 – Motion in one and two dimensions

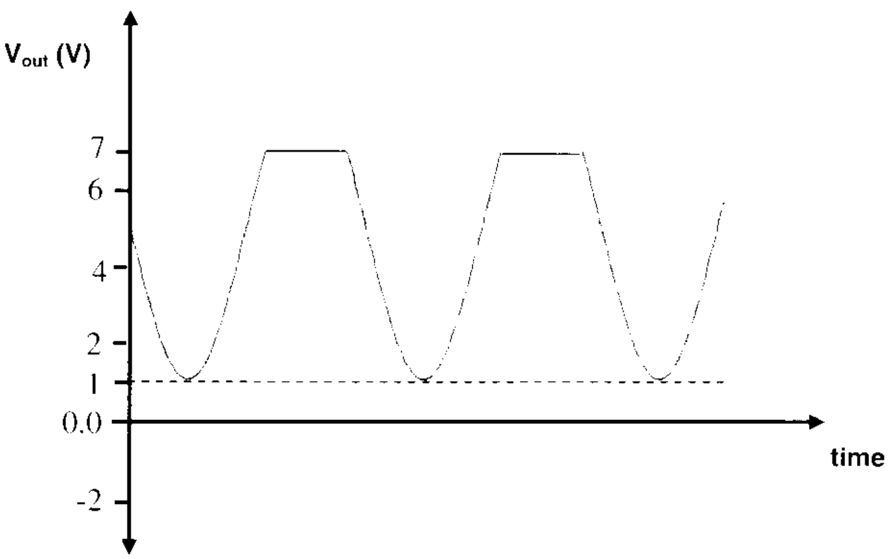
Q	Answer	Solution
1	**3.2 s**	***Vertically:*** $s = ut + \frac{1}{2}at^2$ $u = 0$ $51 = 0 + \frac{1}{2} \times 9.8 \times t^2$ $a = 9.8$ $51 = 4.9\,t^2$ $s = 51$ $t = \sqrt{(51 \div 4.9)}$ $t = ?$ $t = 3.226$
2	**32 m s^{-1}**	***Vertically:*** $v^2 = u^2 + 2as$ $u = 0$ $v^2 = 0^2 + 2 \times 9.8 \times 51$ $a = 9.8$ $v^2 = 999.6$ $s = 51$ $v = \sqrt{(999.6)} = 31.62$ $v = ?$ The speed is found vectorially using Pythagoras. $speed^2 = 31.62^2 + 5^2$ $speed = \sqrt{1024.6}$ $speed = 32.009$ 
3	**81°**	$\tan\theta = \dfrac{31.62}{5} \quad \Rightarrow \quad \theta = \tan^{-1}\left(\dfrac{31.62}{5}\right)$ $\therefore \theta = 81.01^\circ$
4	**B**	At Top GPE = mgh = mg × 51 = 51mg At 10.2 m from bottom GPE = 10.2 mg ∴ Kinetic energy = 51 mg – 10.2 mg = 40.8 mg $\dfrac{GPE}{KE} = \dfrac{10.2\,mg}{40.8\,mg} = \dfrac{1}{4}$ or 1:4
5	**3.3 × 10^4 kg m s^{-1}**	$p = mv = 2200 \times 15 = 33000$

