YEAR 12 PHYSICS

STAGE 3

2010

MARKING GUIDE

Section A

1(a) Any reasonable combination of length and force whose product is 6 N m. However the length of the spanner should not exceed say 0.25 m

1(b) A reasonable estimate of the radius of the bolt would be between 0.002 m and 0.004 m. Using these values a force of between 3000 N and 1500 N would represent the frictional force between the bolt and nut.

2(a) Radius = $\sin 45^o \times 1.3 = 0.92$ m

2(b) $F_g = m\,g = (60 \times 10^{-3}) \times 9.8 = 0.588$ N
$F_c = (0.588 \times \tan 45^o) = 0.588$ N towards the centre
Net force (R)
$R^2 = 0.588^2 + 0.588^2$
$R = 0.832$ N

3(a) m = 700 kg
original height = 40 m
negotiated height (h) = 33 m
original potential energy = mgh = $700 \times 9.8 \times 40 = 2.74 \times 10^5$ J
energy to negotiate next hill = mgh = $700 \times 9.8 \times 33 = 2.26 \times 10^5$ J
loss of energy = $(2.74 - 2.2) \times 10^5 = 4.8 \times 10^4$ J

3(b) The energy has not been “lost”. It has been converted into friction, heat and sound.

3(c) The maximum height above the ground the roller coaster car can achieve as it negotiates successive hills and dips is 40 m. As the only energy it commences with is potential energy this limits the vertical distance the car can travel. The 40 m height can only be achieved if the track is frictionless which is unlikely.

4(a) $v = 0$ m s^{-1}
$u = 7$ m s^{-1}
$a = -2$ m s^{-2}
$v^2 = u^2 + 2as$
$0^2 = 7^2 + 2\,(-2)\,s$
$-49 = -4\,s$
$s = 12.3$ m

The boy travels 12.25 m up the ramp before stopping.

