CSSA

2023
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

Physics

Section I

20 marks
Questions 1–20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	D	PH 12-14	2-4
2	C	PH 12-14	2-4
3	B	PH 12-15	2-4
4	A	PH 12-13	2-5
5	D	PH 12-12	2-5
6	B	PH 12-12	2-5
7	A	PH 12-15	2-5
8	D	PH 12-15	2-5
9	C	PH 12-14	2-5
10	B	PH 12-12	2-5
11	A	PH 12-15	2-5
12	D	PH 12-14	2-5
13	C	PH 12-15, PH 11/12-5	2-5
14	B	PH 12-13	3-5
15	A	PH 12-13	3-5
16	C	PH 12-12	3-6
17	A	PH 12-13	3-6
18	B	PH 12-14	3-6
19	D	PH 12-13	3-6
20	C	PH 12-15	4-6

Section II

80 marks
Question 21 (5 marks)
Question 21 (a) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly calculates KE	2
• Uses the period of a geostationary orbit to find orbit velocity	1

Sample Answer:

Geostationary orbit period = 24 x 60 x 60 = 86400s

Using Kepler's Law of Periods, $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$

$$r = \sqrt[3]{\frac{T^2 GM}{4\pi^2}}$$

$$r = \sqrt[3]{\frac{86400^2 \times 6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{4\pi^2}}$$

$$r = 4.23 \times 10^7\ m$$

$$v = \frac{2\pi r}{T}$$

$$v = \frac{2\pi \times 4.23 \times 10^7}{86400}$$

$$v = 3075.96\ \text{ms}^{-1}$$

$$KE = \frac{1}{2}mv^2$$

$$KE = \frac{1}{2}550 \times 3075.96^2$$

$$KE = 2601925359J$$

$$KE = 2.6 \times 10^9 J$$

Question 21 (b) (3 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Explains the increase in total energy and where this energy is derived	3
• Describes the KE and GPE of satellites at higher orbit	2
• Identifies that a geostationary orbit has larger GPE	1

Sample Answer:

Total energy is defined as the Kinetic energy plus the Gravitational Potential Energy. As KE = -GPE/2, compared to a satellite of equal mass in a low-Earth orbit, the increase in the GPE of a geostationary satellite is greater than of its decrease in KE, resulting in a greater total mechanical energy. According to the conservation of energy, in order for the satellite to have a larger total energy in geostationary orbit, a larger amount of energy from rocket fuel, etc must be used.

Question 22 (5 marks)
Outcomes Assessed: PH 12-14
Targeted Performance Bands:2-5

Criteria	Marks
• Defines absorption spectra, thoroughly describes how the spectra of stars can provide information on four of their characteristics	5
• Thoroughly describes how the spectra of stars can provide information on four of their characteristics OR Defines absorption spectra, thoroughly describes how the spectra of stars can provide information on three of their characteristics	4
• Thoroughly describes how the spectra of stars can provide information on three of their characteristics OR describes how the spectra of stars can provide information on four of their characteristics OR Defines absorption spectra and describes how the spectra of stars can provide information on three of their characteristics	3
• Thoroughly describes how the spectra of stars can provide information on two of their characteristics OR Defines absorption spectra and describes how the spectra of stars can provide information on one of their characteristics	2
• Any relevant information	1

Sample Answer:

The core of a star is a black body and emits all wavelengths of EM radiation. The atoms in the outer layers of stars absorb certain wavelengths which leads to dark lines in the spectrum of the star named absorption lines. The spectra of stars can provide the following information:

- surface temperature can be revealed by observing the peak intensity wavelength or by the spectral type of the star's spectrum – OBAFGKM.
- rotational velocity is found by observing spectral line spreading due to the Doppler shift from either side of the rotating star: one side is approaching while the other side is receding from the observer.
- translational velocity is revealed by a red or blue shift in the entire spectrum of the star – red shift for receding velocity, blue for approaching velocity.
- a star's density affects the width of spectral lines: less dense stars like red giants have thinner lines; more dense stars like white dwarfs have thicker spectral lines.
- The atoms in the outer layers of stars absorb certain wavelengths. Comparing the absorption spectrum of a star with the spectrum of atoms produced in the laboratory can confirm existence of certain elements in the atmosphere of the star.