6	In order for the two vehicles to come to a dead stop after the collision they must have equal and opposite momentum before the collision. $33000 = 910 \times u_{car}$ → $u_{car} = 33000 \div 910$ $u_{car} = 36.26$ m s^{-1} but 50 km/h = 13.89 m s^{-1} Yes the car was **SPEEDING** i.e. exceeding the speed limit!	
7	**4.5×10^3 N**	***Van:*** u = 15 v = 0 t = 0.20 a = ? $v = u + at$ $0 = 15 + a \times 0.2$ $-a \times 0.2 = 15$ $a = -15 \div 0.2 = -75$ ms^{-2} $F = ma = 50 \times -75 = -4500$ Magnitude only, so F = 4500 N OR $p_i = 60 \times 15 = 900$ $p_f = 0$ $\Delta p = -900 = F_{av} \times t$ $\therefore F_{av} = -900 \div 0.2 = 4500$ Magnitude only, so F = 4500 N
8	The driver's inertia keeps him moving in a straight line. As the car turns to the right the driver will feel he is moving outwards relative to the car. His feeling of a force pushing him 'out' is in fact his reaction force to the force from the car pushing him around the curve.	
9	**19 m s^{-1}**	$F_c = 0.30 \times mg = \frac{mv^2}{r}$ $v^2 = 0.30 \times rg = 0.30 \times 120 \times 9.8 = 352.8$ $v = \sqrt{352.8} = 18.78$
10	**S 87° E or 93° T**	v_{pa}= 600 km/h unknown direction v_{ag} = 40 km/h North v_{pg} = unknown speed East  $\sin\theta = \frac{40}{600}$ ⇒ $\theta = \sin^{-1}\left(\frac{40}{600}\right) = 3.8°$ ∴ bearing = 90 + 3.8 = 93.8° True or South 86.2° East
11	**200 N m^{-1}**	k = the gradient of the graph $k = \frac{rise}{run} = \frac{120}{0.6} = 200$

12	**36 J**	EPE → KE EPE = ½ kx^2 = ½ × 200 × 0.6^2 = 36 J
13	**D**	$gravity = g = \frac{Gm}{r^2} \Rightarrow g \, \alpha \, \frac{1}{radius^2}$ An altitude of 2 × r_m is a radius of 3 × r_m The gravitational field will therefore be reduced by a factor of $\left(\frac{1}{3^2}\right) = \left(\frac{1}{9}\right)$ This is $\frac{g_m}{9}$, answer **D.**
14	**2.6 × 10⁸ J**	The increase in KE = decrease in GPE. The change in GPE per kg is given by the area under the field vs altitude graph. Area = 35 squares × 100000 × 0.5 = 1.75 × 10^6 J kg^{-1} Change in KE is then =1.75 × 10^6 J kg^{-1} × 150 kg Δ KE = 2.695 × 10^8 J
15	**540 N**	Read from the graph that at the surface of Mars g_m = 3.6 N kg^{-1} W = mg = 150 × 3.6 = 540
16	**3.19 × 10^4 s**	At $2r_m$ above the surface of Mars g = $\frac{3.6}{9}$ = 0.4 N kg^{-1} And r = 3 × r_m $g = \frac{4\pi^2 r}{T^2} \Rightarrow 0.4 = \frac{4\pi^2 \times 3 \times 3.43 \times 10^6}{T^2}$ $T^2 = \frac{4\pi^2 \times 3 \times 3.43 \times 10^6}{0.4} = 1.0156 \times 10^9$ $T = 31868\ s$

Area of study 2 – Electronics and photonics

1	 The two 20 Ω resistors in parallel are equivalent to a single 10 Ω resistor, ∴ the potential difference will be 6 V across the single 10 Ω resistor and 6 V across the parallel combination.
2	 The switch is open, so no current flows in the circuit so there is no potential difference across the resistors. The whole 12 V drops across the switch.

3	**3.2 V**	40 lux → R = 400 Ω from the graph $V_{out} = \left(\frac{400}{400+350}\right) \times 6 = 3.2$
4	**10000** **or** **10^4**	The magnitude of the slope of the amplifier characteristic gives the gain of the amplifier. $gain = \frac{6}{0.6\times10^{-3}} = 10000$
5	Inverting means that a small positive change in the input voltage results in a large negative change in the output voltage. Conversely a small negative change in the input voltage results in a large positive change in the output voltage. This is indicated by the negative gradient of the amplifier characteristic.	
6		
7	**1**	Amplification should NOT change the frequency of the input signal.
8	**−0.3 mV**	Bias is the voltage value at the centre of the linear section of the characteristic graph = 0.3 mV. To zero bias this amplifier, 0.3 mV needs to be taken off the input signal.