4(b) $v = u + at$
$0 = 7 + (-2)\,t$
$2t = 7$
$T = 3.5$ s

5(a) $R = 200\ \Omega$

$I = 30 \times 10^{-3}$ A

$V = I R$

$V = (30 \times 10^{-3}) \times 200$

$V = 6000 \times 10^{-3}$ V

The voltage drop across the resistor is 6.00 V

5(b) Answer is A

5(c) $P = I^2 R$

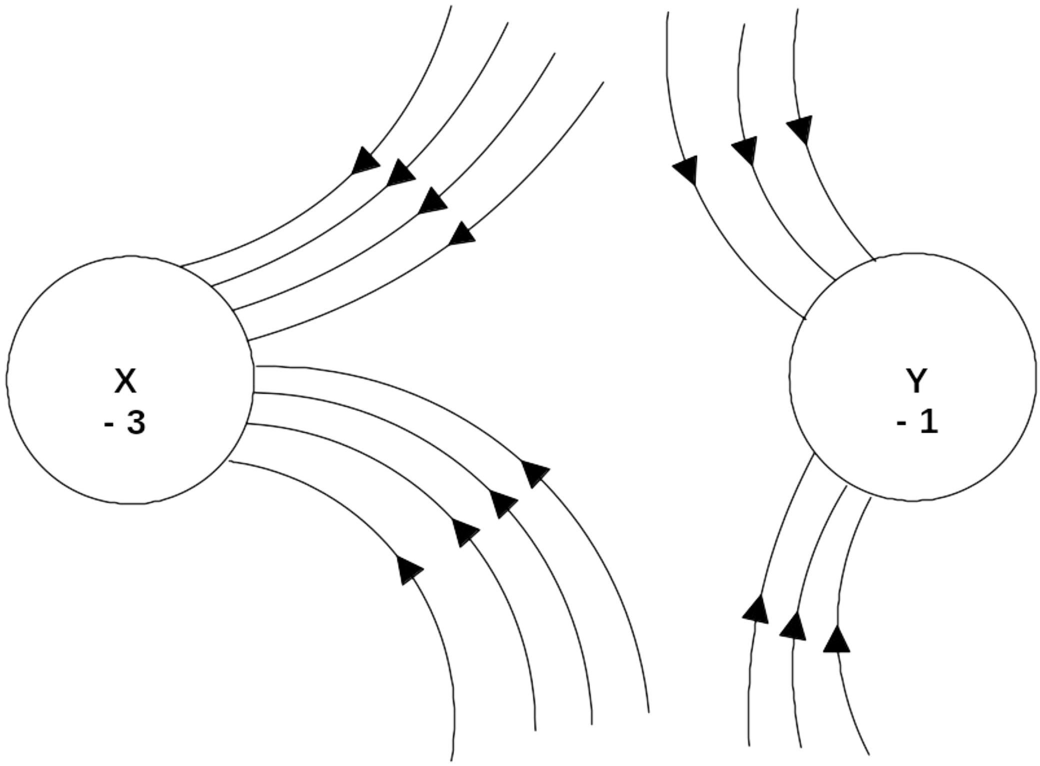
$P = (30 \times 10^{-3})^2 \times 200$

$P = 0.18$ W

6(a) Answer is C

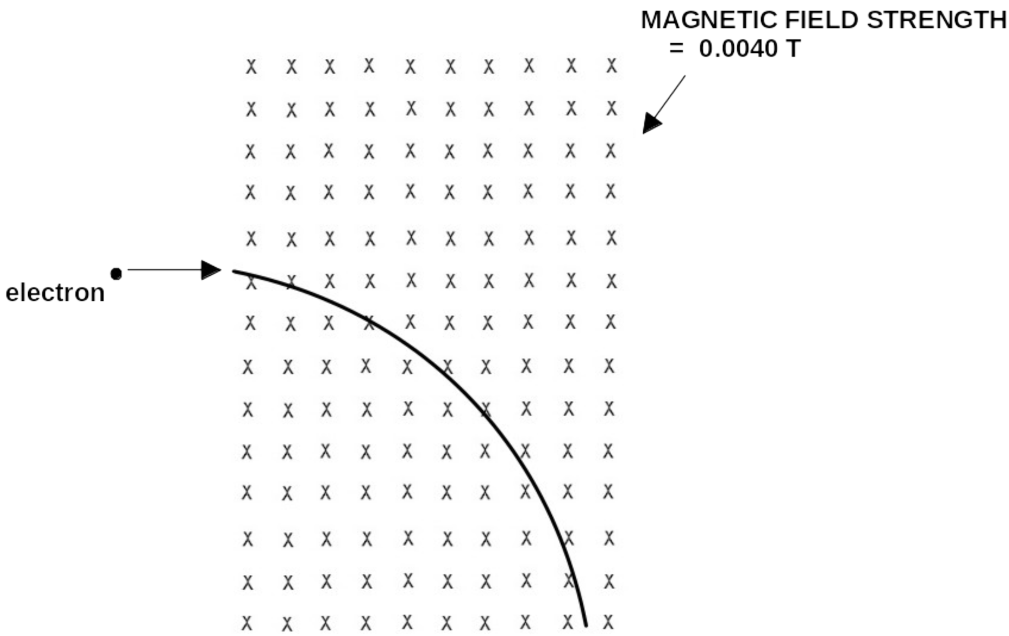
6(b) For an object travelling at relativistic speed, the length in the direction of travel (as seen by a stationary observer) is shorter. The other dimensions remain unchanged.

7



8(a) B= 0.0040 T
v = 1.5 x 10^{6} m s^{-1}
charge on electron = 1.60 x 10^{-19} C
F = ?
F = qvB = (1.6 x 10^{-19}) x (1.5 x 10^{6}) x 0.0040
The force on the electron is 9.6 x 10^{-16} N

8(b)



9(a) V = 12 V
R = (10 + 20) = 30 Ω
V = I R
12 = I x 30
I = 12/30
Current in the resistors is 0.4 A
P = I^{2} R
P = 0.4^{2} x 30
Power produced = 4.8 W

9(b) V = 12 V
1/R = 1/10 + 1/20 = 3/20
so R = 6.67 Ω
V□ = I P
12 = I x 6.67
I = 12/6.67
Total current in the circuit is 1.8 A
Current is divided according to the 10:20 ⇒ 2:1
Current in 10 Ω wire is 1.2 A
Current in 20 Ω wire is 0.6 A
P□ = □I^{2} R
P = 1.8^{2} x 6.67
Total power produced is 21.6 W

10(a) +2/3, +2/3, -1/3

10(b) The charge on a proton is +1. Therefore the sum of charges on the three quarks must add to +1

10(c) +2/3, -1/3, -1/3

10(d) A neutron has no charge. Therefore the sum of the charges on the three quarks must add to 0.

11

Column 1	Column 2 – the same or sometimes different
The **distance** between two given events	Sometimes different
The **time interval** between two given events	Sometimes different
The **mass** of an electron measured at rest	The same

12 $\Delta\lambda = (401.8 - 393.3) \times 10^{-9} = 8.5 \times 10^{-9}$ m
$c = 3 \times 10^{8}$ m s^{-1}
$\lambda = 393.3 \times 10^{-9}$
$v_{galaxy} = \Delta\lambda/\lambda \times c$
$v_{galaxy} = (8.5 \times 10^{-9}/393.3 \times 10^{-9}) \times 3 \times 10^{8}$
The recession speed of the NGC 4889 galaxy is 6.5×10^{6} m s^{-1}

13(a) The aircraft will experience maximum induced EMF when the magnetic lines of force are closest together. This will occur at the poles of the Earth.

13(b) Wingspan of Boeing 747 = approx 60 m
Maximum speed of Boeing 747 = 900 km h^{-1} = (250 m s^{-1})
Earth's magnetic field = 50×10^{-6} T
emf = lvB = $60 \times 250 \times (50 \times 10^{-6})$
emf induced across the wings = 0.75 V

13(c) No. - 0.75 V is a small potential that would not be very useful in providing power for appliances in the aircraft.