Question 23 (3 marks)
Outcomes Assessed: PH 12-14
Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly calculates measured speed for 99% of length with units	3
• Correct substitution into correct formula OR • Correct calculation of measure speed without units / incorrect units	2
• Any relevant information	1

Sample Answer:

The measured length is 99% of the actual length.

$l = l_0\sqrt{(1-\frac{v^2}{c^2})}$

$l_0 = 1$

$l = 0.99$

$0.99 = 1\ \sqrt{(1-\frac{v^2}{c^2})}$

$v = 4.23 \times 10^7\ m\ s^{-1}$

Question 24 (5 marks)

Outcomes Assessed: PH 12-12

Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly calculates angular velocity and clearly shows all steps of the calculations	5
• Calculates angular velocity and clearly shows all steps with one mistake in calculations	4
• Correctly calculates escape velocity AND • States State $v_{esc} = v_{tangential}$	3
• Correctly derives the equation of escape velocity AND • Attempts to calculate escape velocity	2
• Any relevant information	1

Sample Answer:

ΔKE = - ΔGPE

$$\frac{1}{2}mv^2 = \frac{GMm}{r_{Earth}}$$

$$v_{esc} = \sqrt{\frac{2GM}{r_{Earth}}}$$

$$v_{esc} = \sqrt{\frac{2(6.67\times10^{-11})(6\times10^{24})}{(6.371\times10^{6})}} = 11208.6 \text{ ms}^{-1}$$

$$v_{esc} = v_{tangential} = \omega r$$

Circumference of payload path in centrifuge chamber = L = $2\pi r$ = 314.15m

Payload completes $\frac{V_{esc}}{L}$ revolutions per second = $\frac{(11208.6)}{(314.15)}$

= 35.68 revolutions per second

1 revolution = 2π radians

Therefore $\omega = 2 \times \pi \times (35.68) = 224.2$ rad s^{-1}

OR

$$v_{esc} = \omega r$$

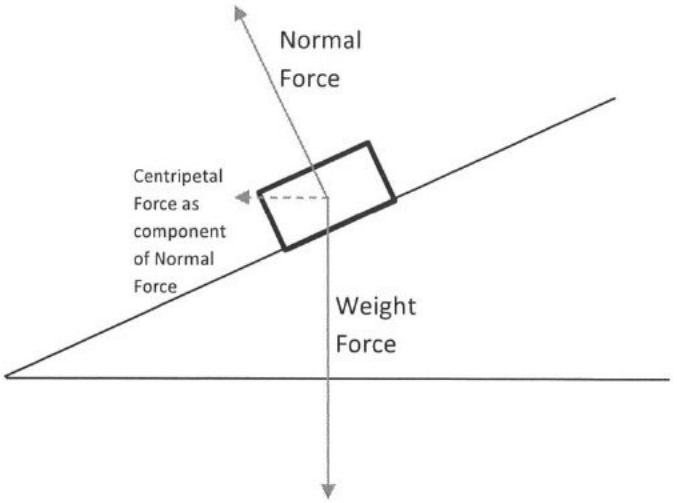
$$(11208.6) = \omega\,(50)$$

$$\omega = 224.2\ rad\ s^{-1}$$

Question 25 (5 marks)
Question 25 (a) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly uses vectors to show Fc as a component of the normal force	2
• Attempts to use some correct vector components	1

Sample Answer:



Question 25 (b) (3 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly calculates the angle	3
• Correctly derives the expression for angle, velocity, radius	2
• Uses some formulae to find centripetal force. Does not derive expression for angle, velocity and radius	1

Sample Answer:

$$N\cos\theta = mg$$

$$N = \frac{mg}{\cos\theta}$$

$$Fc = N\sin\theta = \frac{mg}{\cos\theta}\sin\theta = mg\tan\theta$$

$$\frac{mv^2}{r} = mg\tan\theta$$

$$v = \sqrt{gr\tan\theta}$$

$$tan\theta = \frac{v^2}{gr}$$

$$\theta = tan^{-1}\left(\frac{20^2}{9.8 \times 344}\right)$$

$$\theta = 6.77°$$

Question 26 (5 marks)
Question 26 (a) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly proves the equation	2
• Writes some relevant equations	1

Sample Answer:

Equation 1: $\frac{mv^2}{r} = T \sin\theta$

Equation 2: $mg = T\cos\theta$

Dividing equation 1 by 2: $\tan\theta = \frac{v^2}{rg}$

Question 26 (b) (3 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly calculates tension	3
• Correctly calculates the angle of inclination OR Correctly calculates weight of the ball and F_c	2
• Writes some relevant equations	1

Sample Answer:

$$\tan\theta = \frac{v^2}{rg}$$

$$v = \frac{2\pi r}{T}$$

$$f = \frac{40}{60} = 0.67\ Hz$$

$$T = \frac{1}{f} = 1.5\ s$$

$$v = \frac{2\pi 0.2}{1.5} = 0.84\ m/s$$

$$\theta = \tan^{-1}\frac{0.84^2}{0.2x\ 9.8} = 19.70\ degrees$$

$$mg = T\cos\theta$$

0.050 x 9.8= T cos19.70

T= 0.520 N

Question 27 (5 marks)
Outcomes Assessed: PH 12-13
Targeted Performance Bands: 2-6

Criteria	Marks
• Deduces direction and magnitude of net emf with explicit reference to Faraday's Law and Lenz' Law • Concludes that as emf is approaching zero so will current also approach zero, with reference to Ohm's Law	5
• Correctly deduces the magnitude of current, only refers to 2 Laws	4
• Correctly deduces emf with reference to 2 laws OR • Correctly deduces the current – no reference to Laws	3
• A correct statement leading to deduction of net emf in the motor OR • A correct statement of any two relevant laws	2
• Some relevant information	1

Sample Answer:

A rotating motor consists of a coil of wire experiencing changing magnetic flux. According to Faraday's Law the coil of wire experiencing a changing magnetic flux will have back EMF. The direction of back EMF - found using Lenz' Law - is opposite direction to the motor supply EMF. At maximum speed, back EMF approaches the magnitude of supply EMF, reducing the net EMF to near zero. According to Ohm's Law net EMF results in an electric current which also approaches zero.

Question 28 (6 marks)
Question 28 (a) (4 marks)
Outcomes Assessed: PH 11/12-5, PH 12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Evaluates the accuracy, reliability and validity of the investigation	4
• Evaluates two of following: accuracy, reliability, validity of the investigation	3
• Evaluates accuracy OR reliability OR validity of the investigation	2
• Identifies an aspect of the investigation's reliability, accuracy or validity	1

Sample Answer:

The investigation could be considered accurate as it does identify the specific measurements and tool (Physics Toolbox Suite app) to record the light intensity. A smartphone, however, is less accurate than a photometer or lux/light meter. The method also does specify to accurately measure the angles used using an accurate piece of equipment.
The investigation is also accurate as the results are within an error margin of 1-5 % of the expected/ theoretical value of light intensity.
The investigation is not reliable as it has only been attempted once. In order to improve its reliability, it should be performed, at least, 3 times and get consistent results.
The experiment could be considered valid as the independent and dependent variables are clearly stated / measured / calculated and a correlation between the two is made. A controlled variable of keeping the light at the same distance is stated, however, there are many controlled variables that are not explicitly stated that should be – e.g., background lighting, not changing the source intensity, Overall, the investigation's accuracy is sufficient, however it's reliability and validity could be improved upon, as mentioned above.

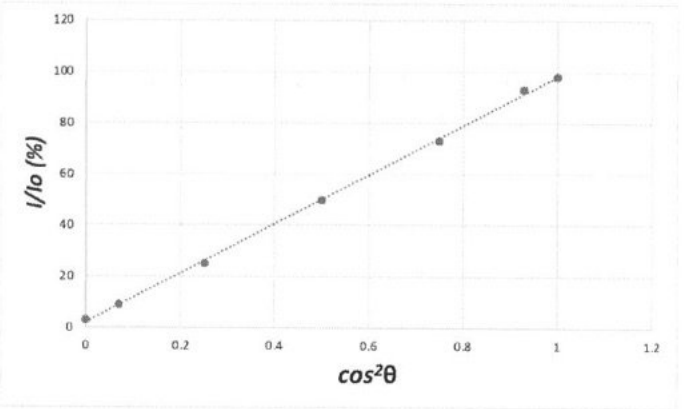
Question 28 (b) (2 marks)
Outcomes Assessed: PH 11/12-5, PH 12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly assesses that student's graph is incorrect and the graph should be a linear graph [Note: student does not have to specifically mention linear graph this can be described or shown diagrammatically)	2
• Identifies the student's graph is incorrect	1

Sample Answer:

The student's graph is incorrect. As shown with the student's results –I/Io and $\cos^2\theta$ have a linear relationship and the graph is linear.