9	**24 μA**	Across R_b: $V_b = I_b \times R_b$ $(6.0 - 0.7) = I_b \times 220 \times 10^3$ $I_b = 5.3 \div (220 \times 10^3)$ $I_b = 2.409 \times 10^{-5}$ $I_b = 24.09\ \mu A$
10	**1.7 V**	$I_c = 150 \times I_b$ $I_c = 150 \times 2.409 \times 10^{-5}$ $I_c = 3.61 \times 10^{-3}$ A Across R_c: $V_c = I_c \times R_c$ $V_c = 3.61 \times 10^{-3} \times 1.2 \times 10^3$ $V_c = 4.34$ $\therefore V_{out} = 6 - 4.34 = 1.66$

Detailed study 1 – Einstein's special relativity

1	The speed of light is so fast that attempting to take visual observations on Earth would give a virtually instantaneous result. To measure the speed of light using relatively short terrestrial distances requires extremely accurate and fast reacting clocks not available in Galileo's time.	
2	**2.3×10^8 m s^{-1}**	The difference between the Earth's position after 6 months is the diameter of the orbit ($2 \times 150 \times 10^9$ m). The time difference is 22×60 s. $v = \frac{2 \times 150 \times 10^9}{22 \times 60} = 2.272 \times 10^8$
3	**1**	The speed of the ball is much less than the speed of light so no time dilation will be observable. The times for the two observers will be the same.
4	**1/7** **or** **1:7**	Steve sees the speed of the ball as 5 m s^{-1}. Sophie sees the ball's speed as 5 + 30 = 35 m s^{-1} ratio $= \frac{5}{35} = \frac{1}{7}$
5	**9.6 years**	$t = \frac{d}{v} = \frac{4.3 + 4.3}{0.9} = 9.56\ years$

6	**4.2 years**	$t_o = \sqrt{1 - \frac{v^2}{c^2}} \times t = \sqrt{1 - \frac{(0.9c)^2}{c^2}} \times 9.6$ $t_o = \sqrt{1 - 0.81} \times 9.6 \qquad \therefore \gamma = 2.29$ $t_o = 0.436 \times 9.6 = 4.18$
7	**1.9 light years**	$l = \frac{l_o}{\gamma} = \frac{4.3}{2.29} = 1.875$
8	**0.87 c**	$l = \frac{l_o}{\gamma} \quad \Rightarrow \quad 20 = \frac{40}{\gamma}$ $\therefore \gamma = \frac{40}{20} = 2$ $v = c\sqrt{1 - \frac{1}{\gamma^2}} = c\sqrt{1 - \frac{1}{2^2}} = 0.866\, c$
9	In special relativity, time is relative and the maximum possible velocity is absolute, the speed of light c. This is basically the opposite of the classical physics model.	
10	Light was thought to be a wave. All waves so far observed needed a medium to travel through. For light this hypothetical medium was called the aether. The consequence of the M-M experiment was that there was no experimental evidence for the existence of the hypothesized aether placing the wave theory of light in question. Many scientists at the time continued to search for evidence of the aether or to find fault with the M-M experiment.	
11	**1.5×10^{-10} J**	$E = \gamma m_o c^2$ $E = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} m_o c^2$ $E = \frac{1}{\sqrt{1 - 0.1^2}} 1.675 \times 10^{-27} \times (3.0 \times 10^8)^2$ $E = 1.515 \times 10^{-10}$

Detailed study 2 – Investigating materials and their use in structures

1	**C**	Both conditions are necessary for stability.
2	**A**	A member under tension could be replaced with a rope. The horizontal member seems to be the only one that would remain in tension if replaced with a rope.

3

Material	Rubber	Steel	Glass
Graph	**C**	**A**	**B**

Glass is brittle → **B** Steel is ductile → **A** Rubber is neither → **C**

4

Description	Elastic region	Ductile failure	Plastic region	Maximum stress	Elastic limit
Point or Region	**D**	**C**	**E**	**B**	**A**

5 The large plastic region on the graph indicates that the material is ductile.

6 **Ductile**

It will stretch a small amount until the elastic limit is reached, then the stretching will increase rapidly with the application of little further stress until the material fails.

OR

Ductile materials will become plastic under large loads.

Brittle

This material will stretch a small amount then fracture with no ductile region.