14 From the formula and constants sheet the frequency of hard X-rays is approx 10^{20} Hz.
$h = 6,63 \times 10^{-34}$ J s
$E = hf = (6.63 \times 10^{-34}) \times 10^{20} = 6.63 \times 10^{-14}$ J
1 keV = 1.6×10^{-16} J
so $6.63 \times 10^{-14} = 4.1 \times 10^{2}$ keV

15 $c = 3 \times 10^{-8}$ m s^{-1}
time gain = 446×10^{-12} s
In 446×10^{-12} s light travels a distance given by:
$s = v \times t = (3 \times 10^{8}) \times (446 \times 10^{-12}) = 0.134$ m
The distance error per second is 13.4 cm

16(a) As the magnet on the spoke passes the coil it induces a current pulse in the coil which is conducted via the wire to the computer on the handlebars. The computer recognizes successive pulses and measures the time interval between pulses. If the circumference of the wheel (and hence the distance travelled by one complete revolution of the wheel), is programmed into the computer, then the computer calculates the speed using the time interval and the distance.

16(b) It is **not** necessary to mount the magnet on the circumference of the wheel. As long as the magnet is close enough to the coil to induce a current the coil/magnet arrangement can be located at any distance from the axle of the wheel. The time taken for the wheel to complete one revolution is the same no matter where the measurement is recorded within the usual error limitations.
There will be less error in the time reading when the distance travelled by the magnet is at its maximum compared to a shorter distance. So cyclists usually mount the magnet/coil arrangement towards the circumference of the wheel rather than closer to the axle.

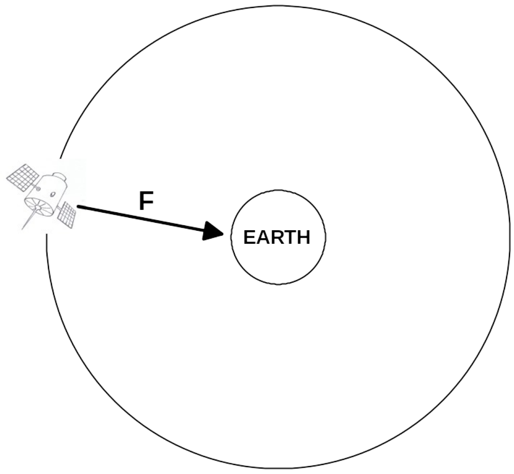
Section B

1(a) $r = 1.45 \times 10^{7}$ m
$m_s = 395$ kg
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
$M_e = 5.98 \times 10^{24}$
$v^2 = GM_e/r$
$v^2 = (6.67 \times 10^{-11}) \times (5.98 \times 10^{24})/(1.45 \times 10^{7})$
$v^2 = 27.508 \times 10^{6}$
$v = 5.20 \times 10^{3}$ m s^{-1}

1(b) $r_e = 6.37 \times 10^{6}$ m
$r_s = 1.45 \times 10^{7}$ m
altitude = $r_s - r_e$
altitude = $(1.45 \times 10^{7}) - (6.37 \times 10^{6})$
the altitude of the satellite = 8.13×10^{6} m

1(c) The force that keeps the satellite in orbit is the centripetal force that acts towards the centre of the orbit. This force is provided by the gravitational attraction between the Earth and satellite.

1(d)



1(e) The satellite would not be in a geostationary orbit. If it was it would remain in orbit above the same location on the Earth and would not be able to map most of the glaciers on Earth. For the mapping to be complete the satellite would be in an orbit other than geostationary.

2(a)

angle = 40^o
speed = 8 km h^{-1} = 2.2 m s^{-1}
a = 9.8 m s^{-2}
h is unknown
convention: let positive be down
To calculate the height (h):
vertical component of the speed is:
sin 40^o = v/2.2
v = sin 40^o x 2.2 = 1.414 m s^{-1}
vertical distance travelled in 2.5 s = 1.414 x 2.5 = 3.535 m
$s = ut + ½ at^2$
s = (-1.414 x 2.5) + ½ (9.8) x 2.5^2
s = -3.535 + 30.625 = 27.1 m
so the helicopter is 27.1 m above the ground when it releases the package.

2(b)

To calculate where the package is with respect to the helicopter:
Because the horizontal speed of the helicopter and the package is the same, and the time of flight is the same, the package will land directly below the helicopter. That is 27.1 m plus the vertical distance the helicopter has travelled during the 2.5 s. That distance is 3.535 m
So the package lands (27.1 + 3.535) = 30.6 m directly below the helicopter.