Note: student could draw a graph as shown below to show what results graph should look like



Question 29 (9 marks)
Question 29 (a) (1 mark)
Outcomes Assessed: PH 12-15
Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly identifies all four stars	1

Sample Answer:

T, U, P, A

Question 29 (b) (3 marks)
Outcomes Assessed: PH 12-15
Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly calculates the total energy released	3
• Correctly calculates the energy for one of the reactions OR • Calculates the change in mass for the overall reaction	2
• Calculates the change in mass for one of the reactions OR • Writes the overall reaction for the proton-proton chain showing products and reactants	1

Sample Answer:

$^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + \nu$

$^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$

Overall reaction $3\ {}^{1}H \rightarrow {}^{3}He + \gamma + e^{+} + \nu$

Mass of reactants	Mass of Products
Mass of $3\ {}^{1}H = 3 \times 1.00784$ amu	Mass of $^{3}He = 3.016029$ amu Mass of $e^{+} = 0.000548756$ amu
Total mass = 3.02622 amu	Total mass = 3.0165778
Mass defect = 3.02622 - 3.0165778 amu = 0.0096422 amu 1 amu = 931.5MeV Therefore Energy = 931.5Mev/amu x 0.0096422 amu = 8.98 MeV	

Question 29 (c) (5 marks)
Outcomes Assessed: 12-15
Targeted Performance Bands: 2-6

i)

Criteria	Marks
• Correctly Identifies both stars	1

Sample Answer:

B = Red supergiant

S = White dwarf

ii)

Criteria	Marks
• Compares and contrasts at least 4 of the following properties of stars - Luminosity - Size - Surface temperature - Evolutionary stage - Colour - Density - Mass	4
• Includes 3 of the above properties of stars	3
• Includes 2 of the above properties of stars	2
• Includes 1 of the above properties of stars	1

Sample Answer:

Similarities	Differences
Final stages of a star's life cycle Nuclear fusion of Hydrogen no longer occurs at the core Formed from low density stars	Luminosity of super giant is higher than the white dwarf Dwarf star is much smaller than super giant White dwarf the size of Earth Super giant 1500 times the size of the Sun Surface Temp of white dwarf is higher than supergiant White dwarf is the next evolutionary stage to the supergiant Super giant still undergoes Nuclear fission using Helium Super giant usually red whereas the white dwarf is white

	Super giant has more mass than white dwarf White dwarf is much denser than super giant

Question 30 (5 marks)
Question 30 (a) (2 marks)
Outcomes Assessed: PH 12-12, PH 12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the speed of the proton	2
• Correctly calculate the kinetic energy of the protons	1

Sample Answer:

$E_k = \frac{1}{2} mv^2 = qV$

$\frac{1}{2} \times 1.673 \times 10^{-27} v^2 = 1.602 \times 10^{-19} \times 50000$

$v = 3.09 \times 10^6$ m/s

Question 30 (b) (3 marks)
Outcomes Assessed: PH 12-12, PH 12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the radius of the cyclotron	3
• Correctly calculates the centripetal force	2
• Calculates speed of the proton OR • Writes Fc=qvB	1

Sample Answer:

$K = \frac{1}{2}mv^2 = 20MeV = 3.204 \times 10^{-12}$ J

$v = 6.19x\ 10^7\ m/s$

$qvB = m\frac{v^2}{r}$

$r = \frac{mv}{qB}$

r= 0.323 m

Question 31 (6 marks)
Question 31 (a) (4 marks)
Outcomes Assessed: PH 12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the wavelengths of light from the n=3 shell to n=2 shell and the n=7 shell to the n=2 shell transitions and demonstrates that the wavelengths are in the region able to be detected by the human eye	4
• Calculates the wavelengths of light for the two transitions	3
• Calculates the wavelength of one of the transitions	2
• Describes the transitions of one or more of the transitions without calculations	1

Sample Answer:

Only need to work out the maximum change and the minimum change between transitions

i.e., n=2 shell to n=3 shell and n =2 shell to n=7 shell.