OR

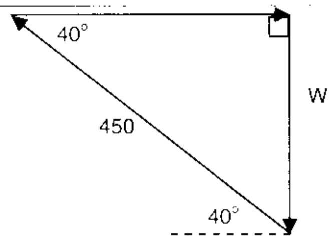
Brittle materials have no yield point and fail under load at their ultimate tensile strength.

7 **29.5 kg**

$$\sin 40^\circ = \frac{W}{450}$$

$$W = 450 \times \sin 40^\circ = 289\ N$$

$$m = \frac{W}{g} = \frac{289}{9.8} = 29.5$$



8 **6.37 × 10^7 N m^{-2}**

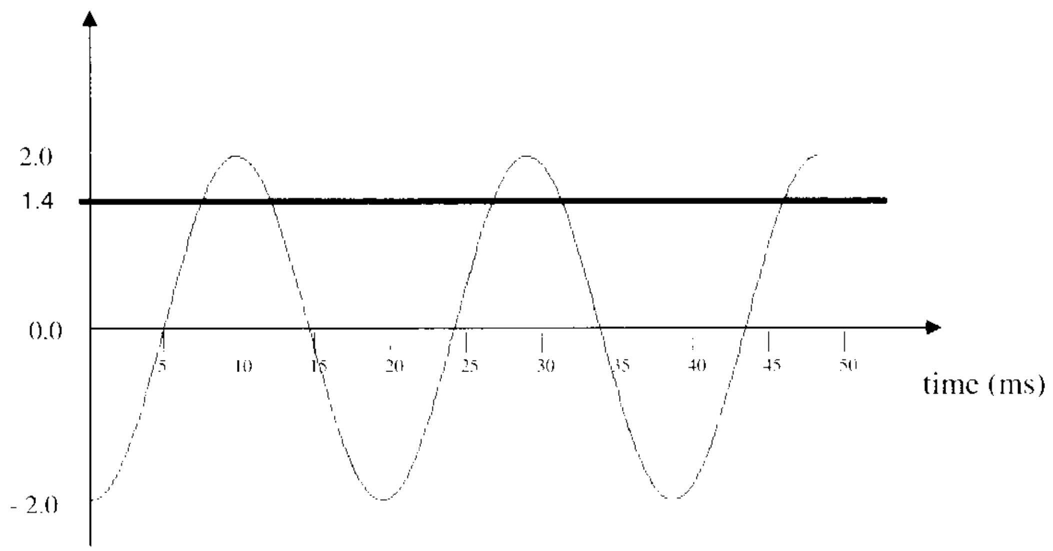
$$\sigma = \frac{F}{A} = 450 \div \left(\frac{\pi d^2}{4}\right) = 450 \div \frac{\pi\left(3\times10^{-3}\right)^2}{4} = 6.366\times10^7$$

9	**5.09×10^{-4} m**	$Y = \frac{\sigma}{\varepsilon} = \frac{\sigma L}{\Delta L} \Rightarrow \Delta L = \frac{\sigma L}{Y}$ $\Delta L = \frac{6.366\times10^7 \times 1.00}{1.25\times10^{4}} = 5.09\times10^{-4}$

Detailed study 3 – Further electronics

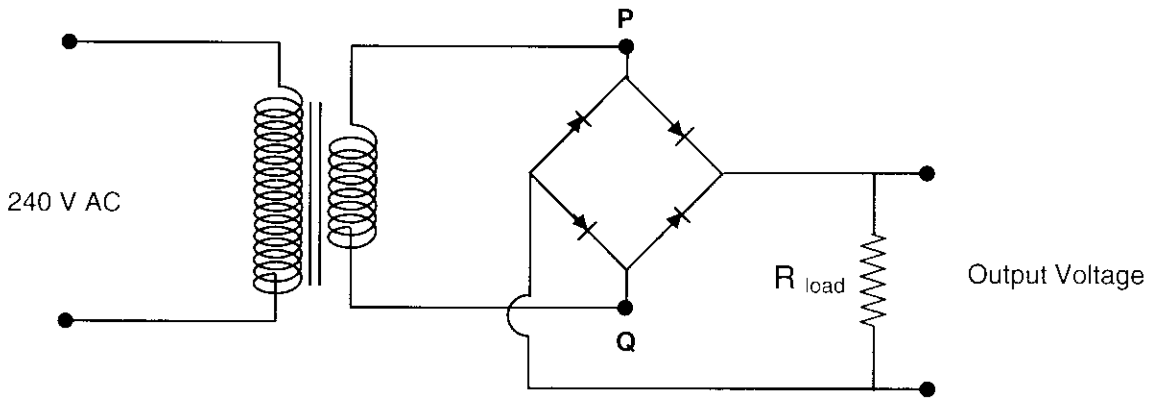
1	**Silicon**	Silicon diodes typically have a switch-on voltage of 0.6-0.7 V while germanium diodes require 0.3 V to switch-on.
2	**B**	The output will be half-wave rectified. This is because the diode only allows the current flowing to the right to pass through it.
3	**3.3 s**	$\tau = RC = 33\times10^3 \times 100\times10^{-6} = 3.3\ s$