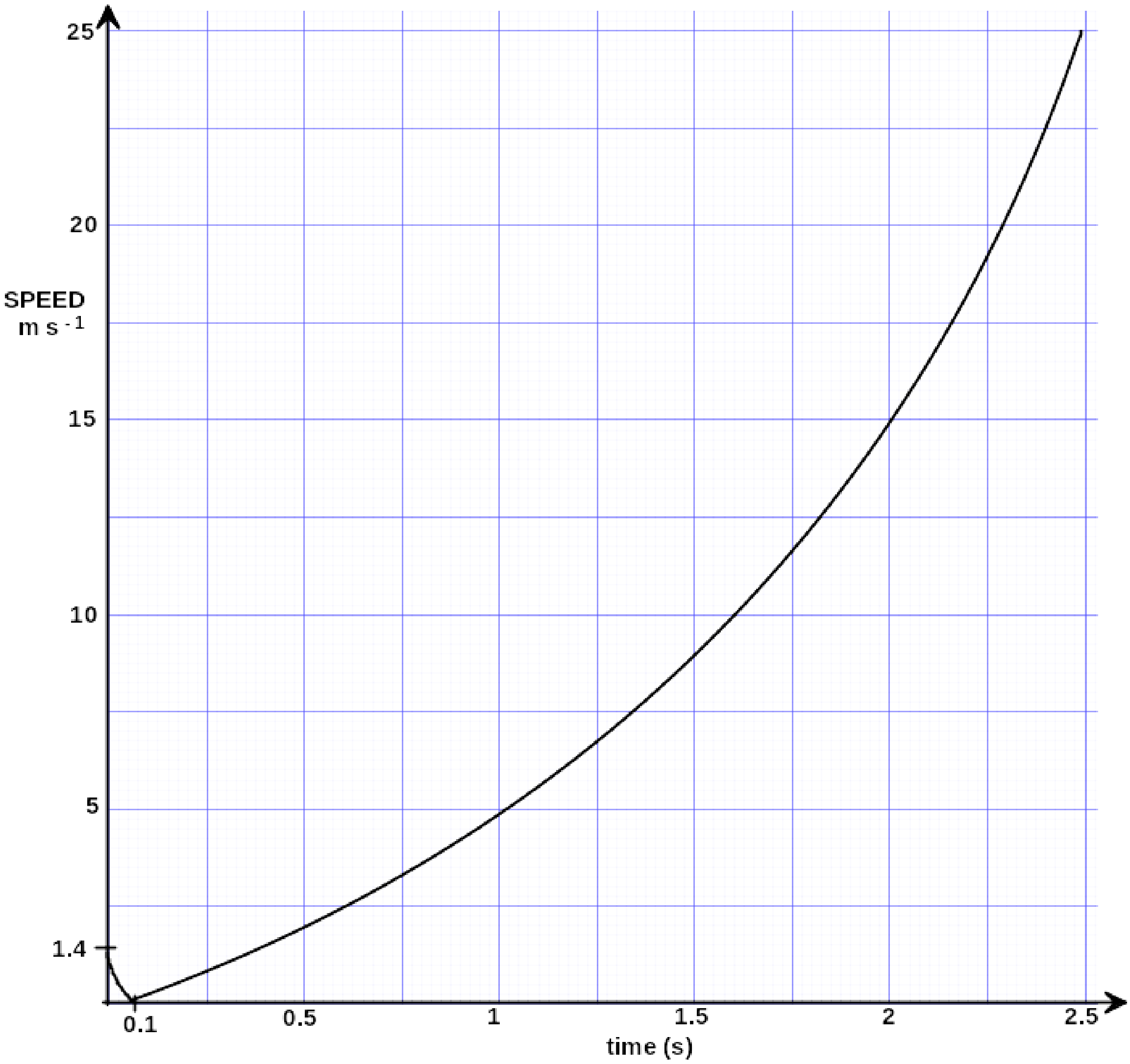
2(c)

To calculate vertical speeds of the package so the graph can be constructed.
Time for the package to reach its highest point (v = 0 m s^{-1})
u = -1.414 m s^{-1}
a = 9.8 m s^{-2}
v = 0 m s^{-1}
t = ?
v = u + at
0 = -1.414 + 9.8 x t
t = 1.414 / 9.8

$t = 0.144$ s
vertical speed of the package when it lands after 2.5 s
$a = 9.8\ m\ s^{-2}$
$u = -1.414\ m\ s^{-1}$
$t = 2.5$ s
$v = ?$
$v = u + at$
$v = -1.414 + (9.8 \times 2.5)$
$v = 23.1\ m\ s^{-1}$

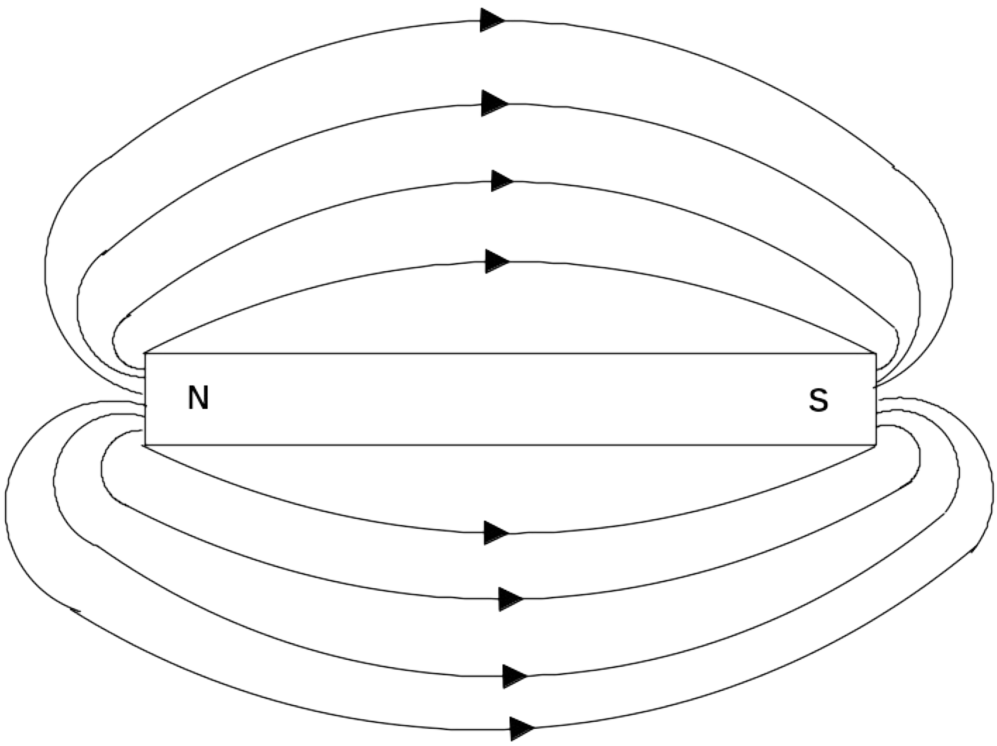
The key points on the graph are:

Time (s)	Speed ($m\ s^{-1}$)
0	1.4 upwards
0.1	0
2.5	23 down



2(d) The package would land further away from the group. The horizontal component of the helicopter velocity is now greater so the package will travel further horizontally than before in the 2.5 seconds it is in flight.

3(a)



3(b) The coil of the motor will rotate in an anticlockwise direction.

3(c) Using the right hand rule, the force on the side JK is downwards and the force on side LM is upwards. This will rotate the coil in the anticlockwise direction about the axis. The forces on the wire are due to the interaction of the field around the coil and the field of the permanent magnet.

3(d) area of coil (A) = 0.15 x 0.20 = 0.03 m^2
number of turns (N) = 1200
magnetic flux (Φ) = 2.5 x 10^{-4} Wb
$\Phi = B A$
$2.5 \times 10^{-4} = B \times 0.03$
$B = 2.5 \times 10^{-4} / 0.03$
$B = 8.3 \times 10^{-3}$ T

3(e) time for ¼ of a revolution = 0.0.015 s (Φ goes from max to 0 during this time)
magnetic flux = 2.5 x 10^{-4} Wb
number of turns = 1200
emf = -N (Φ - Φ)/t
emf = -1200 (2.5 x 10^{-4} – 0)/0.015
emf = 20 V

3(f) The speed of the alternator could be increased by the following changes:
Increase the magnitude of the magnetic field of the magnet.
Increase the number of coils.
Increase the speed at which the coil is rotated.
Increase the area of the coil.

4(a)i Power delivered on each side of the transformer is equal. Voltages are in the ratio of 5 : 1 and transformer is ideal (no energy losses)
$P = V I$
$V_p I_p = V_s I_s$
$5 \times 0.5 = 1 \times A_2$
$A_2 = 2.5$ A

4(a)ii $R = 4\ \Omega$
$I = 2.5$ A
$V = I \times R$
$V = 2.5 \times 4 = 10$ V
Reading on meter V_1 is 10 V

4(a) iii Ratio of turns on primary : secondary :: 5 : 1
current in primary coil = 0.5 A
voltage in primary coil = 10 V ac
Transformer equation $V_s / V_p = N_s / N_p$
$V_s / 10 = 1 / 5$
$V_s = 2.0$ V = the reading on voltmeter V_2

4(b) $V = 2$ V
$I = 2.5$ A
$P = V I = 2 \times 2.5 = 5$ W
Power delivered at the globe is 5 W

4(c) There will be NO power delivered to the globe.

4(d) The battery is DC. For a transformer to work there needs to be a continual change of the magnetic flux. An AC supply provides a fluctuating current which is changing the flux as it alternates between maximum and minimum.

4(e) There would be more resistance in the circuit and so more energy would be lost in transmission. Therefore the energy delivered to the globe would be less, resulting in less power.

4(f) Large currents are responsible for large energy losses in transmission lines so electric power is distributed at high voltages and lower currents to minimize losses. 12 V potential difference would be insufficient to power domestic and industrial appliances. Also if the voltage was DC it could not be used to step up and step down voltages in transformers.

5(a)

$c = 3 \times 10^{8}$ m s^{-1}
$\lambda = 431.1 \times 10^{-9}$ m
$h = 6.63 \times 10^{-34}$ J s
$c = f\,\lambda$
$(3 \times 10^{8}) = f \times (431.1 \times 10^{-9})$
$f = 3 \times 10^{8} / 431.1 \times 10^{-9}$
$f = 6.958 \times 10^{14}$ Hz
$E = h\,f$
$E = (6.63 \times 10^{-34}) \times (6.958 \times 10^{14})$
$E = 4.61 \times 10^{-19}$ J
$c = 3 \times 10^{8}$ m s^{-1}
$\lambda = 486.1 \times 10^{-9}$ m
$h = 6.63 \times 10^{-34}$ J s
$c = f\,\lambda$
$(3 \times 10^{8}) = f \times (486.1 \times 10^{-9})$
$f = 3 \times 10^{8} / 486.1 \times 10^{-9}$
$f = 6.172 \times 10^{14}$ Hz
$E = h\,f$
$E = (6.63 \times 10^{-34}) \times (6.172 \times 10^{14})$
$E = 4.09 \times 10^{-19}$ J

By calculating the energy of the shortest wavelength radiation (431.1 nm) and the next longest wavelength (4.86.1 nm) it demonstrates that the shortest wavelength of those detected has the largest energy.