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Transition from n=3 shell to n=2 shell	Transition from n=7 shell to n=2 shell
$1/\lambda = 1.097 \times 10^7[\,1/2^2 - 1/3^2]$ $= 1.097 \times 10^7[1/4 - 1/9]$ $= 1.523 \times 10^6\ m^{-1}$ Therefore: $\lambda = 1/1.523 \times 10^6 m^{-1}$ $\lambda = 6.56 \times 10^{-7} m$ = 656 nm which is less than 700nm	$1/\lambda = 1.097 \times 10^7[\,1/2^2 - 1/7^2]$ $= 1.097 \times 10^7[1/4 - 1/49]$ $= 2.519 \times 10^6\ m^{-1}$ Therefore: $\lambda = 1/2.519 \times 10^6\ m^{-1}$ $\lambda = 3.97 \times 10^{-7} m$ = 397 nm which is greater than 380nm

Therefore, the Balmer series fits just between the range of detection by the human eye.

Question 31 (b) (2 marks)
Outcomes Assessed: PH 12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the difference in energy between the two transitions	2
• Calculates the energy of at least one of the transitions	1

Sample Answer:

E=hf= hc/ λ

Transition from n=3 shell to n=2 shell E= hc/λ= $(6.626 \times 10^{-34} \times 3.00 \times 10^{8})/6.56 \times 10^{-7}$ $= 3.058 \times 10^{-19}$J	Transition from n=7 shell to n=2 shell E=hc/λ=$(6.626 \times 10^{-34} \times 3.00 \times 10^{8})/3.97 \times 10^{-7}$ $= 5.053 \times 10^{-19}$ J
Therefore: The difference in energy = 5.053×10^{-19} J - 3.058×10^{-19}J $=1.995 \times 10^{-19}$J	

Question 32 (5 marks)
Question 32 (a) (2 marks)
Outcomes Assessed: PH 12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the maximum change of flux with unit	2
• One correct step	1

Sample Answer:

Max change in Magnetic flux occurs when the coil rotates from parallel to the B Field to perpendicular. Zero flux through the coil in the position shown in the diagram to the maximum flux when the coil is perpendicular to the magnetic field.

$Area\ of\ Circle = \pi r^2$

$= \pi \times (0.500)^2$

$= 0.785\ m^2$

$\phi_B = B.A$

$\phi_B = (5.00 \times 10^{-5}) \times (0.785)$

Max $\Delta\ \phi_B = 3.93 \times 10^{-5}$ Wb

Question 32 (b) (3 marks)
Outcomes Assessed: PH 11/12-5, PH 12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Draws a sine graph which starts at zero, increasing (positive gradient) from t=0, 2 full wavelengths shown	3
• Draws a sine graph which starts at zero, increasing (positive gradient) from t=0, 1 full wavelength shown	2
• Draws a cos graph	1

Sample Answer:

A Sine curve with two complete wavelengths which starts at zero and increasing (positive gradient) from t=0.

Question 33 (7 marks)
Outcomes Assessed: PH 12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Makes a complete and thorough justification to compare torque produced by both coils by finding the area of the coils, showing via expression a value for Torque in each coil such that one is double the other AND • Describes two relevant adjustments to aspects (other than dimensions of Jonathan's coil) which result in torque being doubled - justified using relevant Laws and conventions	7
• Makes a satisfactory justification to compare torque produced by both coils. AND • Describes two relevant adjustments to aspects other than dimensions of Jonathan's coil which result in Torque being doubled - justified using relevant Laws and conventions	6
• Makes a satisfactory justification to compare Torque produced by both coils AND • Describes one relevant adjustment to aspects other than dimensions of Jonathan's coil which result in Torque being improved - justified using relevant Laws and conventions	5
• Provides some justification to compare torque produced by both coils AND • Describes one relevant adjustment to aspects other than dimensions of Jonathan's coil which result in torque being improved - justified using relevant Laws and conventions	4
• Provides some justification to quantify torque produced by both coils. OR • Describes one relevant adjustment to aspects other than dimensions of Jonathan's coil which result in Torque being improved - justified using relevant Laws and conventions	3
• Shows a relevant step to justify Torque production	2
• Any relevant information	1

Sample Answer:

L = length of wire (m)