4

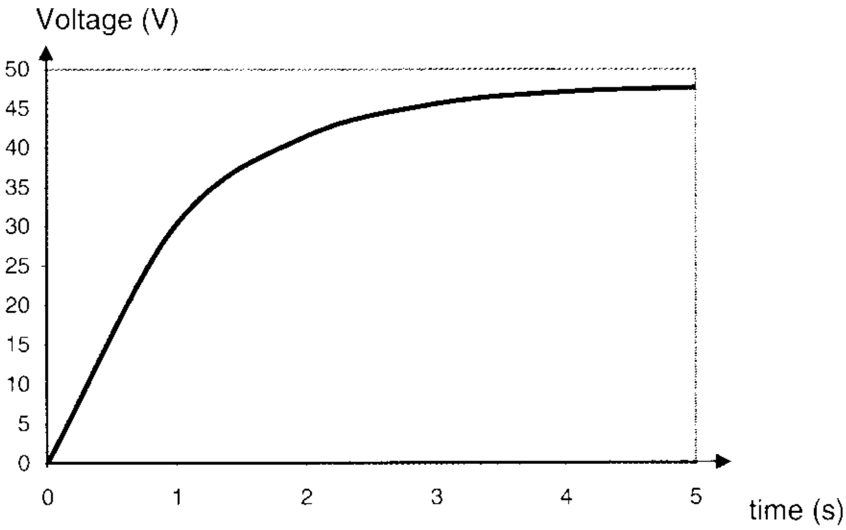


The diode will use 0.6 – 0.7 V which decreases the peak voltage to 1.3 – 1.4 volts. The capacitor will smooth the half wave rectified voltage to a virtually flat line due to the long time constant (3.3 s) compared to the period of the input signal (0.02 s).

∴The output signal will appear as a flat line at ~ 1.3 – 1.4 V with virtually NO ripple voltage.

<table>
<tr><td>5</td><td colspan="2">
</td></tr>
<tr><td>6</td><td>60 turns</td><td>$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow \frac{240}{12} = \frac{1200}{N_2}$
$N_2 = \frac{1200 \times 12}{240} = 60$</td></tr>
<tr><td>7</td><td>C</td><td>Diode Bridge causes full-wave rectification ∴ graph C</td></tr>
<tr><td>8</td><td colspan="2">By placing a large capacitor in parallel across the resistor.</td></tr>
<tr><td>9</td><td colspan="2"><table><tr><th>Situation</th><th>Position</th></tr><tr><td>Charging the capacitor</td><td>X</td></tr><tr><td>Discharging the capacitor</td><td>Y</td></tr></table></td></tr>
<tr><td>10</td><td>5.0 s</td><td>$\tau = RC$
$\tau = 50 \times 10^3 \times 20 \times 10^{-6}$
$\tau = 1.0\ s$
The capacitor is fully charged after ~ 5 time constants.
$\therefore 5\tau = 5$ s</td></tr>
</table>

11



12

Discharge resistor = 250 kΩ compared to 50 kΩ for charging.

$\therefore\ \tau_{discharge} = 5 \times \tau_{charge} = 5 \times 1 = 5$ s

$\therefore$ fully discharged after 25 s