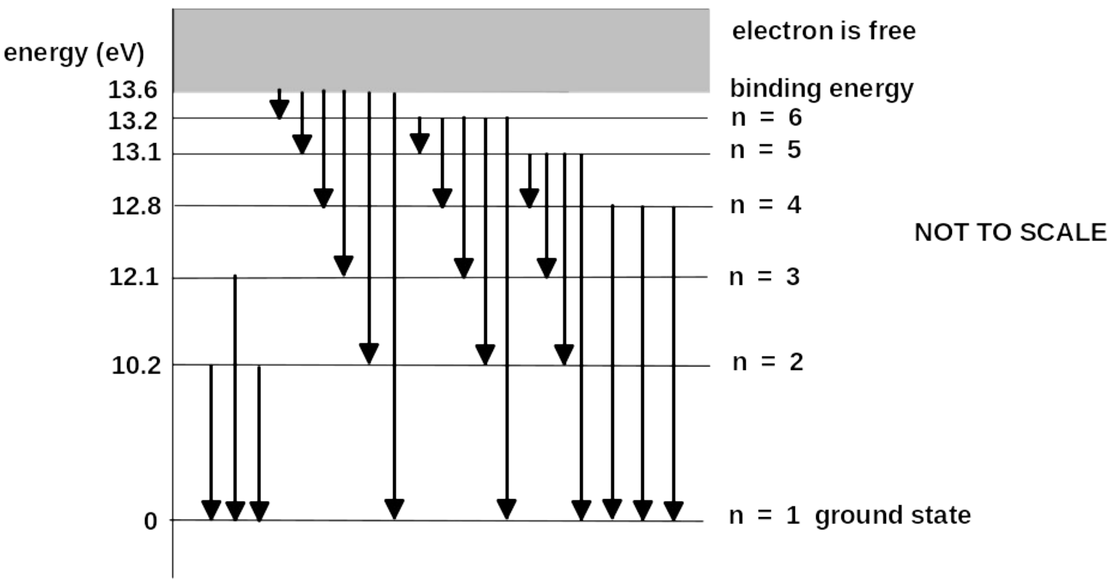
5(b)

Because these radiations have frequencies in the order of 10^{14}, they would appear in the infra red region of the electromagnetic spectrum.

5(c)

The energy required to ionise an electron from the ground state is 13.6 eV
The conversion from eV to joules is: 1 eV = 1.6×10^{-19} J
So the energy in joules is $13.6 \times (1.6 \times 10^{-19}) = 2.18 \times 10^{-18}$ J

5(d)



5(e) The spectrum is an example of a line absorption spectrum.

5(f) The lines are spectral absorption lines. As light travels from the sun to the Earth it encounters various gases in the sun's outer atmosphere. The light interacts with these gases and certain frequencies are absorbed by the atoms, leaving gaps in the visible spectrum when viewed on Earth.

5(g) No these lines would NOT appear on the spectrum produced by an incandescent globe. As the light is not passing through an atmosphere containing gases that will absorb frequencies, there will be no dark lines superimposed on the spectrum.

6(a) The tube with the shortest length would produce the highest frequency note. The wavelength of the fundamental note would be smaller in the short tube compared to the others. Using $v = f\lambda$, if c is a constant and λ is small then the value of f will be greater.

6(b) $f = 440$ Hz
$v = 346 \text{ m s}^{-1}$
λ of fundamental frequency in an open tube is 2 times the length of the tube.
$v = f\lambda$
$346 = 440 \times \lambda$
$\lambda = 346/440 = 0.786$ m
so the length of the tube is ½ of 0.786 = 0.39 m

6(c) The note would be a different frequency. By blocking the tube it is now a closed pipe so the wavelength of the note will be altered. In this case the wavelength is 4 times the length of the tube.

6(d) The note played will have a frequency of ½ the note played when the tube is open. The new frequency in this case would be 220 Hz.

6(e) As the lengths of the tubes remain the same, the frequency of the notes played on the larger diameter will remain the same. However due to the larger quantity of air in the pipes set vibrating, the sounds will be louder. That is the amplitude of the waves will be increased.

6(f) The two waves that superimpose to produce a standing wave must have equal amplitudes, equal frequencies, be travelling in opposite directions and in the same medium.