Perimeter of a square with sides r (m) = 4r

N = number of turns

r_s = dimension of Stacy's coil

r_j = dimension of Jonathan's coil

$N_J = 2\ N_S$

Jonathan and Stacy both have same length of wire to make their coil L

$L = N_S\ (4r_s) = N_J\ (4r_j)$

$N_S\ (4r_s) = 2N_S\ (4r_j)$

$4r_s = 2(4r_j)$

$r_j = \frac{r_s}{2}$

Area Stacey coil = πr_s^2

Area Jonathan coil = $\pi\ r_j^2 = \pi \frac{r_s^2}{4}$

Maximum torque produced = NBIA

Stacy torque $T_s = N_S\ BI(r_s^2)$

Jonathan torque $T_j = 2\ N_S\ BI(^{r_s^2}/_4) = {}^{T_s}/_2$

Jonathan's DC motor coil produces ½ Torque of Stacey's motor coil.

Since the Equation for max Torque is T = NBIA, and the number of turns is fixed.

Jonathan's torque could be doubled by doubling the magnetic field strength. This could be achieved by reducing the distance to the permanent magnets by half or by doubling the number of magnets used.

Torque could also be doubled by increasing the current in the coil to twice its previous value. This could be achieved by doubling the potential difference supplied to the circuit, which will double the current in the coil, using 2 of the 6 volts batteries in series to power the coil.

Question 34 (9 marks)
Outcomes Assessed: PH 12-12, PH 12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly determines orbital period, orbital radius using Kepler's Law of Periods and mass of the planet using the Law of Conservation of Momentum • Explains the movement of the star using the Law of Universal Gravitation and its slower speed by referring to Newton's 2nd law • Explains the deduction of the movement of the star using the Doppler effect	9
• Correctly determines orbital period, orbital radius using Kepler's Law of Periods • Attempts to calculate mass of the planet using the Law of Conservation of Momentum • Explains the movement of the star using the Law of Universal Gravitation and its slower speed by referring to Newton's 2nd law • Explains the deduction of the movement using the Doppler effect	8
• Correctly determines orbital period, orbital radius using Kepler's Law of Periods • Identifies gravity as the cause of star's motion • Refers to the star heavier mass as the cause of slower speed • Explains the deduction of the movement using the Doppler effect	6-7
• Correctly determines orbital period. • Attempts to calculate orbital radius using Kepler's Law of Periods. • Identifies gravity as the cause of star's motion • Describes the deduction of the movement using the Doppler effect	4-5
• Correctly determines orbital period • Identifies the use of the Doppler effect in study of movement of the star	2-3
• Any relevant information	1

Sample Answer:

Using the graph, the exoplanet moves in front of the star at 4 hours and 15 hours elapsed, giving an orbital period of 11 hours (39600 seconds).

Using Kepler's Law of Periods:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$r = \sqrt[3]{\frac{T^2 GM}{4\pi^2}}$$

$$r = \sqrt[3]{\frac{39600^2 \times 6.67 \times 10^{-11} \times 9.9 \times 10^{30}}{4\pi^2}}$$

$$r = 2971190888 \text{ m}$$

$$v_{planet} = \sqrt{\frac{GM}{r}}$$

$V_{planet} = 471427.85$ m/s = 471428 m/s

$F_{\text{the planet exerts to the star}} = F_{\text{the start exerts on the planet}}$

As the law of conservation of momentum

$m_{planet} v_{planet} = m_{star} v_{star}$

$$m_{planet} = \frac{m_{star}\ v_{star}}{v_{planet}}$$

$$m_{planet} = \frac{9.9 \times 10^{30} \times 150}{471427.85} = 3.2 \times 10^{27} \text{ kg}$$

According to Newton's Law of Universal Gravitation the star and the planet exert an equal magnitude of attractive force on each other, and so the star moves as a result of this force. However, as the star is heavier than the planet according to Newton's 2nd law, its speed is much slower. The relative movement of the star can be determined by studying its spectrum. According to the Doppler effect, if a star moves away from us its spectral lines move toward longer wavelengths (red shifted) and if it moves towards us, they move toward shorter wavelengths (blue shifted). Therefore, by studying the spectrum of the star and comparing that to the spectrum of elements in the laboratory condition, the movement of the star can be deduced.

BLANK PAGE

BLANK PAGE

BLANK PAGE