Problem 1

1) E-R diagram

This is an example of an ER diagram. There are other possible options like having binary relationships between Tests with Patients and Doctors instead than ternary. Another approach is to create a relationship between Visits and Tests and not hasOrdered.
2) Primary keys: PatientId, TestId, VisitId, and DoctorId

Weak Entity: none

Cardinalities:

- Tests to hasOrdered: one-to-many with the Patients and Doctors. We assume that a Test is uniquely associated with a single Patient and single Doctor each time.
- Visits to hasVisit and handlesVisit: one-to-many with Patients and Doctors respectively. We assume that a Visit is associated with a single Patient and Doctor.
- Patients to isPrimary: one-to-many with Doctors. We assume that a Patient has a single primary physician.

Total participation:

- Tests to hasOrdered
- Visits to hasVisit and handlesVisit
- Patients to isPrimary

3) Relational Model:

```sql
CREATE TABLE Doctors( DoctorId INT, Name VARCHAR(100), Specialty VARCHAR(60), MedicalSc VARCHAR(100), PRIMARY KEY (DoctorId));

CREATE TABLE Patients( PatientId INT, Name VARCHAR(100), Insurance VARCHAR(100), DoctorId INT, PRIMARY KEY (PatientId), FOREIGN KEY (DoctorId) REFERENCES Doctors(DoctorId));

CREATE TABLE Tests( TestId INT, TName VARCHAR(100), TDate DATE, TResult VARCHAR(60), PatientId INT, DoctorId INT, PRIMARY KEY(TestId), FOREIGN KEY (PatientId) REFERENCES Patients(PatientId), FOREIGN KEY (DoctorId) REFERENCES Doctors(DoctorId));

CREATE TABLE Visits( VisitId INT, CheckIN DATE, CheckOut DATE, PatientId INT, DoctorId INT, PRIMARY KEY(VisitId), FOREIGN KEY (PatientId) REFERENCES Patients(PatientId), FOREIGN KEY (DoctorId) REFERENCES Doctors(DoctorId));
```

We created one table for Patients and isPrimary. We created one table for Tests and hasOrdered. We created one table for Visits, hasVisit, and handlesVisit. For all of them we used the fact we have one-to-many and total participation constraints to create single tables.

Problem 2

1) E-R diagram
This is also one possible ER diagram. We created Test_events as weak entity with date as the partial key and owner entities to be Airplanes, Tests, and Technicians. Another approach is to create a relationship instead of the weak entity. This is also correct.

2) Relational Model:

CREATE TABLE Models( mod_no INT, capacity INT, weight INT, PRIMARY KEY(mod_no));

CREATE TABLE Airplanes( reg_no INT, mod_no INT, PRIMARY KEY(reg_no), FOREIGN KEY (mod_no) REFERENCES Models(mod_no));

CREATE TABLE Tests( FAA_no INT, name VARCHAR(100), max_score INT, PRIMARY KEY(FAA_no));
CREATE TABLE Employees( SSN CHAR(9), name VARCHAR(100), address VARCHAR(150), phone_no CHAR(12), PRIMARY KEY(SSN));

CREATE TABLE Traffic_controllers( SSN CHAR(9), mr_exam DATE, PRIMARY KEY(SSN), FOREIGN KEY (SSN) REFERENCES Employees(SSN));

CREATE TABLE Technicians( SSN CHAR(9), salary INT, PRIMARY KEY(SSN), FOREIGN KEY (SSN) REFERENCES Employees(SSN));

CREATE TABLE isExpert( SSN CHAR(9), mod_no  INT, PRIMARY KEY(SSN, mod_no), FOREIGN KEY (mod_no) REFERENCES Models(mod_no), FOREIGN KEY (SSN) REFERENCES Technicians(SSN));

CREATE TABLE Test_events( SSN CHAR(9), reg_no  INT, FAA_no INT, date DATE, name VARCHAR(100), score INT, PRIMARY KEY(SSN, reg_no, FAA_no, date), FOREIGN KEY (SSN) REFERENCES Technicians(SSN), FOREIGN KEY (reg_no) REFERENCES Airplanes(reg_no), FOREIGN KEY (FAA_no) REFERENCES Tests(FAA_no));

Problem 3.

1. \( \pi \text{model} (\sigma \text{speed} > 3 (\text{PC})) \)

2. \( \pi \text{maker} (\sigma \text{hd} > 100 (\text{Laptop}) \Join \text{Product}) \)

3. \( \pi \text{maker} (\text{Laptop} \Join \text{Product}) - \pi \text{maker} (\text{PC} \Join \text{Product}) \)

4. \( \rho(T(1->\text{model2}, 2->\text{speed2}, 3->\text{ram2}, 4->\text{hd2}, 5->\text{price2}), \text{PC}) \)
   \( \pi \text{hd} (\sigma \text{hd}=\text{hd2 AND model}<>\text{model2} (\text{PC x T}) \)

5. \( \rho(T, \pi \text{model, speed} (\text{PC})) \)
   \( \rho(Y(1->\text{model1}, 2->\text{speed1}), T \times T) \)
   \( \pi \text{maker}(\pi \text{model}(\text{PC}) - \pi \text{model}(\sigma \text{speed1} > \text{speed} (Y)))) \Join \text{Product} \)
Problem 4.

Empl is short for Employees

1. $\pi_{SSN, name} (((\sigma_{Location='Boston'} Project) \bowtie (\sigma_{hours>100} HourLog) \bowtie Empl))$

2. $\pi_{SSN, name} (((\sigma PNo = 2 HourLog) \bowtie (\sigma DNo=1 Empl))$

3. $\rho(T(1-> SSN1, 2->PNo1), HourLog X HourLog))$
   $\pi_{SSN, name} (Empl \bowtie (\sigma SSN1 = SSN AND PNo1 <> PNo(T))$

4. $\pi_{SSN, name} (((\pi_{SSN,PNo} (HourLog) / \pi_{PNo}(Project)) \bowtie Empl)$