7 potential = 35 kV
distance between plates = 330 mm
charge on electron = -1.6×10^{-19} C
mass of electron $= 9.11 \times 10^{-31}$ kg
magnetic field strength = 0.300 T

(a) Electric field strength = V/d
Electric field strength = $35 \times 10^{3} / 0.33$
Electric field strength = 1.06×10^{5} N C^{-1}

(b) Energy = W = q V
Energy = $(-1.6 \times 10^{-19}) \times 35 \times 10^{3}$
Energy = 56×10^{-16} J
Energy = KE = $\frac{1}{2} m v^2$
$(56 \times 10^{-16}) = \frac{1}{2} (9.11 \times 10^{-31}) \times v2$
$v^2 = (56 \times 10^{-16}) \times 2 / (9.11 \times 10^{-31}) = 122.9 \times 10^{14}$
$v = 1.11 \times 10^{8}$ m s^{-1}

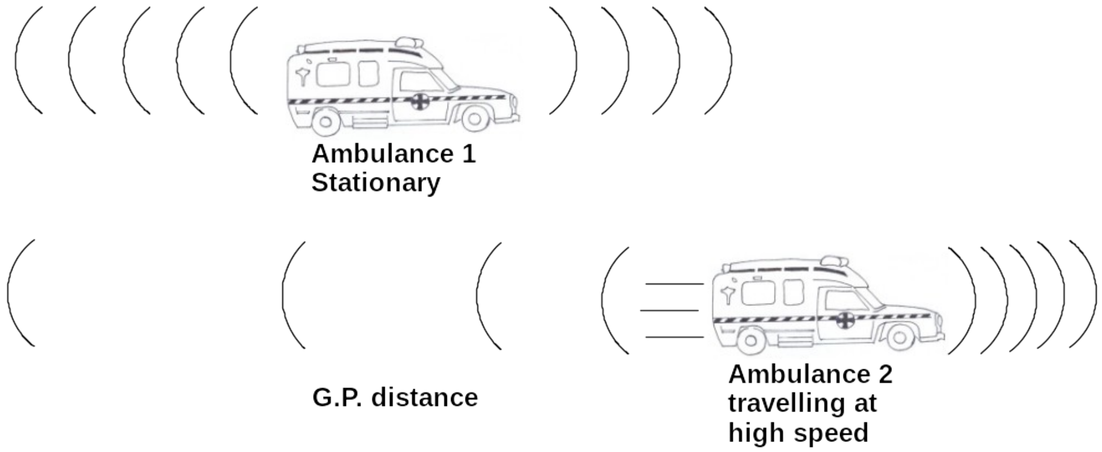
(c) $F = qvB = m v^2/r$
$q B = m v/r$ so $r = m v / q B$
$r = (9.11 \times 10^{-31}) \times (1.11 \times 10^{8}) / (1.60 \times 10^{-19}) \times 0.300$
$r = 0.0021 \times 10^{-3}$ m
The radius is 2.1 mm

Section C

Question 1 The Doppler effect

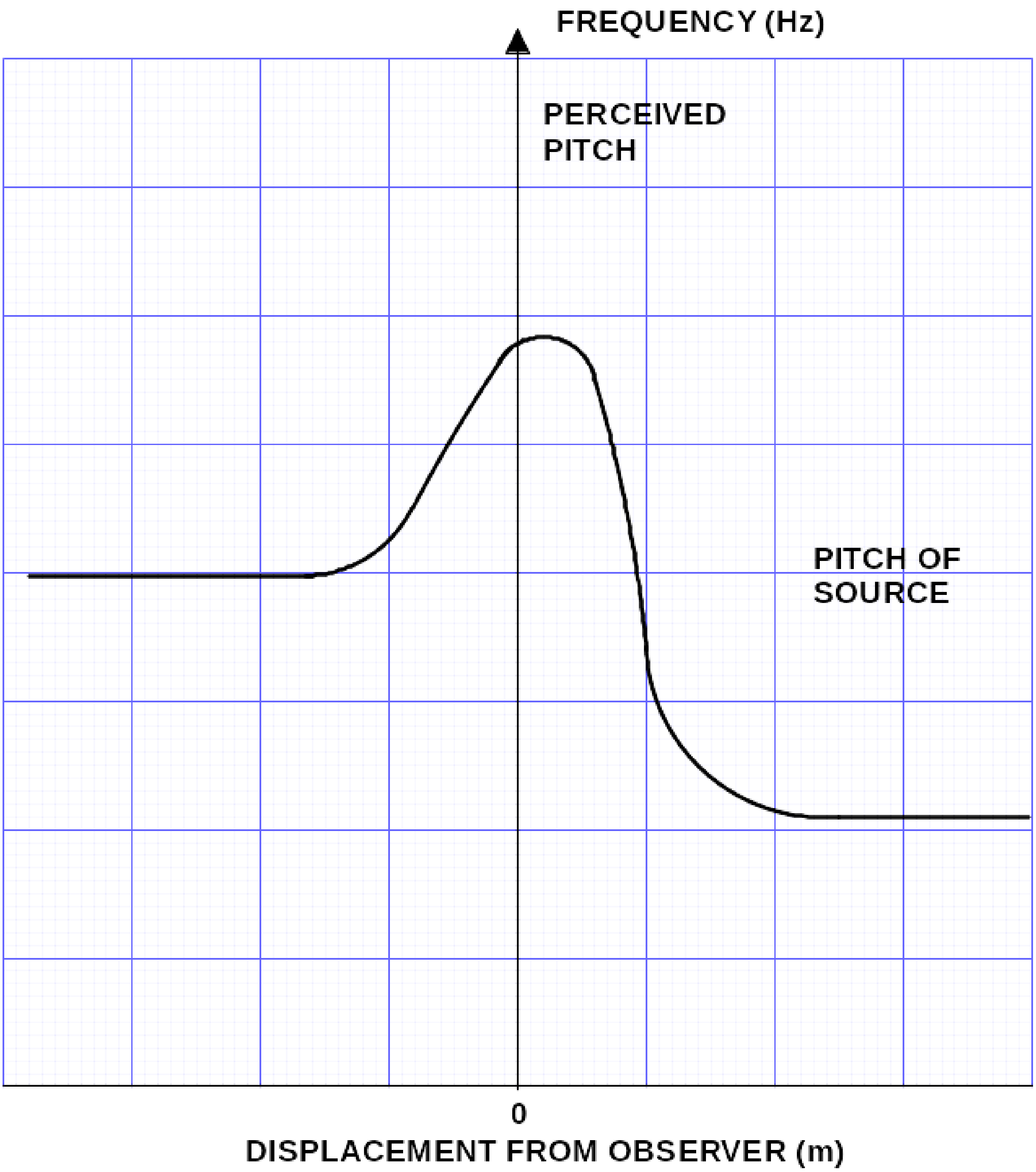
1 Pitch of a note depends upon the frequency.

2



3 The actual pitch of the siren remains constant. The higher and lower pitch heard by the observer is a function of the source moving, not the actual source itself.

4


FREQUENCY (Hz)
PERCEIVED PITCH
PITCH OF SOURCE
0
DISPLACEMENT FROM OBSERVER (m)

5 $\lambda = v\,T$

6 The source has moved a distance of uT

7 I vT – uT

ii vT + uT

8 Redshift is the name given to the phenomenon in which the movement of galaxies, stars etc can be detected by measuring the change in wavelength of light between the actual wavelength emitted and the observed wavelength on Earth. If the velocity of light is constant and the body is travelling away from the observer, the wavelength of the light increases. That is the wavelength corresponds to the red region of the spectrum.

9 Blueshift is the name given to the phenomenon in which the movement of galaxies stars etc can be detected by measuring the change in wavelength of light between the actual wavelength emitted and the observed wavelength on Earth. If the velocity of light is constant and the body is travelling towards the observer, the wavelength of the light decreases. That is the wavelength corresponds to the blue region of the spectrum.

10 Yes. The observer would experience the Doppler Effect. As he travelled towards the source the wavelengths would be closer together and hence the pitch would be greater. Conversely as he travelled away from the source the wavelength would be greater and the frequency lower.

Question 2 - Model Rocket

(1) By referring to the graph the energy can be calculated for a compression of 0.25 m:
The area under the curve is equivalent to the energy stored in the spring
= ½ (1000 x 0.25) = 125 J

(2) If the potential energy stored in the spring is converted into kinetic energy then:
PE = KE
$mgh = \frac{1}{2} m v^2$
$125 = \frac{1}{2} \times 0.25 \times v^2$
$v^2 = 125 / 0.125$
$v = 31.6 \text{ m s}^{-1}$

(3) m = 0.25 kg
$v = 31.6 \text{ m s}^{-1}$
p = mv
p = 0.25 x 31.6
momentum = 7.9 kg m $^{-1}$

(4) The forces acting on the rocket are the decelerating forces of gravity and air resistance (friction)

(5) $u = -31.6 \text{ m s}^{-1}$
$v = 0 \text{ m s}^{-1}$
$t = 2.9 \text{ s}$
$a = ?$
$v = u + at$
$0 = -31.6 + a \times 2.9$
$-31.6 / 2.9 = a$
$a = -10.9 \text{ m s}^{-2}$

So the rocket undergoes a negative acceleration of 10.9 m s^{-2}

(6) $a = 10.9 \text{ m s}^{-2}$
$v = 0 \text{ m s}^{-1}$
$u = -31.6 \text{ m s}^{-1}$
$s = ?$
$v^2 = u^2 + 2as$
$0^2 = -31.6^2 + 2 \times 10.9 \times s$
$s = 31.6^2/(2 \times 10.9)$
$s = 45.8 \text{ m}$

(7) The results of the deceleration ARE consistent with the rocket being subject to air resistance. The air resistance would add an additional retarding force to the upward movement of the rocket thus increasing the rate at which its velocity is reduced.

(8) If there was no air resistance the rocket would undergo deceleration at the rate of 9.8 m s^{-2}. In this case the retarding force would be:
$F = m\,a = 0.25 \times 9.8 = 2.45 \text{ N}$
If the rocket is subject to air resistance in addition to the gravitational force the force would be $F = m\,a = 0.25 \times 10.9 = 2.73 \text{ N}$
The difference in these two forces is (2.73 – 2.45) = 0.275 N
The average retarding force due to air resistance is 0.275 N

(9) During the first 2 seconds of descent the rocket is accelerating at a fairly uniform acceleration. At time = 2 s the graph plateaus indicating there is a sudden change in velocity. This would indicate that there is a sudden retarding force acting on the rocket. This is the time at which the parachute is deployed.

(10) From the graph the retarding force at 3 seconds is 2 N.
$F = m\,a$
$2 = 0.25 \times a$
$a = 2 / 0.25 = 8 \text{ m s}^{-2}$
The acceleration at 3 seconds is -8 m s^{-2}